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Mitolo, M., Gardini, S., Caffarra, P. et al. (3 more authors) (2015) Relationship between spatial ability, visuospatial working memory and self-assessed spatial orientation ability: a study in older adults. Cognitive Processing, 16 (2). 165 - 176. ISSN 1612-4782

https://doi.org/10.1007/s10339-015-0647-3

Relationship between spatial ability, visuospatial working memory and self-assessed spatial orientation ability: a study in older adults

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Keywords: spatial ability, orientation ability, sense of direction, aging

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Abstract

This paper describes some novel spatial tasks and questionnaires designed to assess spatial and orientation abilities. The new tasks and questionnaires were administered to a sample of 90 older adults (41 Males, age range: 57-90), along with some other tests of spatial ability (Minnesota Paper Form Board, Mental Rotations Test, and Embedded Figures Test), and tests of visuospatial working memory (Corsi's Block Test and Visual Pattern Test). The internal reliability of the new tasks and questionnaires was analyzed, as well as their relationship with the spatial and working memory tests. The results showed that the new spatial tasks are reliable, correlate with working memory and spatial ability tests and, compared with the latters, show stronger correlations with the self-report questionnaires referring to orientation abilities. A model was also tested (with reference to Allen et al, 1996) in which the new tasks were assumed to relate to spatial ability and predict orientation abilities as assessed by the self-report measures.

Introduction

Spatial orientation is the ability to ascertain our own position in relation to the surrounding environment. It is typically assessed by means of environmental tasks, such as way-finding, estimating distances or directions of unseen landmarks, landmark recognition, map learning, and map drawing. These are all tasks which performance may be influenced by broad individual differences, and they require specific cognitive processes, abilities and types of spatial representation (see Hegarty and Waller, 2005; Hegarty and Wolbers, 2010; for reviews).

An alternative way to measure spatial orientation abilities is by means of self-reports. People are able to assess their own orientation skills (Hegarty, et al. 2002; Labate, Pazzaglia and Hegarty, 2014; Pazzaglia and Taylor, 2007) and strategies (Lawton, 1994). Self-reported sense of direction (a verbal expression of people's estimation of their own spatial orientation) has been shown to reflect orientation abilities. Several studies identified significant relations between self-reported estimations of spatial orientation and actual performance in environmental tasks (e.g. Bryant, 1982, 1991; Kozlowski and Bryant, 1977; Montello and Pick, 1993): people with a good sense of direction were better able than those with a poor sense of direction to point towards unseen goals in a familiar environment (Kozwlosky and Bryant, 1977), or navigate in virtual and real environments (Labate et al., 2014; Pazzaglia and Taylor, 2007).

Another category of cognitive skills intensively studied in the domain of spatial cognition is spatial ability, which has long been the object of debate on its definition, measurement, and malleability (Uttal et al. 2013). Spatial ability is defined as the mental operation needed “to encode, maintain and process a visual configuration” (Hegarty et al., 2006). It is typically assessed using paper and pencil tests, which involve mentally manipulating small objects and imagining the final output of mental activities such as rotation or integration. Over the years, there has been much research on how to measure and classify individual differences in young adults’ spatial abilities (e.g. Carroll, 1993; Eliot and Smith, 1983; Lohman, 1988; McGee, 1979), and different aspects of spatial ability have been discussed (Linn and Petersen, 1985; MacGee, 1979; Voyer, Voyer, and

Bryden, 1995), distinguishing between spatial perception, spatial visualization and mental rotation. Spatial perception is the ability to identify spatial relationships between objects; it involves disembedding or disregarding distracting perceptual information. Typical tests for measuring spatial perception are the Rod and Frame Test (Witkin, 1994), the Water Level Test (Vasta and Liben, 1996), and the Embedded Figures Test (Witkin, 1971). Spatial visualization refers to the ability to perform a multistep manipulation of complex spatial information, and it is typically assessed with the Minnesota Paper Form Board (Likert and Quasha, 1973) and the Paper Folding Test (Ekstrom French, Harman, and Dermen, 1976). Mental rotation concerns the ability to rotate visual stimuli in the mind’s eye, and is usually measured using the Mental Rotations Test (Vandenberg and Kuse, 1978), the Card Rotations Test, and the Cube Comparisons Test.

