Memory for familiar locations: The impact of age, education and cognitive efficiency on two neuropsychological allocentric tasks.

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Abstract

This research aims to reconsider and support the use of spatial tasks based on familiar geographical information in the neuropsychological assessment of topographical (dis)orientation. Performance on two spatial tasks based on familiar information - Landmark Positioning on a Map (LPM) and Map of Italy (MOI) - were compared in two studies assessing allocentric orientation among young and healthy elderly with different levels of education (Study 1) and elderly with and without probable cognitive impairment (Study 2). Results from Study 1 showed that the MOI task was affected by education while the LPM was not. Results of Study 2 showed that both tasks were sensitive to different levels of cognitive functioning in a sample of community-dwelling seniors. Overall, spatial tasks based on mental representation of the hometown environment may be an important supplement in the assessment of allocentric topographical disorientation, discriminating typical from atypical aging.

Introduction

Detailed environmental information can be acquired and retained in map-like representations. Several research fields have addressed spatial mental representations, including geography / topography and psychology, sometimes using different terms to reference the same notion. The process of spatial information gathering - from spatial properties (e.g. environmental features / landmarks) to turns (changes in direction or orientation) in route and survey representations - (Ishikawa & Montello, 2006; Goldin & Thorndyke, 1982; Thorndyke & Hayes-Roth, 1982; Moscovitch, Kapur, Köhler, & Houle, 1995; Palmiero & Piccardi, 2017) is associated in mental imagery (Montello, 2009; Alibali, 2005). This process is, in some cases, called acquisition of *geographical knowledge* (e.g., Montello, 2009), and in others, acquisition of *topographical knowledge* (Turriziani, Carlesimo, Perri, Tomaiuolo, & Caltagirone, 2003), *spatial information*

(Cheng, Shettleworth, Huttenlocher, & Rieser, 2007), or *geographical reasoning* (e.g., Costa & Bonetti, 2017). All of these terms are used in the scientific literature almost without distinction. These spatial concepts rely on cognitive or mental maps, related to landmarks, paths, regions and boundaries (Evans, 1980; Lynch, 1960; Nadel, 2013) and functionally describe an important human skill dedicated to processing spatial information (Montello, 2009; Taylor, 2010). We have chosen to use *topographical* as adjective to identify the spatial mental organization of the environment.

Human beings learn real-life environments by sensing and moving through the environment: this results in *first-hand environmental experiences* or internal knowledge (Montello, 2009; Costa & Bonetti, 2017). Alternatively, they can acquire information via symbolic sources, through interaction with visual and verbal artefacts (external knowledge), such as paper /digital maps or verbal descriptions of environments (Bosco, Longoni, & Vecchi, 2004; Picucci, Gyselinck, Piolino, Nicolas, & Bosco, 2013; Montello & Freundschuh, 1995; van Asselen, Fritschy, & Postma, 2006; Meilinger, Frankenstein, & Bülthoff, 2013).

Consequently, as stated before, human beings can create spatial mental representations, derived from ongoing exploration or from map-study of the environment, and then are able to judge spatial distances and represent their surroundings in an abstract allocentric way, through topographical cognitive maps (e.g., Tversky, 2000).

Aging is associated with a functional decline in cognitive performance in executive function, attention, verbal and visual explicit memory, working memory, episodic and semantic memory (e.g., Moffat, 2009). Aging also affects acquisition of spatial information. Several studies have investigated navigational skills, allocentric and egocentric representations, cognitive mapping, landmark processing and spatial memory in pathological aging (see e.g., Lithfous, Dufour, & Després, 2013 for a review; Hort et al., 2007). It is well known that neurodegenerative processes associated with aging can lead to mild cognitive impairment, frequently converting into dementia, especially Alzheimer's disease. In such case, the generation and use of cognitive maps, the use and location of landmarks and the retrieval of topographical aspects of the environment are impaired (e.g., Caffò et al., 2012).

If individuals lose the ability to know where they are and to head toward their destination, they are affected by *Topographical Disorientation* (TD, Aguirre & D'Esposito, 1999). TD could occur during pathological aging as an early stage of a range of neurodegenerative diseases (Benton, Levin, & Van Allen, 1974; Aguirre & D'Esposito, 1999; Caffò et al., 2014a, Lopez, Caffò, & Bosco, 2018). As shown in several studies TD arises early in the development of Mild Cognitive Impairment (MCI), and it is also then an incipient symptom even in Alzheimer's Dementia (AD). Moreover, it can be useful for monitoring the progression of the disease (e.g., Hort et al, 2007; Desikan et al 2008; Lim, Iaria, & Moon, 2010). In the last decade, the assessment of spatial orientation in people with age-related cognitive impairment and in particular with AD is becoming increasingly important due to emerging evidence that disorientation is a more specific behavioural sign of AD compared to other cognitive disorders, such as impairments in episodic memory (Johnson et al., 2009). For instance, Yew, Alladi, Shailaja, Hodges, & Hornberger (2013) have suggested that disorientation and posterior hippocampal deficits appear to be specific to AD allowing neuropsychologists to distinguish AD patients from those with other neurocognitive disorders, such as Frontotemporal Dementia, who otherwise exhibit comparable profiles on standard memory tasks.

