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Title:

Spatial memory assessment reveals age-related differences in egocentric and allocentric memory performance

Abstract

Humans move through the environment to reach a place mainly using two strategies: egocentric, taking the viewer's position as a point of reference, and allocentric, employing external landmarks in order to create a mental map of the environment. Aging seems to be associated with a deterioration in these functions, and although participants are evaluated with both virtual and real-environment tasks, performance on these two strategies is not frequently compared. Our objective was to evaluate egocentric and allocentric spatial memory in young and older adult populations using three tasks performed in real environments that allow the perception of 3-D information present in our daily orientation and make it possible to analyse each strategy separately. Twenty-eight young adults and 27 older adults performed Egocentric and Allocentric Spatial Memory Tasks, the Spatial Span task from CANTAB to assess visuospatial span and visuospatial working memory, and Benton's Judge of Line Orientation Test to measure the ability to establish judgments of spatial relations. Young adults outperformed older adults on spatial memory tasks. The older group improved across allocentric blocks. Young men outperformed older men on both the egocentric and allocentric tasks, whereas young women only achieved better scores than older women on the allocentric task. Our findings support the existence of age-related differences in spatial memory performance.

Keywords: egocentric strategy; allocentric strategy; spatial memory; aging; older adults; young adults.

1. Introduction

Normal aging is related to decreases in several cognitive functions, including spatial orientation: the ability to move through our environment to reach a spatial location goal [1]. This ability involves a large number of cognitive and sensorial processes. It requires processing of visual, proprioceptive, vestibular, and somatosensory information, as well as the ability to encode and remember spatial information and plan movements [1]. This function depends on two types of strategies or frameworks. With the egocentric strategy, we specify locations with respect to our own body [2], following our own movements and perceiving turns, distances, and directions related to our point of view [3]. This ability depends on optic systems and kinaesthetic and vestibular stimuli, finally integrating all this sensorial information with the motor output [2]. With the allocentric strategy, we are able to codify, recall, and recognize landmarks, that is, cues or objects that are located in the environment [4]. This framework is created independently of our point of view, and so allocentric landmarks do not change while the subject is walking through the environment [5]. This configuration also allows us to create mental maps, that is, cognitive representations of our surrounding environment [6] that are made from the representations of some objects with respect to others, as well as the relationships between these objects and a target object [7]. In our daily lives, we usually use both frameworks. We switch and combine different spatial strategies, depending on the environmental requirements. However, it could be useful to assess egocentric and allocentric strategies separately because neuropsychologists need tasks that can evaluate each framework in order to detect impairments and plan cognitive rehabilitation. Moreover, in regular development, these two frames of reference develop independently and at different times [4]. This could lead us to think that throughout the life cycle and in healthy aging, these two types of spatial memory also follow patterns of worsening at different times. With regard to the evaluation of these frameworks in this population, regular aging seems to be associated with progressive impairment of the allocentric strategy and with switching from the egocentric frame to the allocentric frame, and vice versa [8].

Currently, spatial orientation assessment is performed through virtual reality or computer-based tasks [9–13] as well as real-environment tasks [14–18]. Computer-based tasks use simple environments, like a room or a round maze in which few landmarks are presented [10–12], while more complex virtual environments recreate large spaces, long distances, including complex mazes and several functional landmarks [9,13]. Although virtual environmental tasks have shown great equivalence with real-world navigation in young adult subjects [19], these tasks cannot guarantee that the participant will receive all the signals that are present in orientation (proprioceptive, vestibular, and locomotive signals) [20,21]. Older people are not usually familiar with new technologies, and previous studies in this population have found that navigation skills are impaired if the task is performed virtually, but not when locomotion is allowed [22]. Therefore, on virtual tests, older people tend to more frequently and efficiently use the egocentric framework than the allocentric framework [13,23]. However, these results are not as clear on real tasks. On these kinds of tests, some studies find that the egocentric strategy seems to be preserved in this population [17], whereas others report a decline from the age of 60 [18,24].

In both young and older adult populations, gender-associated differences in spatial memory performance are often found, where men generally perform better than women, executing faster responses and adapting better to possible increases in difficulty [10,12,25,26]. However, it has also been found that this differential performance may depend on many other factors, such as the type of cues available, previous experience and/or training in these skills, familiarity with the environment, etc. [27–30], and the type of information. In this regard, males employ Euclidean information more efficiently than points of reference [31–33], and they perform better using an allocentric strategy than women do [34]. Thus, it seems of vital importance to consider the gender of the participants when analysing the egocentric and allocentric performance.

As mentioned above, the skills of memorizing and moving through our environment are complex and, therefore, involve other spatial-related cognitive functions. Hence, visuospatial skills and visuospatial working memory may influence orientation performance. This has been found in previous studies where egocentric and allocentric performance in young subjects was related to their span and visuospatial working memory [35]. Besides, older people's performance on different types of environment-based tests has been associated with other measures of perception and visuospatial span and working memory [36].