One issue still under debate concerns the relationship between orientation ability (assessed with large-scale environmental tasks) and spatial ability (measured using small-scale, paper and pencil tests). The question is whether spatial tests assessing spatial perception, visualization, and mental rotation correlate with and predict performance in environmental tasks (e.g. way-finding, distance/location estimation, landmark recognition). Experimental evidence supports the impression that there is a substantial difference between the outcomes of spatial tests and environmental tasks.

Lorenz and Neisser (1986) ran a wide battery of environmental and spatial measures in an exploratory factor analysis, and found a single spatial factor that was separate from three distinct facets of environmental knowledge. More recently, Hegarty et al. (2006) conducted an extensive study using both spatial tests and environmental tasks, and concluded that spatial and orientation abilities are partially distinct, but have a number of components in common. Using structural equation models, they found that small-scale spatial abilities predicted performance in a number of environmental tasks, but were more predictive of learning from media than from direct experience; the opposite applied to self-rated sense of direction, which predicted performance after learning from direct experience better than after learning from media.

Allen et al. (1996) tested an alternative view, making the point that finding no direct links between spatial and environmental abilities does not preclude the possibility of a mediated relationship. In two structural model studies on young adults, they analyzed direct and mediated relations between three kinds of measure: psychometric spatial tests for examining spatial ability, experimental tasks for testing perspective-taking ability and sequential memory, and environmental tasks for assessing participants' knowledge after a walk through a town. The results showed no direct links between the performance of spatial ability tests and environmental tasks, in agreement with other published evidence (see Hegarty and Waller, 2005). But the spatial test scores were found to predict those obtained in the experimental tasks, which in turn were predictive of those achieved in the environmental tasks. The authors concluded that the experimental tasks acted as mediators between spatial skills and orientation skills, and thus had a key role in the relational pattern. The sequential memory and perspective-taking tasks were characterized by a certain resemblance to typical tasks of everyday life, and, although they were small-scale paper and pencil tasks, they tapped into abilities typically needed in everyday environmental tasks. They also involved mentally manipulating complex visual stimuli, an ability typically assessed by means of psychometric spatial tasks. The combination of these characteristics made them a sort of "bridge" between spatial and environmental skills.

The aim of the Allen et al. study was theoretical and focused on understanding the relationship between spatial and orientation abilities, but the results can provide useful suggestions for assessing spatial abilities in clinical settings. If some tasks can be used for the assessment of basic spatial skills and orientation abilities, it becomes important to identify such tasks and define their characteristics with a view to using them to assess spatial competence.

Numerous studies have also found that an adequate visual and spatial working memory capacity is fundamental to success in performing environmental tasks. Visuo-spatial working memory is implied in spatial language comprehension (Pazzaglia, Gyselinck, Cornoldi, and De Beni, 2012), way-finding, (Labate et al., 2014; Nori, Grandicelli, and Giusberti, 2009), and map learning (Coluccia, 2008), so measuring orientation ability should include testing working memory. Several tests have been used in the field of visual and spatial working memory, in both clinical and experimental settings. Among them, Corsi's Block Test (Milner, 1971) and the Visual Patterns Test (Della Sala, et al., 1997) have been widely used to assess spatial and visual working memory, respectively, but how they relate to spatial and environmental abilities would need to be further investigated.