A recent work by Lopez and colleagues (2018), emphasized that it is necessary to assess spatial abilities by referring to well-consolidated spatial information in the evaluation of spatial cognitive decline. Indeed, TD reflects both anterograde and retrograde memory components of disorientation. In the original taxonomy of Aguirre and D'Esposito (1999), egocentric and heading (allocentric) components clearly refer to spatial data acquired in the past (retrospective traces), whilst anterograde disorientation refers to spatial information to be acquired. Starting from this assumption, the importance of studying how people, potentially affected by TD, represent well-known spatial information would seem indisputable. Nevertheless, people are often tested only on newly learned environments, in which information is processed in brain areas typically more prone to impairment with aging (Winocur, Moscovitch, & Sekeres, 2007; Moscovitch et al., 2005). Moreover, during pathological aging, there could be greater loss of episodic compared to semantic spatial memory, and very remote spatial memories could endure even after a large hippocampal lesion, given that such memories have been transformed in more schematic forms in extra-hippocampal structures (Moscovitch, Nadel, Winocur, Gilboa, & Rosenbaum, 2006). Rosenbaum and colleagues (2000) showed that although the presence of cognitive decline was associated with amnesic disorder in cases of bilateral hippocampal lesions, patients did not show remote memory loss: only details and negligible spatial information were lost.

In neuropsychological evaluation, topographical knowledge is mostly assessed by localizing landmarks on a map and is thus also based on temporally remote spatial information (e.g., Benton et al., 1974; Spinnler & Tognoni, 1987). An example of a such a task is the Map of United States (MUS, Benton et al., 1974). In the Italian context, an outdated standardization of the Map of Italy task (MOI, Spinnler & Tognoni, 1987) is available. Both are map completion tasks mostly based on symbolic sources of topographical information, such as the study of topographical country maps. The topographical knowledge is represented in an allocentric way, since it refers to the relationship between landmarks.

According to Golledge (2002) allocentric topographic knowledge depends on education levels. In the Italian context, people are continuously exposed to maps in primary school from 6 to 10 years of age. After primary school, exposure to maps becomes more erratic due to individual habits, interests and the field of study undertaken after schooling. Map study, as a direct form of learning (Tversky, 1993), allows people to form a map-like mental representation of the environment (Thorndyke & Hayes-Roth, 1982; Kosslyn, Ball, & Reiser, 1978; Thorndyke, 1981; Hishikawa & Montello, 2006; Wolbers & Hegarty, 2010). Memory traces for this kind of information are relatively preserved in people who have completed their education recently. Thus, the period of maximum exposure to maps is closer for people who have completed their education more recently (Roser & Ortiz-Ospina, 2017). From this perspective, the topographical ability on the MOI may be a relatively unfair method for assessing spatial knowledge in aging.

In this respect, it seems important to underscore the fairness of the spatial assessments with regard to group, individual and cultural differences. Every assessment should guarantee results regardless of changes in variables such as individual variation, education or gender (Cole & Zieky, 2001; Picucci, Caffò, & Bosco, 2011).

At the same time, people are exposed to lifelong learning of their environments. Individuals form coherent mental representations of the spatial relations among landmarks (indirect – *survey* - learning, Tversky, 1993) learned from repeated, massive and direct exploration of paths and routes. Indeed, the greater the exposure over the years, the more the memory trace is considered to be strengthened by experiences. However, mental spatial representation processing based on massive exploration of the environment requires a deep transformation of the original memory contents and it is not yet completely clear how this transformation process works in aging. Learning from navigation requires a perspective change that can translate procedural knowledge into survey knowledge: the space is first experienced in an egocentric format, and then transformed into an allocentric *map-like* representation (Zhong & Moffat, 2016).

In this regard, Serino and colleagues (2013; 2014) introduced the concept of *mental frame syncing* which enables the recovery of stored spatial mental information through synchronization between *view-point independent* and *view-point dependent* representations. Humans identify and record the correct position of the objects, forming allocentric mental representation (object to object representation). At the same time, humans memorize their egocentric position and the objects' position. This object representation is ego-oriented bearing. In order to transfer this ego-oriented bearing object representation on the allocentric view-point independent representation, it is necessary to compute the object position in relation to the ego-oriented bearing. In this way the allocentric view-point independent representation becomes an allocentric view-point dependent representation. Thus, the allocentric representation of the space can be translated into an egocentric one and vice versa.