We aimed to assess the egocentric and allocentric spatial frameworks separately in healthy younger and older adults using real world-based tasks, in order to compare age groups and frames of reference, also considering the gender of the participants and trying to relate spatial orientation performance to short-term memory, working memory, and visuospatial abilities. We expected to find worse performance on all the tests in older adults compared to young adults. We assumed that both the egocentric and allocentric frameworks would be impaired in older adults compared to younger adults, but only the older group would obtain lower scores on the allocentric test compared to the egocentric test. We also hypothesised that both young and older women would perform worse on the egocentric and allocentric spatial memory test than men, with greater differences between genders on the allocentric task. Finally, we expected performance on visuospatial short-term memory and working memory, as well as on visuospatial the test, to be related to scores obtained on spatial memory tests.

2. Materials and methods

Participants included 28 young adults (age: 20.21 ±2.846, range=18-28 years, 16 females) and 27 older adults (age: 71.19 ±6.940, range=60-82 years, 16 females). In order to assess general cognitive status, older adults completed the Montreal Cognitive Assessment test (MoCA) [25] (normal ≥ 26), and young adults took the *Reynolds Intellectual Screening Test (RIST)* [26] for IQ estimation (normal 85-115). Those participants who did not reach the normal range were excluded from the study. Therefore, older adults who finally participated in the study achieved a mean of 27.22 and a standard deviation of 1.601 on the MoCA, whereas young adults obtained a mean of 100.86 and a standard deviation of 8.231. Other exclusion criteria included circumstances that could affect the performance of the neuropsychological assessment, such as severe visual or hearing impairment, psychological or neurological disorders, and/or cognitive impairment / intellectual disability. All the study procedures were conducted in compliance with the European Community Council Directive 2001/20/EC and the Helsinki Declaration for biomedical research. Young adults were students from the University of Oviedo (Spain), and older adults were recruited from local associations. All the participants volunteered and provided written informed consent.

Assessments include the Allocentric task, the MoCA for older adults, and the RIST for younger adults, followed by Benton’s Judge of Line Orientation Test [27], the Spatial Span from the Cambridge Neuropsychological Assessment Battery (CANTAB) [28], and Egocentric Memory tasks. This protocol was applied in the order mentioned, individually and by a trained psychologist, and it lasted approximately 60 minutes.

2.1. Egocentric and Allocentric Spatial Memory Tasks

The Egocentric Spatial Memory Task is an adaptation of the Hashimoto test [37] (See Fig. 1A). It assesses the ability to represent spatial placements located around the participant and includes two parts. In Part A, while the participant stood in the centre of a square formed by four opaque panels to avoid access to environmental cues, s/he was asked to remember the position of three cards (triangle, circle, and cross) located in one of the eight locations around him/her. Instructions given to the participant were: "*We are going to perform a memory task. I am going to place each of these cards – a square, a circle, and a cross – in some of the squares around you, and you have to remember the location of these three cards; that is, each card should be in its square*". The examiner removed the cards after a 10-second delay and asked the subject to put them in their previous position. Thus, Part A of the Egocentric test assesses short-term location memory in an environment that covers the 360 degrees surrounding the participant in a cue-poor room, and it serves as a control for remembering procedural aspects of the task.

In Part B, the participant had to remember the placement of the same three cards, but immediately after the cards had been removed the participant was rotated to the right or left by 90º or 180º and then asked to return the cards to the same placement as before. Instructions for this part were: "*Now, we are going to continue with this task. Like before, you have to remember the location of these three cards that I am showing you. However, now I'm going to move you; that is, I'm going to turn you around, and you have to place each card in its square. Like before, each card must go in its place"*. Thus, in Part B of the Egocentric test, the participant has to, first, be aware of his/her initial position and, second, monitor how it has changed, which involves proprioceptive and vestibular senses, as well as the ability to monitor his/her own turns, all of which are required for an egocentric orientation response. Subjects received 1 point for each card placed correctly on 10 consecutive trials in each part. Therefore, on Parts A and B of the test, the participant could score 30 points on each (60 points in all).

The Allocentric Spatial Memory Test was used to evaluate the ability to represent spatial positions of objects using distal environmental cues placed in a room (See Fig. 1B). The participant was shown a round table with 8 possible locations in a square shape, and s/he was instructed to remember the position of the three previous cards. Instructions for this test were: "*Now, on this task, you also have to remember the location of the three previous cards: each must go in its square. After that, I am going to ask you to cover your eyes, and I am going to move you; that is, I'm going to guide you in walking around the template until you reach a new position. Once we get there, you have to remove your mask and put the cards in their place*". After 10 seconds, the participant was blind-folded, and the examiner moved him/her around the table to another location. From this new placement, the subject was asked to restore the cards to their previous location. Mistakes were corrected, showing the subject the right position. The test consisted of 5 blocks of 4 trials that were carried out continuously, with no breaks between the different trials and blocks. The location of the cards was the same in each block and repeated across 4 trials, but the subject was moved to a different location in each trial. The participant scored 1 point for each card correctly placed, obtaining a maximum of 12 points in each block and 60 points on the whole test.