It should also be borne in mind that orientation ability - as assessed with environmental tasks - is prone to considerable inter-individual variability (Hegarty and Waller, 2005; Wolbers and Hegarty, 2010). Some differences are attributable to gender (Lawton, 1996) or to the use of strategies in spatial representations (Denis, Pazzaglia, Cornoldi, and Bertolo, 1999; Pazzaglia and De Beni, 2006). Age might be another reason for individual differences, though the decline in spatial abilities with aging is more evident in abstract laboratory tasks than in real-world tasks (Devlin, 2001). Some studies (Lachman and Leff, 1989; Schaie, 1990;Willis, 1991) support the adequacy of older participants in performing everyday tasks. Evans et al. (1984) found that aging did not affect memory for salient landmarks and their positions. In Kirasic (1989) too, older participants performed just as well as younger people in solving spatial perspective-taking and mental rotation tasks when they were operating in a familiar environment. In contrast, spatial and/or orientation abilities can become severely impaired in neurodegenerative disorders, to such a point that it is considered an initial symptom of MCI (mild cognitive impairment) (Mitolo et al., 2013), and a marker of the onset of Alzheimer's disease (Quental et al., 2013). An impaired spatial and/or orientation ability is also a typical symptom of patients with acquired or developmental topographical disorientation (Aguirre and D'Esposito, 1999; Bianchini et al., 2010; De Renzi, 1982; Iaria et al., 2009).

Overall, the picture described so far highlights the importance of identifying new tools for assessing spatial and orientation ability in clinical settings. Such tools should be quick and easy to administer, resemble situations and tasks of everyday experience, and use meaningful and familiar stimuli and material because performance (particularly in older adults) may be underestimated when tasks are too dissimilar from those used in daily life (Devlin, 2001). Any spatial tests of this kind should also refer to specific theoretical constructs of spatial ability and visuospatial working memory models in order to make it clear which spatial processing components are being tested. Finally, a battery of tests for measuring spatial ability should contain tools potentially correlating with orientation ability, as expressed in the context of daily living (environmental tasks).

On the basis of these considerations, we developed three tasks and three self-rating questionnaires with a view to producing tools for assessing spatial and orientation ability in healthy older adults and patients with neurodegenerative diseases. The characteristics of these tools could also make them useful for assessing patients with brain injuries or developmental deficits when impaired spatial and orientation abilities are suspected. The new tasks refer to three typical everyday life situations: route learning, map learning, and memory for object location. They were devised to tap into orientation abilities and to reflect actual performance in environmental tasks. They are meaningful for older participants/patients and elicit familiar patterns of behavior (e.g. remembering where we left our keys or glasses; learning a new route; looking at a map). A recent study also demonstrated that they have a high discriminatory power in distinguishing between healthy older people and cases of MCI (Mitolo et al., 2013).

In addition to the spatial tasks, we prepared three questionnaires designed to examine different variables involved in orientation ability. One questionnaire (on sense of direction, SOD-Q; revised from Pazzaglia and De Beni, 2001; see also Nori and Giusberti, 2006) examines sense of direction and the strategies (route, survey, and landmark-centered) used in performing environmental tasks. The second questionnaire is a self-rating scale on spatial self-efficacy (Efficacy-Q; Bordin et al. 2011) based on Bandura's self-efficacy theory (Bandura, 1997), in which respondents indicate how effectively they feel they deal with typical environmental tasks. These two questionnaires are assumed to reflect different, but still partially related constructs. In the SOD-Q respondents give a general assessment of their own sense of direction and indicate how much they use specific strategies to orient themselves. In the Efficacy-Q people judge their own capacity to cope with specific everyday spatial activities. The third questionnaire investigates the anxiety triggered by spatial experiences (Anxiety-Q; revised from Poli, Pazzaglia and De Beni, 2004; see also Lawton, 1994): it is used to record the self-reported level of anxiety experienced in typical environmental tasks. The three questionnaires thus examine different variables within the spatial domain: two “ability” variables (sense of direction and self-efficacy), and one “emotion” variable (spatial anxiety) (Lawton and Kallai, 2002). The “ability” measures were devised for their predictive value: it has been well documented that self-reports of sense of direction predict actual performance in environmental tasks (e.g. Hegarty et al. 2002), and the power of self-efficacy measures in predicting performance has been demonstrated by an impressive number of studies in various cognitive domains (Bandura, 1997). As for the spatial anxiety questionnaire, several studies have reported significant correlations between anxiety and performance in spatial tasks (Bell and Fox, 2003; Viaud-Delmont, Berthoz and Jouvent, 2002), and suggested a relationship between spatial ability and emotional variables.