As navigation experience increases, previously unknown details are added to the old representation and all of its elements become strengthened and more easily retrievable (Lopez, Caffò, & Bosco, 2019). Therefore, spatial experiences contribute to increasing familiarity with topographic information; as a consequence, greater familiarity increases orientation skills (e.g. Nori & Piccardi, 2012). Recently, it was suggested that familiarity with an environment can protect spatial representations from the effects of aging and spatial cognitive impairment (e.g., Muffato, Della Giustina, Meneghetti, & De Beni, 2015, Lopez, et al., 2018; Lopez et al., 2019).

The present research aims to reconsider and support the use of spatial tasks based on familiar, remote allocentric topographic knowledge, and consists of two studies.

In the light of the foregoing, we intend to assess whether healthy aging and young participants perform comparably on spatial mental representation tasks using information acquired far back in time. This result would help confirm that difficulties with the mental representation of space in the elderly may largely relate to difficulties with learning new materials, as is characteristic of tasks involving the acquisition of new and / or fictitious environments. Secondly, we intend to assess whether mental representations of geographical information, such as that sourced from national map study, is dependent on the level of education of healthy aging participants and if, conversely, a task based on information related to the participant's hometown does not suffer from this effect.

Finally, we plan to assess whether tasks based on familiar geographical information can discriminate between *typical* and *atypical* aging (O'Malley, Innes, & Wiener, 2017). The development of an allocentric task based on familiar information that is unaffected by education and age, yet sensitive to cognitive impairment, for comparing young and healthy elderly, should allow a more effective assessment of allocentric topographic disorientation as an effect of very early atypical aging, and avoid the additive side-effect of the anterograde agnosia that surely contributes to the poor performance of elderly participants (Descloux & Maurer, 2018; Ruggiero, D'Errico, & Iachini, 2015; Lopez et al., 2019).

Study 1

The first study aimed to compare performance on the Map of Italy (MOI, Spinnler & Tognoni, 1987) task with performance on a new, ecologically valid task based on participants' hometown knowledge: The Landmark Positioning on a Map (LPM, Lopez et al., 2018). The LPM task is a map completion test, mainly derived from the exploration and navigation of familiar locations. Specifically, the task evaluates participants' ability to recall and pinpoint eight landmarks in their hometown, according to two fixed reference points, and to arrange these landmarks on a blind map.

In the first instance, Study 1 aimed to verify whether healthy young and old participants would exhibit similar performance on two tasks requiring allocentric representations acquired through direct learning – map study – (MOI) and through massive exploration experiences (LPM), since both are based on well-consolidated information. Secondly, it aimed to assess whether the expected effect of education on MOI also extends to the LPM task or whether the absence of an education effect already found in a previous study (Lopez et al., 2019) could be confirmed. Finally, we wanted to understand if performance on both spatial tasks was influenced by the locations of landmarks with reference to the topographical coordinate system, namely the North/South (y-axis) and East/West (x-axis). No specific assumptions could be made on the interaction between axes and age, education and gender.

Methods

Participants

Three hundred healthy participants (150 women) took part in the study. All participants were from the metropolitan area of Bari, Apulia, Italy. One hundred Young university students (i.e., age mean±sd 23.08 ± 3.34; level of education mean±sd 16.29 ± 1.89, Y), 102 Elderly people with a High level of education (i.e., age mean±sd 70.88 ± 6.40; level of education mean±sd 15.45 ± 2.96, EH) and 98 Elderly people with a Low level of education (i.e., age mean±sd 75.41 ± 6.40; level of education mean±sd 6.97 ± 2.26, EL), were enrolled in the study. Descriptive statistics for the three groups are reported in Table 1. All participants, blind to the hypothesis of the study, signed a consensus form. The Ethical Committee of the Institution approved the study protocol, and the whole study was performed following the Helsinki Declaration and its later amendments.

Insert here Table 1.

Materials and procedure

Elderly participants were volunteers recruited from senior centres and third age universities with the support of a proxy informant, generally undergraduate or graduate students, trainees, employers of the centres and also general practitioners. They were instructed to reach out to people in a general state of physical and psychological health. Elderly participants were consecutively enrolled between February 2016 and July 2017, until the reaching of the sample size. No one rejected the proposal of the proxy to participate to the study. First of all, in order to exclude people with a history of suspected uncompensated systemic/traumatic/psychiatric disease, or with severe vision/hearing loss, which could have affected cognition, a general anamnesis was assessed, carried out by supervised trainees in psychogeriatric assessment. Eighteen participants were excluded at this level. Secondly the global cognitive function was evaluated by the Montreal Cognitive Assessment (MoCA, Nasreddine et al., 2005; Krishnan et al., 2017; Bosco et al., 2017). The inclusion cut-off was a MoCA score higher than 17, which seems to be the best cut-off for discriminating healthy participants from participants with probable cognitive impairment in an Italian elderly sample (Bosco et al., 2017). Twenty-eight participants were excluded because they had a MoCA score less or equal to 17. Moreover, the Activities of Daily Living and Instrumental Activities of Daily Living (ADL, Katz, 1983; IADL, Lawton & Brody, 1969), for a possible occurrence of functional decline usually associated with dementia (inclusion cut-off higher than four for ADL, and higher than four for males and six for females for IADL), the 15 - item version of the Geriatric Depression Scale (GDS, Brink, Yesavage & Lum, 1982; inclusion cut-off less than four), in order to exclude depressive symptoms, and the Subjective Memory Complaints Questionnaire (SMCQ, Youn et al., 2009) to exclude robust complaints regarding memory loss (inclusion cut-off less than five) were administered. No one was excluded from the sample. Some thresholds of the sample size were reached early, such as the number of female participants with low level of education, the remaining portion of the sample was purposefully sought after. Data of all potential participants, not fulfilling the requirements, were not recorded. At the end of the enrolment procedure the final sample was composed of 200 elderly participants. Means and standard deviations for each test and for each group of elderly participants are reported in Table 1.