2.2. Statistical analysis

After verifying the lack of normal distribution of the data, nonparametric statistics were used. Mann-Whitney tests were employed to compare younger and older participants on Short-term Memory Location, Egocentric orientation, Allocentric orientation, and their blocks (1, 2, 3, 4 and 5), JoLO, and Spatial Span Forward and Backward. In addition, Mann-Whitney tests were conducted to compare age groups by gender on these tasks. Wilcoxon-signed rank test analysis was used to compare the performance on different spatial tasks in each age group. To do this, the scores on the Egocentric task were transformed to make them equivalent to the Allocentric task (maximum score of 60 points on each task). Friedman repeated measures were conducted to analyse Allocentric blocks in each age group with post-hoc Wilcoxon-signed rank tests with Bonferroni correction (significant results were considered when $p<0.005$). Spearman correlation analysis was conducted to discover relations between spatial assessment tasks in the two groups.

3. Results

First, we compared the spatial test performance of the age groups. The younger group presented better scores than the older group on Egocentric Part A ($U=160$, $p<0.001$, $Z=-3.181$, $r=0.428$), Egocentric Part B ($U=250$, $p=0.031$, $Z=-2.196$, $r=0.296$), the Allocentric task ($U=88.5$, $p<0.001$, $Z=-5.150$, $r=0.694$), Spatial Span Forward ($U=30.5$, $p<0.001$, $Z=-5.981$, $r=0.806$), and Spatial Span Backward ($U=81$, $p<0.001$, $Z=-5.108$, $r=0.689$). Egocentric Part A, Allocentric, and Spatial Span Forward and Backward showed a large effect size, whereas Egocentric Part B showed a small effect size (See Fig. 2A). Means and standard deviations of both groups on each test are shown in Table 1. Analysing the performance of the age groups in each of the Allocentric blocks, we observe that young adults outperformed older adults in each Allocentric block: first ($U=102.5$, $p<0.001$, $Z=-4.593$, $r=0.619$), second ($U=105$, $p<0.001$, $Z=-4.571$, $r=0.616$), third ($U=152$, $p<0.001$, $Z=-3.983$, $r=0.537$), fourth ($U=163$, $p<0.001$, $Z=-3.729$, $r=0.502$), and fifth ($U=232$, $p=0.003$, $Z=-0.293$, $r=0.039$). Comparisons showed a large to intermediate effect size, except for the fifth block, which showed a small effect size.

Then, we compared the two frameworks, egocentric and allocentric, in the same age group (Egocentric Part A vs. Part B and Egocentric vs. Allocentric). Higher significant scores were obtained on Egocentric A than Egocentric B in both the younger group ($Z=-3.926$, $p<0.001$, $r=0.741$) and the older group ($Z=-3.801$, $p<0.001$, $r=0.731$). However, only the younger group showed significantly better scores on the Allocentric test compared to the Egocentric test ($Z=-3.177$, $p=0.001$, $r=0.600$). This difference was not found in the older group ($p=0.639$). All the significant results showed large effect sizes.

We also analysed whether there was a progressive improvement in the different blocks of the Allocentric test, that is, if there was a learning effect in each of the age groups separately. Our data showed significant differences between Allocentric blocks in the older group ($\chi^2_4=53.312$, $p<0.001$, $r=0.703$), with large effect sizes, but not in the younger group. Post-hoc tests revealed lower scores on the first block compared to the second ($p<0.001$, $r=0.484$), third ($p=0.001$, $r=0.467$), and fifth ($p=0.001$, $r=0.462$) blocks, as well as lower scores on the fourth block compared to the fifth ($p=0.004$, $r=0.384$) (See Fig. 2B).

We also compared the differences in spatial memory according to the gender of the participants, that is, young men with older men, on the one hand, and young women with older women, on the other. Young men outperformed older men on Egocentric Part A (U=25.5, p=0.006, Z=-2.758, r=0.575), Egocentric Part B (U=18.5, p=0.004, Z=-2.948, r=0.614), and the Allocentric Task (U=8, p<0.001, Z=-3.599, r=0.750), whereas young women only obtained higher scores than older women on the Allocentric Task (U=31.5, p<0.001, Z=-4.033, r=0.713). All the results showed large effect sizes. We also analysed both genders within each age group, i.e. young men with young women and older men with older women. Thus, young men performed better on the Egocentric B task than young women (U=46, p=0.026, Z=-2.245, r=0.420), with an intermediate effect size, but no significant differences were found in the older group (See Fig. 3).

Finally, we analysed the possible associations between the Egocentric and Allocentric test performance in each group, and we compared them with the visuospatial skills and visuospatial working memory and span test scores in each group independently. In the young adult group, we found significant positive correlations between Egocentric B Task and the Backward Spatial Span (r=0.596 p=0.001), and between the Allocentric Task and the Forward (r=0.567, p=0.002) and Backward Spatial Span (r=0.488, p=0.008). In the older adult group, we obtained significant positive correlations between the Allocentric Task and the MoCA (r=0.415, p=0.031), as well as between the Egocentric A Task and Egocentric B (r=0.632; p<0.001) and between the Egocentric B Task and the Allocentric task (r=0.550; p=0.003) (Table 2 and 3).