The tasks and questionnaires were administered to a sample of healthy older adults because our tools were specifically designed to assess spatial abilities in normal and pathological aging (see Bordin et al., 2011; Mitolo et al. 2013), though their use could be extended to other age groups too. Other measures of spatial ability and visuo-spatial working memory were used in the study as well. We used the Minnesota Paper Form Board (MPFB; Likert and Quasha, 1970), the Mental Rotations Test (MRT; Vandenberg and Kuse, 1978), and the Embedded Figures Test (EFT; Oltman, Raskin and Witkin, 1971) to assess spatial ability (i.e. spatial visualization, mental rotation, and spatial perception), and two measures of visual (the Visual Pattern Test, VPT; Della Sala et al., 1997) and spatial (Corsi’s Block Test, CBT; Milner, 1971) working memory.

Our study had several aims: first, we wished to test the internal reliability of the new tasks and questionnaires; second, we aimed to see which cognitive processes were measured by the new tasks, and their value in predicting self-ratings of sense of direction, self-efficacy, and spatial anxiety. For the latter goals, we sought correlations between the new tasks, the new questionnaires, and the spatial and working memory tests; and a factor analysis was run on the same variables for the same purpose.

We expected the new tasks to reveal significant correlations with the spatial and the visuo-spatial working memory (VSWM) tests, supporting the hypothesis that the new tasks shared the capacity of the spatial and VSWM tests to test participants' ability to encode, maintain, and manipulate visuo-spatial material. In particular, we expected specific correlations: (a) between the route learning task and Corsi's Block Test, because both involve memorizing sequences of spatial locations; and (b) between the memory for object location task and the map learning task on the one hand, and the Visual Patterns Test on the other, because they all involve recalling simultaneously presented visuo-spatial configurations (Mammarella, Pazzaglia, and Cornoldi, 2006). We also expected the new tasks to correlate significantly with the questionnaires, i.e. the new tasks (unlike the spatial and VSWM tests) were assumed to measure the same orientation abilities used in everyday life as those assessed by the questionnaires. As for the factor analysis, we expected separate factors for the spatial tests (assumed to load on a single factor, in agreement with the results reported by Lorenz and Neisser, 1986) and for the new tasks and questionnaires.

A further aim of the study was to test a model similar to the one proposed by Allen et al. (1996) in older adults and with different variables. In the model tested here, the new tasks were predicted by spatial ability and VSWM and, in turn, predicted orientation abilities (as assessed by the questionnaires), so the following pattern of relations among variables was expected: (i) direct effects of the spatial and VSWM tests on the new tasks, which would in turn have direct effects on the questionnaires; (ii) no direct effects of the spatial and VSWM tests on the questionnaires.

Materials and Methods

Participants

A sample of 90 healthy older adults (41 males; mean age = 70.46 years, SD = 7.19; range = 57-90; mean education = 8.53 years, SD = 3.45, range = 5-18) was enrolled for this study. All participants were selected from among the older adult population attending the University of the Third Age in Verona, Italy. None had any history of neurological or psychiatric disorders, and they all had a cognitive performance within normal range (i.e. a Mini Mental State Examination [MMSE] score higher than 25) and were competent in activities of daily living.