The inclusion criteria for young participants was academic performance considered as a measure of cognitive efficacy (Richardson & Norgate, 2015; Mangels, Butterfield, Lamb, Good & Dweck, 2006; Fenollar, Román & Cuestas, 2007). Young participants had high / adequate academic achievement measured as the number of exams per years (inclusion cut-off five or more exams, maximum number of exams per year: seven).

The inclusion criteria for all participants, in order to assess experience with their hometown environment and the Map of Italy, were as follows: the more the exposure, the better their knowledge of landmarks should be (Pick, 2012). All the participants fulfilled three minimum requirements, regarding their level of familiarity with the area of Bari: a) having lived in Bari from birth; b) having an active lifestyle as measured by an index of activity “in daily routine" called the Hometown Index of Exposure inspired by the Daily Questionnaire of World Health Organization's Quality of Life Questionnaire -WHOQOL-BREF (WHOQOL Group, 1995). Participants were rated as *active*, if they responded that they had moved around within their hometown by foot and/or using vehicles at least three times a week (inclusion cut-off higher than two). In particular they answered questions about how many times a week times a week they get around by foot by foot or by vehicle, on a scale from 1 (=never) to 7 (= every day of the week). Finally, c) having recognized the relevant landmarks. Participants were required to recall the names of the landmarks displayed on 21x15 cm photographs, which would be used in the LPM task. All participants recalled / recognized the names of the 10 landmarks used in the spatial tasks correctly.

Moreover, all participants were rated for their knowledge of the national map of Italy based on three items: the current use of Google Maps, Paper Maps and Weather Forecasting (mediated by web or TV), on a scale from 1 (=never) to 7 (= always). The rating approach was similar to that used for the Hometown Index of Exposure. The general index of Map of Italy Index of Exposure was the mean of the previous three items. Means and standard deviations for all the criteria for inclusion are reported in Table 2.

Insert Table 2 here

Afterwards, participants were required to complete the following two maps:

a) *Map of Italy* (MOI, Cartina di Italia Spinnler & Tognoni, 1987)

Participant had to pinpoint ten cities on the map of Italy. The old scoring method consisted in a qualitative categorical evaluation of positions on North-South and East-West axes. The participant had to pinpoint the following cities: Milan, Genoa, Turin, Venice, Naples, Bari, Palermo, Bologna, Firenze and Rome. For each correct position, we assigned one point for a maximum of 20 points.

The new scoring method was based on the use of a Cartesian coordinate system (Lopez et al., 2018). It allows for the detection of positions above and below, and to the right or left of a given landmark, with respect to all other landmarks. This kind of encoding enables the evaluation of performance, by awarding one point for every correct comparison on the North/South, East/West y and x-axis, respectively. The participants are instructed to pinpoint all the landmarks, keeping in mind the metric (i.e., relative distances) as well as categorical ("A is above/below and left/right of B") spatial relationships between landmarks. The distance between the participant's positioning and the true location of each landmark in an xy-Cartesian coordinate system provides the error score. The Cartesian coordinate system allows the detection of position above and below, and right and left of a landmark, with respect to all the others. This kind of encoding permits to evaluate the performance, by giving one point for every correct comparison. More specifically, the score is based on the comparison between the actual and the produced-by-the-participant relationship, in terms of both x and y axis, for each couple of landmarks. Considering two landmarks, A further East and further North of B, if the produced relationship is congruent with the actual one, then one point will be allocated for each axis. Conversely, if the relationship of A relative to B is distorted, i.e. A is further West of B and/or A is further South of B, the point will not be assigned for the x axis and/or the y axis. Consequently, 10 landmarks compared in pairs return 45 different comparisons for each axis. The highest possible correct score for the map of Italy was 90 points (45 on the North-South and 45 on the East-West axis). The final score was reported using proportions (range between 0 and 1, e.g., Agresti & Min, 2005). This encoding system was well suited to our purposes. The correct position of every landmark was compared with that provided by the participant and led to an overall measure of performance.