4. Discussion

Two different tasks were tested to analyse age differences in short-term memory and egocentric and allocentric spatial memory strategies, trying to assess the regular frameworks that are used for orientation in the real world, but performed in a controlled environment.

Non-pathological aging, compared to younger ages, is related to a decrease in spatial memory abilities that is more marked in the allocentric framework, but also present in the egocentric one. Previous literature showed allocentric impairment in healthy older people [17,24,38]. We also found egocentric framework alterations, as in previous studies [18,24], but contrary to others where this frame of reference was not impaired [17] or was preferred [13,23]. We must consider, however, that Gazova et al. [17] evaluated egocentric aspects related to active locomotion, whereas our research focused on coding and updating one's own point of view.

Some of the results found could be due to brain areas involved in both tasks. First, the decline in allocentric performance in healthy aging seems to be related to a lower hippocampal contribution [39], the main brain area supporting this function. Analysing the neuro-anatomical basis of the egocentric framework, we need to separate tasks that employ movement, including simulated, from those that include rotation. When the egocentric perspective involves simulated locomotion, as other studies measure [13,23], the brain areas involved (right hippocampus, left superior parietal lobe, and right middle and superior temporal gyrus) are different from those that use a rotated point of view (right retrosplenial cortex and superior parietal lobe), as in our task [40].

Thus, the divergence in behavioural outcomes found in the older population may be due to the different methodologies employed in assessing the egocentric framework that activate different brain areas.

Moreover, differences between young and older groups have been observed in all the allocentric blocks. The performance of the young group hardly improves on the different trials of the Allocentric task because it reaches a ceiling effect almost in the first block, whereas a learning process is observed in the older population. That is, allocentric spatial learning is slower for older people than for young people, but this ability is still preserved, even if this framework is progressively impaired with age. Some aspects of spatial learning have been found to be preserved in the elderly in previous research [17,41]. On the other hand, the ceiling effect found in young people means that this task is too simple for them, and, therefore, increasing the complexity of the procedure for this population may be a line of future research.

We observed that both young and elderly people performed better on Egocentric Part A (the static part of the task) than on Part B (the rotated one). Thus, it seems that both younger and older groups have better location memory than egocentric memory, as previous studies have shown in children [42]. Whereas Part A is more related to the ability to memorize locations in a real-world spatial environment, Part B is related to monitoring position changes and, therefore, to implementing the egocentric framework in daily life, where we do not remain static, but rather our point of view changes throughout the environment. However, it seems logical to think that if a subject is not able to properly solve Egocentric part A (static), which is easier to answer, s/he will hardly be able to execute part B (rotated) correctly. That is, a limited location memory in a real-world-based environment could negatively affect egocentric memory. Our results suggest that there is a deficit in visuospatial working span and memory in this population, and this finding is also observed in the previous literature [43]. Thus, another possible explanation for the lower performance on the Egocentric test that has not been found consistently in previous studies would be that older people are more likely to be affected by a problem in short-term visuospatial memory in real-world settings than by a deterioration in the egocentric strategy per se.

Whereas older people showed similar scores on the Egocentric and the Allocentric tasks, young group performed better on the Allocentric test. These results were not expected because, as we mentioned, other authors found that the egocentric framework is employed more efficiently than the allocentric one in older people to solve spatial tasks [13,23]. Thus, our results may indicate, as we discussed previously, an egocentric impairment or an egocentric alteration associated with a short-term memory alteration. Another possibility is that the older people implemented egocentric reference strategies during the resolution of the Allocentric task. While the participant moves around during the Allocentric test, he/she continues to perceive vestibular, proprioceptive, and other signals, that is, egocentric information. These signals could be used by the subjects, and the joint action of the two sources of information, egocentric and allocentric, in the older people could have improved their allocentric performance. The same arguments can be applied to the better performance of the young group on the Allocentric test. However, other studies generally find a preference for the egocentric framework in young adults [44] when the two sources of information, egocentric and allocentric, are contradictory. However, we assess orientation strategies separately and their information is not contradictory, and so our results could not coincide. At this point, it should also be considered that although both tasks are referred to as spatial memory, the complexity and implications of both tasks are different. In this way, the egocentric task evaluates a simpler form of spatial memory based on real environments, while the allocentric task not only evaluates spatial memory, but also requires updating spatial information based on environmental landmarks.