Materials

1. New spatial tasks

Object Location Task (Objects; Mitolo et al. 2013). This task assesses object recognition, recall and location skills. It is divided into two subtests that involve recognizing, recalling and locating some objects in a picture. In the recognition subtest (Objects-a), participants are shown six objects (elephant, lamp, slipper, guitar, bottle, and hat) and asked to memorize them. Then, for each object, participants are asked to recognize the target among three options. The total number of items correctly recognized is recorded. The second subtest (Objects-b), which is assumed to demand spatial memory for locations, involves memorizing a picture (42 cm x 30 cm) of a room containing twelve objects (table, cat, chessboard, guitar, etc.) (Figure 1a) for one minute, then recalling all the objects and locating them in a picture of an empty room immediately afterwards (Figure 1b), by writing the name of the object in its location. The resulting score corresponds to the number of objects recalled and correctly located.

Please insert Figures 1 here

Map learning task (Map; Mitolo et al. 2013; revised from Sgaramella et al., 1995). This task was developed to assess the respondent's ability to memorize a map. It involves remembering the names and locations of eight landmarks on a map (21 cm x 30 cm), i.e., pharmacy, school, cinema, hospital, bakery, park, bar, dairy (Figure 2a). Immediately after being exposed to the map for five minutes, participants have to write the names of the landmarks in the right position on a blank map (Figure 2 b). The learning phase (and subsequent recall and localization phase) is repeated, and we calculated the number of landmarks recalled and located in the right position after the first and second learning trials.

Please insert Figure 2 here

Route learning task (Route; Mitolo et al. 2013) This task assesses memory for routes. Similarly to the procedure used by Piccardi et al. (2008), this task involves memorizing routes within a matrix of 25 squares (5 x 5) located on the floor; each square is 15x15 cm and the distance between the squares is 30 cm. The task is divided into three sub-tests and, for each one, participants have to remember increasingly long routes. In the first sub-test (route learning from action), the participant first learns the routes by stepping on the sequence of squares with the examiner, and is asked to repeat each route immediately afterwards. In the second sub-test (route learning from vision), the participant is asked to watch as the examiner covers a route, and to repeat it immediately afterwards. In the third sub-test (route learning from a map), participants learn each route on a map and then reproduce it on the matrix. Each sub-test begins with a route of just two segments, then the routes become gradually longer (comprising three segments, four segments, and so on). For our study, two sequences were used for each length and the test came to an end when a participant was unable to reproduce both the sequences of the same length. The longest route that a participant reproduced correctly in at least one of the two trials was taken as the score for each sub-test.

2. Questionnaires

Sense of Direction Scale (SOD-Q; Bordin et al. 2011, revised from Pazzaglia, Cornoldi and De Beni, 2000; Pazzaglia and De Beni 2001). The SOD-Q measures sense of direction, spatial representation and use of strategies to orient oneself in the environment. This questionnaire consists of 18 items that are scored on a 5-point scale: from 1 (not at all) to 5 (very much). The questionnaire identifies the skills and strategies commonly used to navigate in the environment. The final score is calculated by adding together the scores for each item. Example item: “Think about the way you orient yourself in different environments around you. Would you describe yourself as a person who: a) orients himself/herself by remembering routes connecting one place to another; b) orients himself/herself by looking for well-known landmarks; c) tries to create a mental map of the environment” [respondents separately awarded a score for (a), (b), and (c)].

Spatial Anxiety Questionnaire **(**Anxiety-Q, Bordin et al. 2011; adapted from Lawton, 1994). The Anxiety-Q investigates the levels of anxiety experienced while performing everyday spatial tasks. It consists of 8 items that are scored on a 4-point scale: from 1 (not at all), to 4 (very much). The final score is calculated by adding together the scores for each item. Example item: “Indicate the level of anxiety you experience in the situation described: Reaching an appointment venue in an unfamiliar part of a town”.

Self-Efficacy Questionnaire **(**Efficacy-Q, Bordin et al., 2011). The Efficacy-Q investigates how confident individuals feel about their ability to perform specific environmental tasks. This questionnaire consists of 4 items that describe precise tasks (e.g. finding the car in a large parking lot; visiting friends who live in an unfamiliar neighborhood), scored on a 6-point scale from 1 (not at all) to 6 (very much) in response to the question: “Indicate how well you think you would cope in the situations described”.