Insert figure 1 approx. here

b) Hometown task: Landmark positioning on a map (*LPM,* Lopez et al., 2018)

Participants were first required to recognize 10 well-known landmarks in their hometown that were displayed in photographs. Two of the landmarks were then fixed on the hometown map as reference points: one in the centre of a blind map and the other further outside the city on the map. The participant had to pinpoint all the other eight landmarks, keeping in mind the metric (i.e., relative distances) as well as categorical ("A is above/below and left/right of B") spatial relationships between landmarks. The scoring procedure was the same as that described for the MOI task, as was the use of proportion for the final score. The highest possible score for the LPM was 56 points (28 on the North-South and 28 on the East-West axes). (See figure 2).

Insert figure 2 approx. here

Participants were assessed individually in a well-lit and quiet room without disturbances. Each step in the tests was made clear to the participants beforehand. Data were collected in one session ranging between 90-120 minutes. Breaks were allowed on request.

Results

Descriptive statistics and preliminary analysis of the inclusion criteria was performed, as reported in Tables 1 and 2. Significant statistical (but not clinical) differences emerged for cognitive functioning and level of depressive symptoms between EH and EL (see Table 1). The reliability of the spatial tasks was also considered: Cronbach's Alpha was 0.91 for the LPM and 0.92 for MOI task. Finally, the measure of association between the two scoring procedures (old vs. new) for the Map of Italy was Pearson $r=0.65$, ($t(298) = 14.8$, $p<0.01$), and the measure of association between the LPM task and the MOI was Pearson $r=0.32$, ($t(298) = 5.7$, $p<0.01$).

In order to accomplish the purposes of the first study, various mixed factor Analyses of covariance (ANCOVA) were performed, with groups (three levels: Y, EH and EL) and gender as between-subject variables, and axis (two levels: North/South and East/West) as repeated measure variables (the variable "axis" is not part of the analysis with the old method of scoring of MOI), for performance on the MOI and the LPM tasks controlling for covariates, namely Map of Italy and Hometown Index of Exposure scores.

The first ANCOVA was performed using the old encoding of the MOI (according to Spinnler & Tognoni scoring), in order to indirectly compare the results provided by that method with those obtained using the new scoring method. The main effect of group was significant (F (1, 292) = 18.31, $p<0.001$; η_p^2= 0.11). The covariate (i.e., Map of Italy Index of Exposure) was not significant (Means and sds in Table 2 line 8). A post-hoc inspection of the table revealed that only the comparison between Y and EL groups were significant (see Table 2).

The second and the third mixed factor ANCOVAs were then performed and the results were as follows:

1) MOI task: The main effects of group (F (1, 288) = 17.47, $p<0.001$; η_p^2= 0.06) and axis (F (1, 288) = 33.41, $p<0.001$; η_p^2= 0.19) proved to be significant (Means and sds in Table 2 line 9). Moreover, the group x axis interaction (F (2, 288) = 13.84, $p<0.001$; η_p^2= 0.09) was also significant. No other main, interaction or covariate effects were significant. From the inspection of the graph (see Figure 3) it emerged that the advantage on the East/West axis with respect to North/South axis was smaller for the EL participants, compared to Y and EH participants.

Insert figure 3 approx. here

2) LPM task: Only the main effect of gender F (2, 293) = 28.01, p=0.000; η_p^2= 0.09 (male mean±sd = 0.61±0.11; female mean±sd = 0.52±0.11) proved to be significant. All the other main, interaction and covariate effects (i.e., Hometown Index of Exposure) were not significant.

Finally, levels of cognitive functioning and depression were controlled as covariates (MoCA and GDS scores), in the performance of both spatial tasks (MOI and LPM tasks) only for EH and EL participants, using the same kind of analysis. In both cases, the covariates were not significant.

Study 2

The second study investigated performance on the MOI and LPM comparing two new groups of old participants (paired by age, gender and education). We wanted to show that measures based on well-consolidated spatial information are sensitive to age-related cognitive impairment. The aim of the present study was to understand if participants 65+ years old, either with high or low cognitive functioning, performed differently in topographic orientation tasks based on familiar information, such as the MOI and LPM. In pursuit of this aim, two samples of elderly participants with high and low scores on the MoCA were tested.

Method

Participants

One hundred and ninety participants (95 women), took part in the study. Ninety-five participants were classified as High Cognitive Functioning (HCF) and the remaining as Low Cognitive Functioning (LCF) by using the following MoCA cut-off scores: > 17 for healthy and ≤17 (but ≥14) for cognitively impaired participants (Bosco et al., 2017). Other potentially influential variables were paired between the two groups. Descriptive statistics for the two groups are reported in Table 3.