Regarding gender, whereas older men, compared to young men, obtained worse performance on both strategies, women only obtained lower results on the allocentric strategy. Other studies agree that older women perform worse than younger women, especially in environments with landmarks compared to environments without them [45]. Although during youth young women have been found to perform worse than men in the use of the allocentric [32,46] and egocentric frameworks [35], women seem to be able to preserve the egocentric strategy longer than men in old age. Therefore, there seems to be an effect of gender on spatial orientation during aging, which could be explained by gender-related biological variables. Whereas in women right parietal and right prefrontal areas are involved during spatial navigation, in men the left hippocampal area is usually involved [47]. Thus, women's greater dependence on the parietal cortex, which is another area that participates mainly in the egocentric strategy [48], could explain why egocentric orientation seems to be maintained longer in elderly females. In addition, men's spatial advantage during youth may be related to higher testosterone levels [10]. Therefore, aging-related testosterone decline could be related to the greater loss of spatial skills shown by males compared to females. We mentioned previously that the young group performed better on the allocentric frame than on the egocentric one. However, it is possible that these data are also mediated by gender because it appears that men perform similarly on both types of orientation, but women employ the allocentric strategy rather than the egocentric strategy [35].

As mentioned above, our results show that in comparison with young subjects, older people present lower visuospatial span and lower visuospatial working memory, which is supported by previous studies [43]. These memory differences have been related to contrasting brain activation patterns during these tasks, where older subjects with poorer performance have less prefrontal activation, unlike younger participants [49], as well as a more bilateralised activation pattern involving areas other than prefrontal ones, such as Broca's or the lateral supplementary motor area [50].

We also found that, whereas these visuospatial processes are related to spatial orientation achievement in younger adults; this association does not exist in the elderly. Thus, in young subjects, performance on the Egocentric B task (rotated part) is related to visuospatial working memory, whereas performance on the Allocentric test is associated with both span and visuospatial working memory, but the assessment of visuospatial skills, specifically line orientation judgment, does not seem to be related to egocentric and allocentric memory performance. Different single case studies with topographic disorientation, which may present varied symptoms but have spatial navigation difficulties in common, show that there is a dissociation between span and visuospatial working memory, as well as with different types of visuo-perceptive skills, obtaining normative values on these tasks [51–53]. However, studies in other neurological populations with visuospatial impairment, such as neglect [54] or temporal lobe epilepsy [55], have found that, in most cases, there is impairment in both spatial memory in large-scale environments and visuospatial working memory and span. Likewise, other studies with brain-injured patients show the involvement in visuospatial working memory of areas such as the posterior parietal cortex or the hippocampus [56], which, as we mentioned, are involved in egocentric and allocentric memory tasks. We have also stated that these areas decline in healthy aging, and so it is possible that these associations between space functions are only found in young people. Given these clinical data, it is not surprising that egocentric and allocentric memory skills are associated with other visuospatial abilities in healthy subjects as well. In a healthy population, it seems that these abilities have not been compared, but their performance on span has been compared, that is, how many items the subject is able to remember, either in a close peri-personal space, as occurs with span and working memory, or in a larger environment, as on navigational tasks. Thus, some studies suggest that young men may have better navigational span than classically measured span in an environment closer to the individual, with no difference in women [21], young or old [45]. To sum up, it can be expected that the execution of memory tasks in large environments is related to working memory and span capacities, based on the brain areas involved, and there may also be some influence of gender.

On the other hand, we found that allocentric performance is related to the general cognitive state only in older people. The Allocentric framework is altered early in amnesic-subtype mild cognitive impairment [57], and it has even been postulated that an early deterioration in this strategy could predict an increased risk of further development of dementia [58]. If this allocentric - general cognitive index association could also be established in populations with cognitive impairment, it would be interesting to include allocentric strategy evaluation in standard neuropsychological assessments when cognitive impairment is suspected. Moreover, only in the older group were the spatial memory task results related to each other. Thus, the execution of Egocentric part A (static) is associated with Part B (rotated), and the performance on Egocentric part B (rotated) and the Allocentric task is also associated. These results point out that, on the one hand, in a healthy young population these tasks assess dissociated abilities; that is, achievement on one of the tests does not seem to influence the others. On the other hand, it would also seem that the older group could employ more than one spatial ability when performing the tests. Thus, as mentioned above, it is possible that problems with visuospatial location memory could impair the performance on self-centred memory with a rotated point of view. In addition, we have also pointed out that some egocentric information could be used during the Allocentric test, which, according to these results, seems to occur in this older group. This noted association between Egocentric B (rotated) and Allocentric performance could also explain why we have not found differences between these two frameworks in the elderly. That is, if the older group also used egocentric information, presumably more preserved in advanced ages, for Allocentric test resolution, differences in performance on Egocentric B and the Allocentric test might not have been marked enough to detect a significant difference. However, based on our current data, it is difficult to establish how far the influence of egocentric cues during Allocentric performance could have affected the result in the older group, and so more research on this topic would be necessary to address this issue.

5. Conclusions

In sum, egocentric and allocentric spatial memory ability is impaired in older adults compared to young adults. Despite this progressive deterioration, it should be noted that older adults are still able to improve their allocentric performance because their ability to learn spatial locations is preserved. Older adults show similar performance on allocentric and egocentric frames of reference, probably due to alterations in short-term visuospatial memory that may, in turn, increase errors on the egocentric task. Egocentric spatial memory seems to be maintained longer in elderly females compared to men. Thus, Egocentric and Allocentric Spatial Memory Tasks reveal age-related differences in spatial memory performance.