3. Spatial tests

Minnesota Paper Form Board (MPFB, Likert and Quasha, 1970). The MPFB measures spatial visualization abilities (Linn and Peterson, 1985). It is a paper-and-pencil test comprising 16 items, each including one 2D target and 5 alternative sets of separate parts. Participants have to mark with an ‘x’ the alternative sets that, once combined, would make up the target. The time allowed to complete the task was 5 minutes. One point was awarded for each correct answer and the total number of correct answers was considered as the MPFB score.

Embedded Figures Test (EFT, Oltman, Raskin and Witkin, 1971). This paper-and-pencil test measures the ability to detect embedded simple pictures in complex configurations. Participants have to find simple shapes (shown separately at the top of a page) that are embedded within a set of complex figures shown lower down the same page. There are 20 items and they are administered in two parts. For each item, when respondents identify the simple shape within a complex figure they have to trace its contour with a pencil. One point was assigned for each correct answer and the total number of correct answers was considered as the EFT score.

Mental Rotations Test (MRT, Vandenberg and Kuse, 1978). The MRT assesses the ability to mentally rotate abstract visual configurations. It is a paper-and-pencil test comprising 20 items. Each item consists of a criterion figure (an abstract object made up of assembled cubes), two correct alternatives and two incorrect ones (distractors). The correct alternatives are identical to the criterion figure but shown in a rotated position. The distractors may be rotated mirror images of the criterion figure or completely different figures. Participants are asked to identify the correct alternatives. Each test item was awarded a score of 1 if both correct alternatives were chosen, and the sum of the scores was considered.

4. Visuo-spatial working memory (VSWM) tests

Corsi's Block Test (CBT, Milner, 1971, in the version adapted by Mammarella, Toso, Pazzaglia, and Cornoldi, 2008). The apparatus used in Corsi's Block Test consists of 9 identical blocks randomly arranged on a board. The experimenter points to a series of blocks at a rate of one block per second, then the participant is asked to point at the same blocks in the same order. The length of each sequence of blocks to be reproduced ranged from 2 to 9 blocks, and two sequences were used for each length. The procedure stopped when a participant was unable to reproduce both sequences of a given length. The longest sequence in which at least one of the two trials was reproduced correctly was taken as the measure of spatial span.

Visual Patterns Test (VPT, Della Sala et al., 1997, in the version adapted by Borella, Carretti and De Beni, 2007). The apparatus comprises patterns of black and white squares in grids of different sizes (containing from 4 to 22 squares). The task involves memorizing the location of the black squares in a given matrix for one minute, then reproducing the pattern by marking squares in an empty grid of the same size. Patterns of increasing complexity are used. Three patterns were presented for each level of complexity and the test stopped when a participant was unable to correctly reproduce two of the three patterns for a given level. The final score was the sum of the values for the last three items identified correctly (for instance, if the last three correctly identified items were two on the third level of complexity and one on the fourth, the participant's score was 3+3+4=10).

Procedure

All participants were tested during two separate sessions, each lasting about one hour. In the first session participants were tested in groups, and the tests were administered in the following order: MRT, MPFB, EFT, SOD-Q, Anxiety-Q, and Efficacy-Q. In the second session, participants were tested individually using the following tests: MMSE, VPT, CBT, Objects, Map, and Route.