Materials and procedure

Setting and materials were the same as in Study 1 with respect to elderly participants. As in the previous study a combination of a convenience and purposive sampling was employed. For the enrolment procedure a large number of proxy informants were instructed to reach out to elderly participants with a high level of education in a general state of health but also with supposed memory, cognitive complaints. No one rejected the proposal of the proxy to take part to the study. After the general anamnesis 27 participants were excluded for supposed uncompensated systemic/traumatic/psychiatric disease or with severe vision/hearing loss. In this case the Subjective Memory Complaints Questionnaire (SMCQ, Youn et al., 2009) was not considered as an inclusion criterion. As showed in the literature a subjective memory complaint is associated with cognitive decline (e.g., Reid & MacLullich, 2006; Amariglio, Townsend, Grodstein, Sperling, & Rentz, 2011; Jonker, Geerlings, & Schmand, 2000). The subsequent part of the procedure was the same of study 1. Finally, the entire sample was composed of 190 elderly participants.

Results

Descriptive statistics and preliminary analysis of the inclusion criteria was performed, as reported in Tables 3 and 4. Data transformations and statistical analyses were the same as in Study 1. Two ROC Curves were calculated to compare the old and new scoring method of MOI and LPM task in order to distinguish between HCF and LCF participants. Regarding the MOI task, the new method of scoring seemed to be considerably more accurate in discriminate HCF and LCF participants (new scoring method: AUC value 1.0; old scoring method: AUC value 0.75). Regarding the LPM task the accuracy to discriminate between HCF and LCF participants was excellent (AUC value 0.94) showing that the test accurately discriminates the groups of elderly participants with high and low cognitive functioning.

Insert here Table 3 and 4

Insert here Figure 4 and 5

With regard to the aims of Study 2, a mixed factor ANCOVA was performed with group (two levels: HCF, LCF) and gender as between-subject variables and axis position (two levels: North/South and East/West) as repeated measure variables, on the MOI and the LPM tasks, controlling for covariate effects of the Map of Italy and Hometown Index of Exposure scores, respectively.

The results were as follow:

1) Map of Italy (old scoring method): The main effects of group ($F(1, 185) = 43.31$, $p<0.001$; $\eta_p^2 = 0.19$) proved to be significant (Means and sds in Table 4 line 8). All the other interaction effects as well as the covariate (i.e., Map of Italy Index of Exposure) were not significant;
2) Map of Italy (new scoring method): The main effects of group ($F(1, 185) = 52.63$, $p<0.001$; $\eta_p^2 = 0.22$; means and sd in Table 4 line 9) and the main effect of gender $F(1, 185) = 16.67$, $p<0.001$; $\eta_p^2 = 0.08$ proved to be significant. Moreover, group x axis ($F(2, 185) = 9.04$, $p<0.001$; $\eta_p^2 = 0.05$) and group x gender ($F(2, 185) = 16.88$, $p<0.001$; $\eta_p^2 = 0.08$) were also significant. All the other main, and interaction effects as well as the covariate (i.e., Map of Italy Index of Exposure) were not significant. It can be seen from an inspection of the graph (see Figure 6), that the difference between male and female participants favoring males was greater for the LCF participants, compared to HCF participants. Moreover, from the inspection of the graph (see Figure 7) it emerged that the advantage on the East/West axis with respect to North/South axis was minor for the LCF participants, compared to HCF participants;

Insert figure 6 and 7 approx. here

3) LPM task: The main effect of group (F (1, 185) = 147.62, p<0.001; η_p^2= 0.44; (means and sds in Table 4 line 10) and the main effect of gender F(1, 185)= 29.89, p<0.001; η_p^2= 0.14 (male mean±sd = 0.55±0.06; female mean±sd = 0.49±0.06) proved to be significant. All the other main, interaction and covariate effects were not significant.

General Discussion

The core aim of the present research was to analyze the limitation of a task mainly based on the symbolic acquisition of spatial information, compared to a more naturalistic task, namely the LPM task, based on remote allocentric information, derived from exploration / navigation of the environment. The correlation between LPM and MOI was moderate. Even if convergent validity requires medium-to-large correlation (>= .50), it is important to note that, although both tasks assess allocentric memory, they refer to two most likely different kind of learning, repeated experiences of navigation and direct expositions to maps, respectively. The study 1 compared one young and two groups of healthy elderly people (with low and high levels of education) on their performance on the MOI and LPM tasks. Both tasks are thought to evaluate allocentric topographic knowledge. The information required to accomplish the MOI is more likely acquired through map study, while information relevant to the LPM is more likely acquired through repeated experiences of navigation.

All the participants were enrolled in the study on the basis of their self-reported spatial experience, their exposure to maps and their overall functioning. There were no differences between the young and the elderly in terms of self-reported global spatial experience, namely the use of traditional device or web-based services was balanced across the two groups.