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Conflicts of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Figure captions

Figure 1. Experimental setup and example of sample position and retention trials on the Egocentric (A) and Allocentric (B) Spatial Memory Test.

Figure 2. (A) Percentage of correct responses of Egocentric – part A (EGO A), Egocentric – part B (EGO B) and Allocentric (ALLO) in young and older groups. Significant differences were found between groups in EGO A, EGO B, and ALLO (**p<0.001, *p=0.031). (B) Percentage of correct responses on the Allocentric blocks (ALLO 1, 2, 3, 4 and 5) in young and older groups. Significant differences between younger and older groups were found in the first, second, third, fourth, and fifth blocks (**p<0.001). In the older group greater improvement was found comparing the first block with the second, third and fifth (#p≤0.001), as well as comparing the fourth with the fifth (&p=0.004).

Figure 3. Gender differences between age groups on Egocentric part A, Egocentric part B, and Allocentric tasks. Significant differences were found between young and old men on every task, whereas young women only outperformed older women significantly on the Allocentric test. Young men obtained better scores than young women on Egocentric part B (**p<0.01, *p<0,05).

Tables

Table 1. Mean and SD of young and older group in neuropsychological tests.

Neuropsychological tests	Young group Mean (SD)	Older group Mean (SD)
Egocentric – part A	29.39 (1.197)**	27.30 (2.998)
Egocentric – part B	25.46 (3.564)*	21.74 (7.145)
Allocentric	55.75 (5.140)**	42.30 (11.371)
Benton's Judge of Line Orientation	25.43 (6.380)	24.37 (3.553)
Spatial Span Forward	6.68 (1.278)**	4.70 (0.823)
Spatial Span Backward	7.46 (0.922)**	5.15 (0.818)

Significant differences between younger group and older group *p<0.05, **p<0.001

Table 2. Correlation of Egocentric and Allocentric Spatial Memory Tests with RIST, Spatial Span Forward and Backward, and Benton's Judge of Line Orientation Test in young group

		Egocentric Part A	**Egocentric Part B**	**Allocentric**
RIST	Spearman correlation	.169	.177	.330
	p value	.390	.367	.086
Spatial Span Forward	Spearman correlation	-.076	.345	**.567****
	p value	.700	.072	**.002**
Spatial Span Backward	Spearman correlation	.147	**.596****	**.488****
	p value	.456	**.001**	**.008**
Benton's Judge of Line Orientation	Spearman correlation	-.127	.129	.152
	p value	.520	.513	.440
Egocentric Part A	Spearman correlation	1	.147	-.074
	p value		.456	.709
Egocentric Part B	Spearman correlation		1	.429
	p value			.053
Allocentric	Spearman correlation			1
	p value			

RIST Reynolds Intellectual Screening Test. Significant correlations **p<0.01

Table 3. Correlation of Egocentric and Allocentric Spatial Memory Tests with MoCA, Spatial Span Forward and Backward, and Benton's Judge of Line Orientation Test in older group

		Egocentric Part A	**Egocentric Part B**	**Allocentric**
MoCA	Spearman correlation	.014	.295	**.415***
	p value	.944	.135	**.031**
Spatial Span Forward	Spearman correlation	.043	.219	.264
	p value	.830	.272	.184
Spatial Span Backward	Spearman correlation	.217	.207	.069
	p value	.277	.300	.733
Benton's Judge of Line Orientation	Spearman correlation	-.371	.028	.183
	p value	.057	.891	.360
Egocentric Part A	Spearman correlation	1	**.632****	,103
	p value		**.000**	,608
Egocentric Part B	Spearman correlation		1	**.550****
	p value			**.003**
Allocentric	Spearman correlation			1
	p value			

Table 3. *MoCA* Montreal Cognitive Assessment Test. Significant correlations *p<0.05, **p<0.01