Statistical analyses

The analyses were carried out in different stages. First, we generated descriptive statistics for all variables and calculated Cronbach's alpha to check their internal reliability. Then univariate correlation analyses were run for all measures. An exploratory factor analysis was also performed on the variables to ascertain the pattern of relations between the new spatial tasks and questionnaires, and the other spatial and VSWM tests. The factor analysis used the maximum likelihood extraction method with a direct varimax rotation. Path analysis was then used to test relations among variables. The analysis was performed in LISREL (Jöreskog and Sörbom, 1993) using maximum likelihood estimation. Standardized regression coefficients (β) were estimated for all paths, as well as direct and indirect effects. Model fit was assessed using the chi-square statistic (χ^2), which should be nonsignificant. The root mean square of approximation (RMSEA), non-normed fit index (NNFI), and comparative fit index (CFI) are also reported. For RMSEA, a value of .05 or less indicates a good fit. For NNFI and CFI a value of .95 or higher indicates good fit.

Results

Table 1 shows the means, standard deviations, range score, skewness, kurtosis, and Cronbach's alpha for all variables.

Please insert Table 1 here

The internal reliability of the instruments was acceptable (alpha ranged from .60 to .90), except for MRT and the Objects-a (recognition subtest), for which alpha was .46; .26, respectively). The latter two measures were consequently omitted in the subsequent analyses.

Pearson's correlations were tested between all variables, as shown in Table 2 (the upper part of Table 2 shows the correlations with MMSE and age partialled out). As expected, we found significant correlations between the new spatial tasks and the questionnaires (SOD-Q, Efficacy-Q, Anxiety-Q). In particular, Route and Objects correlated with all three questionnaires, while Map only correlated with Efficacy-Q. Further, significant correlations also emerged between the Route task and all the spatial (MPFB, MRT, EFT) and VSWM (CBT and VPT) tests; the Objects task correlated with MPFB; no significant correlations emerged between the Map task and the spatial and VSWM tests. As expected, no significant correlations were found between the questionnaires and the spatial tests (MPFB, MRT, EFT), but two significant correlations emerged between the questionnaires and the VSWM tests, i.e. SOD-Q with VPT, and Anxiety-Q with CBT.

Please insert Table 2 here

Factor analysis

Factor analysis was run on the scores obtained in the new tasks (Objects, Map, Route), the questionnaires (SOD-Q, Efficacy-Q and Anxiety-Q), and the spatial and working memory tests (MPFB, EFT, VPT, CBT).

Please insert Table 3

The rotated pattern matrix is shown in Table 3. Loadings higher than .50 were used to interpret the factors. Factor 1 can be interpreted as measuring spatial ability. The two spatial tests and one of the WM tests (VPT) loaded on this factor. The new tasks loaded independently on the other two factors. To be more specific, Factor 2 can be interpreted as a measure of route learning. Both the measures that involve memorizing sequences of spatial locations loaded highly on this factor, along with two of the questionnaires assumed to measure spatial orientation (SOD-Q and

Anxiety-Q). Factor 3 can be interpreted as a measure of object location ability. Both Map and Objects, the two tasks that involve memorizing the location of items within a global configuration, loaded on this factor, along with Efficacy-Q.

Path analyses

Finally, in the light of the findings reported by Allen et al. (1996), we tested a model to elucidate the pattern of direct and indirect relations between all the variables of interest. In our model, the questionnaires (which are self-report measures of spatial orientation) were the dependent variables, and the scores obtained in the two spatial tests were added together (MPFB + EFT) to obtain a single spatial ability category. All the other measures were kept separate. We expected direct effects of the spatial and VSWM tests on the new tasks (Objects, Route, Map), which would in turn have direct effects on the questionnaires. No direct effects of the spatial tests or the two VSWM tests on the questionnaires were expected.

Our analysis started with a model that included all possible relations between predictors and dependent variables. Then further models were run, eliminating the non-significant relations between variables one at a time, starting with the lowest β values. The final path model (Figure 4) included only the significant relations between variables. The model fitted the data well [NNFI = 1, CFI = 1; RMSEA = .013; $\chi^2(20) = 20.28$, p=.44] and explained 14% of the variance in Anxiety-Q scores (R^2 = .14), 12% of the variance in Efficacy-Q scores (R^2 = .12), and 8% of the variance in SOD-Q scores (R^2 =. 08).