Moreover, elderly participants were classified on the basis of their educational level. In this regard, educational level may prove to be a relevant confounding variable in studies involving age-related effects on cognition (Stern, 2002; Caffò et al., 2016). Studies of spatial cognition that compare young and elderly people, tend to ignore the effect of educational level, and neglect to include this variable in statistical analyses. This could be due to the fact that the young are usually recruited from university courses. By contrast, young people who have a low level of education may have poor environmental and family support, and these kinds of participants are excluded from individual difference studies (e.g., Hamadani et al., 2014). For this reason, in the present study and others on the same topic, there is no variability in the level of education among young participants, excluding the possibility of using covariation methods (e.g., Fry, Langley & Shelton, 2017) Moreover, the elderly proved, on average, to be less educated than younger people. Such sampling limitations cannot be easily overcome. Therefore, the present study can be considered as an effort towards including level of education as a potential predictor of performance.

For the LPM task, the results showed no differences in performance between the three groups. Familiarity and continuous exposure to an environment protected the elderly, but they showed a significant decrement in performance compared to young adults when compared on tasks that required learning new information (Lopez et al., 2019; Merriman et al., 2016). This result confirmed previous findings (Lopez et al., 2019). Moreover, as reported in the previous research by Lopez and colleagues (2019), male participants outperformed female in the hometown task.

In line with several studies, as well as LPM task, male participants are favourite in performing allocentric spatial tasks (e.g., Picucci et al., 2010, Coluccia & Louse, 2004), and, moreover, female participants are less efficient than male participants in carrying out the evaluation and the judgement of directional relationships between landmarks. These results could be extended across life span (e.g., Montello, Lovelace, Golledge & Self, 1999; Galea & Kimura, 1993; Picucci et al., 2009; Iachini et al., 2009; Postma, Jager, Kessels, Koppeschaar, van Honk, 2004).

Information consolidated across time, due to the high frequency of environmental exploration, seemed to preserve elderly people from the effects of aging on spatial mental representations, supporting the idea of a sort of *topographical / environmental cognitive reserve* for the elderly (e.g., Cassarino, O'Sullivan, Kenny, & Setti, 2016; Cassarino, & Setti, 2015; Caffò et al., 2016). Finally, it is possible to claim that LPM tasks can be considered age and education fair.

By contrast, the Map of Italy task can inflate age-related differences due to the level of education. In fact, both young and elderly with a high level of education exhibited a better performance than elderly with a low level of education. The young and the elderly with the same level of education did not show differences in performance. This result is in line with previous research in which map completion tasks related to allocentric knowledge were shown to depend on the educational background of the participants (Golledge 2002, Benton 1974; Spinnler & Tognoni, 1987). Level of education should be considered a confounding variable that plays a key role in completing such tasks. The analysis did not reveal gender differences.

The LPM seemed to be more difficult than the Map of Italy task, probably because of the different way in which such information is acquired. In the LPM task, topographic information is gained in an egocentric way. Repeated exploration of the environment generates an egocentric representation. Then, the egocentric representation must be converted into an allocentric one, in order to form a cognitive map. This shifting process makes LPM more complicated than tasks based on direct map study. Some scholars (Thorndyke & Hayes-Roth, 1982; Hishikawa & Montello, 2006; Wolbers & Hegarty, 2010) have already stated that learning from navigation requires a perspective change, translating procedural knowledge into survey knowledge and thus the chance of making mistakes in such spatial tasks is greater. Nonetheless, these findings contribute to support for the notion that familiarity with the environment protects elderly people from the effects of allocentric spatial memory decline, more likely due to the general difficulty of acquiring new information (Iachini, Ruotolo, & Ruggiero, 2009; Caffò et al., 2017, Lopez et al., 2019; Lopez et al., 2018; Muffato, Della Giustina, Meneghetti, & De Beni, 2015). Moreover, the geographical arrangements of the Italy and the area of Bari are different. Then all these elements could make the MOI easier to complete than the LPM task.

Regarding the inspection of potential differences due to coordinate systems, the LPM task did not show axis differences. The Map of Italy, in the original scoring method, did not point to any differences on the North-South and East-West axes. In contrast, the new encoding of the Map of Italy showed a difference, favouring the horizontal axis. This result overlaps with that of Costa and Bonetti (2018) although obtained using a different procedure. In a preliminary analysis we investigated axes differences on the actual Map of Italy in order to assess whether vertical judgements were more / less difficult with respect to horizontal ones. Results were not significant. As a consequence, differences on the axes cannot be attributable to task difficulty, but, probably, relate to their mental representation. Participants pinpoint landmarks more easily on the x-axis than the y-axis, because the East-West axis tends to be encoded with more accuracy than the North-South axis, due to the presence of *anchoring elements* (e.g. Tversky, 1981, 1993). In the case of the Italian Peninsula these anchoring elements seemed to be the coastlines of Tyrrhenian and Adriatic Sea, which extend along the West and the East of the peninsula, respectively.

Finally, controlling for the effect of cognitive functioning and depression, elderly performance on the MOI and LPM tasks was shown to be unbiased by these factors.