Figure 1

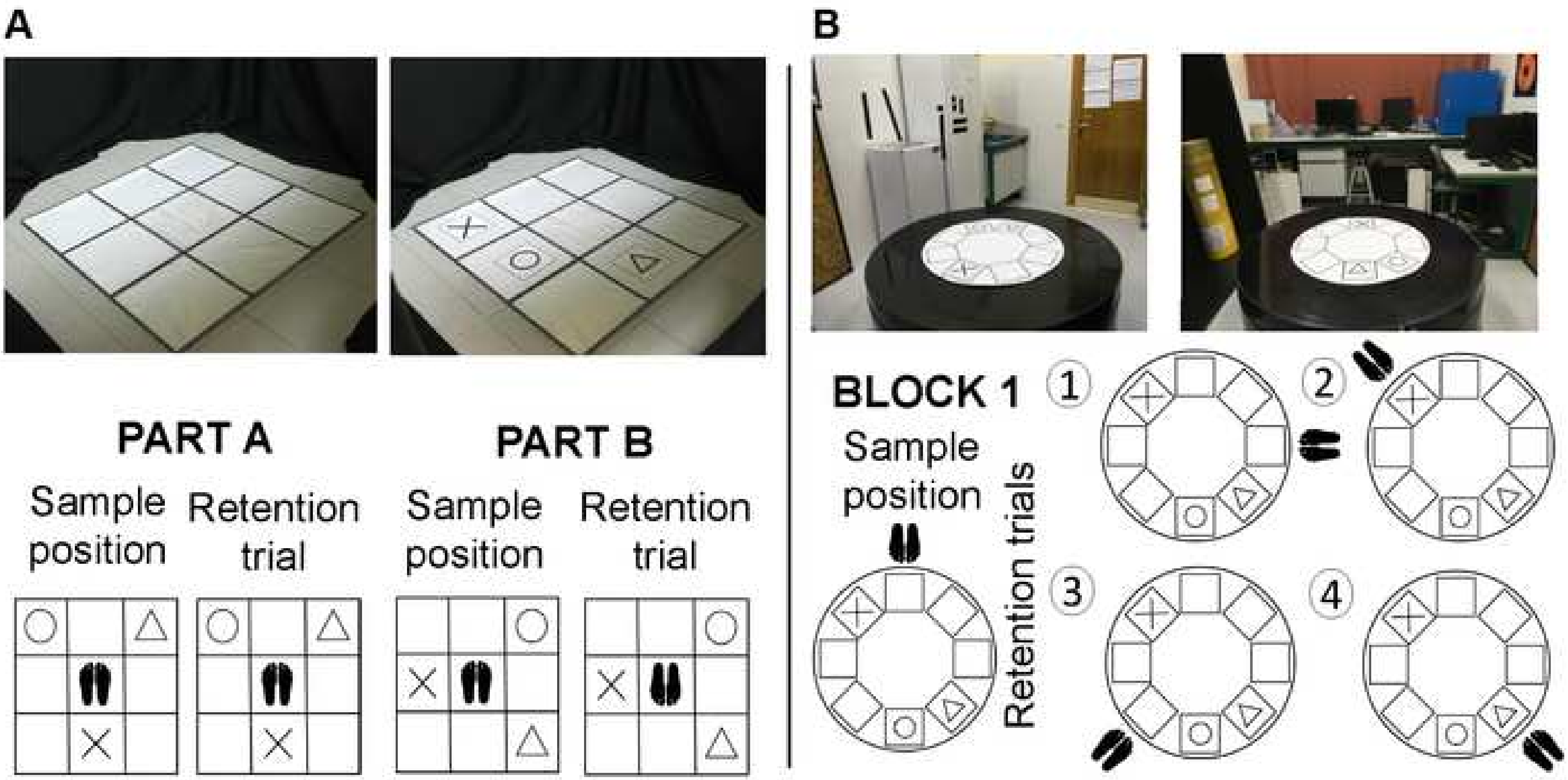
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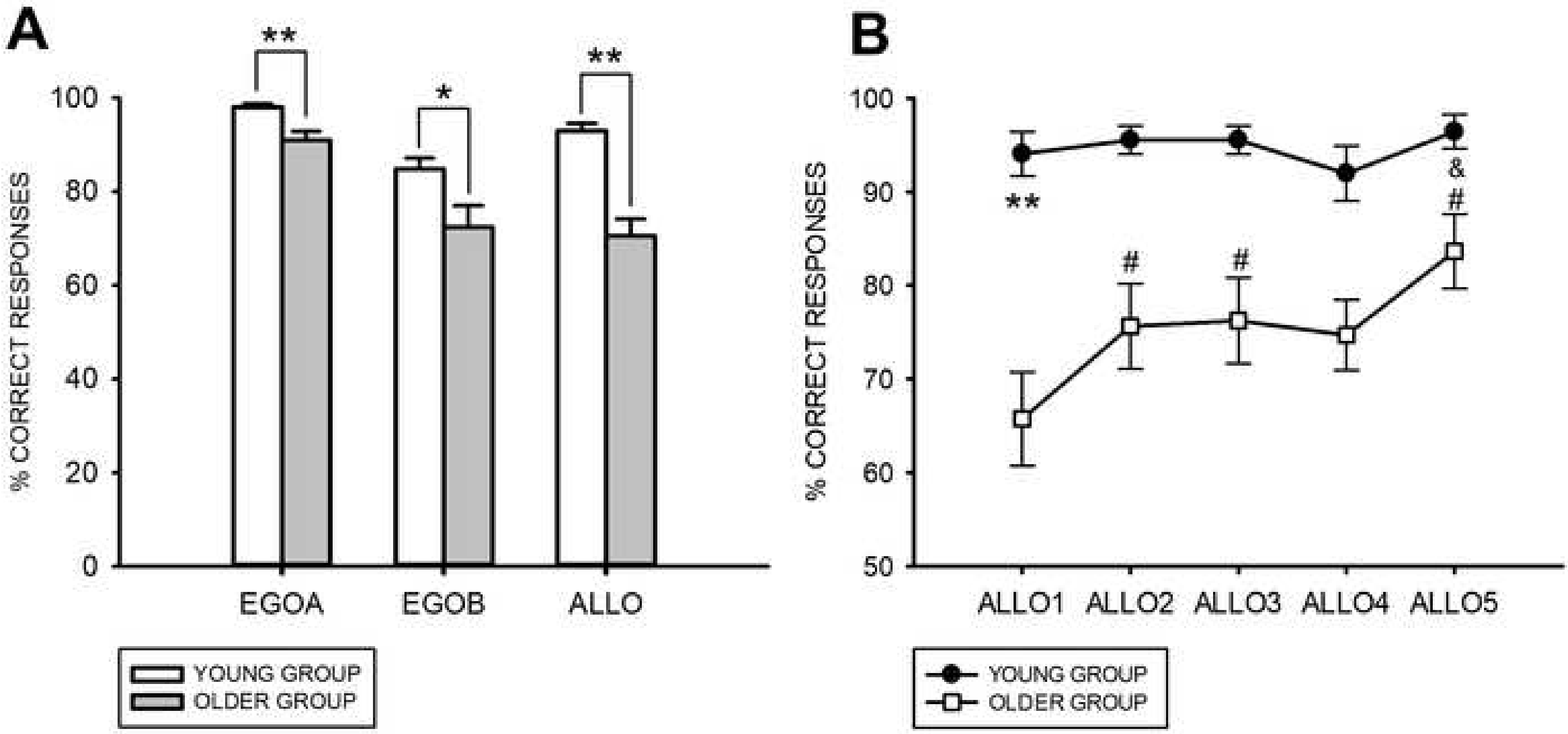