In conclusion, the LPM task proved to be age and education fair, it did not favor young people compared to old ones or healthy elderly with high level of education by the less educated ones. Education level did, however, impact the performance of the elderly in the Map of Italy task.

The aim of the study 2 was to better assess whether different levels of cognitive efficiency affect mental representations of the environment. We compared two groups of elderly participants with high and low cognitive functioning, comparable for demographic variables such as age and education (see Table 3). The results can be considered only marginally influenced by the characteristics of the samples, such as the level of education. People with low general cognitive functioning showed a decline in temporally remote information with respect to participants with high general cognitive functioning, excluding the level of education. The MoCA test was used to measure the level of cognitive functioning, notwithstanding it cannot be considered a fully reliable tool for an in-depth neuropsychological assessment. This aspect could be considered as a limitation of the study. On the other hand, an extensive literature investigates the validity of MoCA test (Julayanont, & Nasreddine, 2017). It assesses key cognitive domains such as, executive function, visuo-construction skills, naming, memory, attention, language, abstract thinking, and orientation, in a short amount of time. In the future it would be desirable to deepen the neuropsychological evaluation of cognitive functioning with the use of other tools providing a detailed evaluation of cognitive functioning.

The MOI appeared to discriminate exceptionally between participants with high and low levels of cognitive functioning, again demonstrating its practicality in neuropsychological assessment. Furthermore, the MOI based on our new system of encoding appeared to be more sensitive to other individual variables, such as gender. This result was at odds with the results of Study 1. Nonetheless, this result confirmed previous findings regarding gender differences in spatial cognition in typical and atypical aging (e.g. Picucci, Caffò & Bosco, 2009; 2011; Coluccia & Louse, 2004; Iachini, Ruggiero, Ruotolo, & Pizza, 2008). Moreover, several studies showed gender differences to the disadvantage of female participants, in the rate of cognitive decline during aging (e.g., Lin et al., 2015). Debate is open on biological and psychosocial factors that explain the female fall, such as genetic factors or individual differences (Wilder, 1996). The females' vulnerability to pathologies could explain their greater difference in performance compared to male participants. Finally, distortions with respect to the locations of Italian cities, favouring the East-West (x) axis were also confirmed in this study.

The LPM task proved to be sensitive in discriminating participants with different levels of cognitive functioning, and also pointed to gender differences. Thus, it is plausible that it would be an advantage to include the local version of the LPM task for the evaluation of topographic abilities in neuropsychological assessment. It adds important information in terms of assessing memory traces acquired far back in time and can enrich and supplement the assessment of cognitive functioning in aging (Lopez et al., 2019).

Conclusion

An efficient mental representation of the environment allows for topographical orientation. In the Italian context, this fundamental skill is evaluated according to a map completion task, namely the Map of Italy (Spinnler & Tognoni, 1987). The use of more ecological tasks for spatial orientation, based on standardized and largely shared strategies of construction, could be useful for measuring and evaluating topographical orientation in aging (Caffò et al., 2012, Lopez et al., 2019; Lopez et al., 2018), as well as for designing effective intervention strategies in order to maintain functional independence in daily living activities (Lancioni et al., 2013; Caffò et al., 2014a, 2014b; Lancioni et al., 2017; Lancioni et al., 2018).

In particular, the LPM task is characterized by age and education fairness, and the capacity to discriminate between participants with different levels of cognitive efficiency. Instead, the MOI is influenced by participants' educational background, making it a less flexible tool compared to the LPM task.

The present research highlighted the importance of evaluating spatial mental representations based on well consolidated memory traces, which are less affected by decreasing hippocampal function in aging (Winocur et al., 2007). Performance in both the LPM and the MOI tasks, compared to neuropsychological tasks based on learning recent spatial information, is affected by rapid deterioration with aging (for a review, Serino, Cipresso, Morganti, & Riva, 2014), making these particularly useful tools for assessing TD in aging without anterograde disorientation, which is, by contrast, primarily confined to novel environments (Lopez et al., 2018).

In conclusion, the assessment of topographical (dis)orientation through different tasks based on familiar spatial information appears to offer several advantages for monitoring the impairment of orientation skills in aging. Indeed, in previous research it was largely demonstrated that almost every kind of task that requires learning new environmental information was affected by aging. This is not true for tasks based on familiar, well consolidated, environmental information. The present study confirmed that a task based on general geographical knowledge appears to be affected by level of education (Golledge, 2002). Conversely, a task based on hometown information seemed to be unaffected by differences in education (Study 1) but can detect cognitive impairment (Study 2). Overall, topographical tasks based on mental representations of very familiar environments, such as the hometown area of a participant, seem to be the most suitable supplement for assessing topographical disorientation across typical and atypical aging. Indeed, these tasks are unaffected by the decrease in learning skills expected in healthy aging (Serino et al., 2014), and seem to be more fair than tasks based on familiar topographical information, that is, a map of the participant's country, for the assessment of people with relatively low levels of education.

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