Figure2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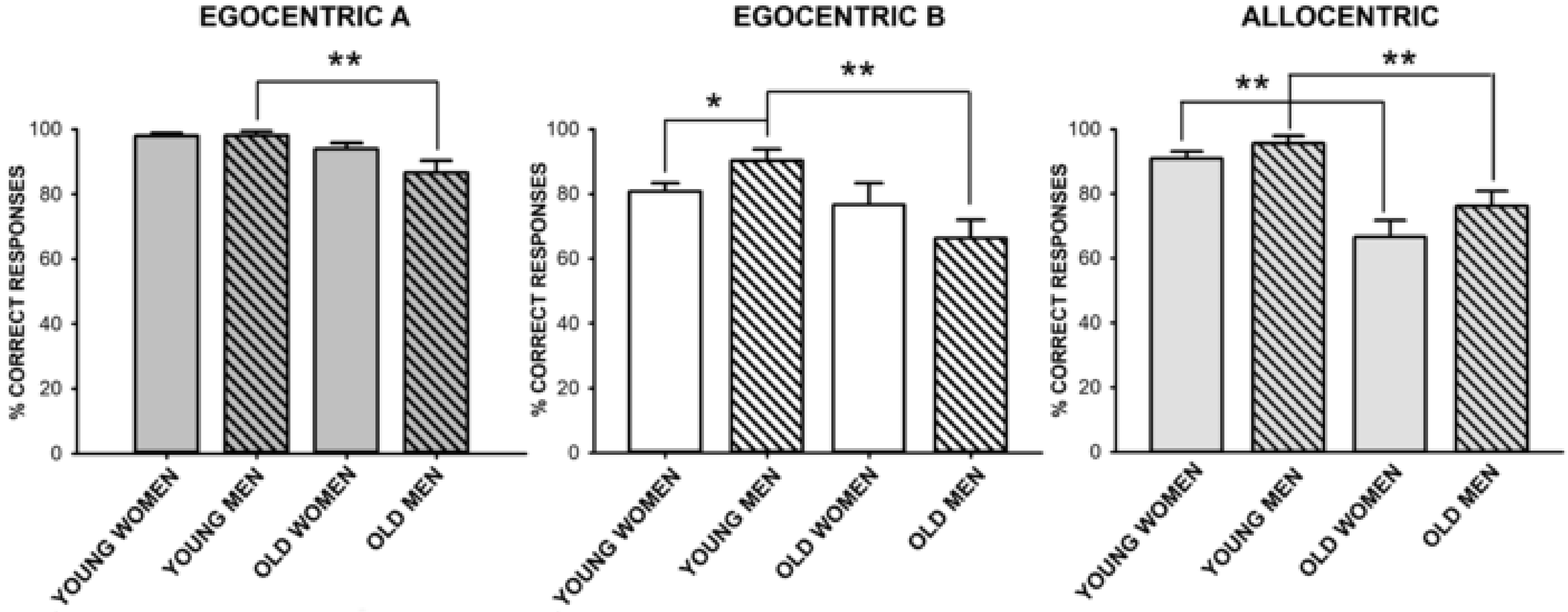
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