Significant direct effects of the spatial ability tests, CBT and VPT on the new spatial tasks came to light. The spatial ability tests (MPFB + EFT) predicted Objects and Map; CBT predicted Map and Route; and VPT had a direct effect on Route. There were also direct effects of the new tasks on the questionnaires: Objects on Anxiety-Q, Map on Efficacy-Q, Route on SOD-Q and Anxiety-Q. As expected, there were no direct effects of CBT and VPT on the questionnaires, but there were significant indirect effects of CBT and VPT on SOD-Q, operating via Route (CBT: β

=.08, z=2.01, p =.044; VPT: β =.09, z=2.20, p =.028). An unexpected direct link emerged between spatial ability and Anxiety-Q, with a positive relationship between the two variables (β =.26, z=2.60, p =.009).

Please insert Figure 4 here

Conclusion

The ability to move about efficiently and reach nearby places is particularly important for the purpose of living independently, especially for older adults. This ability declines to some degree with normal aging (Devlin, 2001), and may be severely impaired in patients suffering from topographical disorientation (Aguirre and D'Esposito, 1999) and neurodegenerative diseases (Mitolo et al. 2013). It is therefore essential to monitor the preservation of this ability in daily living as people grow older in order to support their well-being and quality of life. The main purposes of the present study were to develop a battery of spatial tasks and questionnaires for assessing orientation ability, to test their internal reliability, and to ascertain their relationship with spatial and VSWM tests, measured using typical spatial (MPFB, EFT) and working memory (VPT, CBT) tests, and orientation abilities (assessed by the questionnaires).

Overall, our new tasks and questionnaires showed a good internal reliability. Factor analysis also supported the impression that the new tasks measure different variables within the spatial domain. Route, a task that involved memorizing a series of routes in a matrix of squares on a floor, loaded highly on the same factor as CBT, a sequential memory test (Mammarella et. al., 2006), and two self-report measures, SOD-Q and Anxiety-Q. On the other hand, Map and Objects (both of which were designed to measure recall of positions of simultaneously-presented objects) loaded together on a different factor. These results confirm the existence of two distinct memory systems - one involved in route learning, the other devoted to memorizing object locations (Hartley and Burgess 2005; Maguire et al. 1998; White and McDonald 2002; Piccardi et al. 2008) - and they are consistent with the report from Mitolo et al. (2013) that Route, Map and Object had distinct areas of significant correlation between grey matter density and performance.

It is important to note that, as expected, the new tasks and questionnaires described here measure partially different abilities from those assessed using psychometric spatial tests. This outcome sustains the view that spatial abilities (traditionally measured with psychometric tests that involve mentally manipulating small-scale objects) are separable from orientation abilities, which are typically measured by means of self-reports and large-scale environmental tasks (Hegarty et al., 2006). Several of our findings support this view. First, factor analysis showed that the spatial tests loaded on a different factor from the new tasks and questionnaires. Second, numerous significant correlations emerged between the questionnaires and new tasks, but none between the questionnaires and the spatial tests. Third, path analysis revealed no direct effects of the spatial and VSWM measures on the questionnaires (apart from the positive relationship between spatial ability and anxiety).

From a practical point of view, the main finding emerging from our study is that typical spatial and working memory tests alone are not enough to measure the orientation abilities needed in everyday life. They need to be associated with tools that have some characteristics in common with traditional spatial tests, but also some considerable differences. The similarities lie in that the tests considered in the present study involve representing, memorizing, and manipulating visuospatial configurations in the mind's eye. The differences concern various aspects. Between Route and CBT, for instance, the main difference is in the "scale" (see also Piccardi et al. 2008): CBT is displayed in a figural space (which is smaller than the body), whereas Route involves a vista space at least as large as the body (Montello, 1993). Route and CBT also differ in terms of motor and vestibular involvement (both engaged in navigation and way-finding; Wolbers and Hegarty, 2010), which is minimal in CBT, but high in Route. Other differences are due to the nature of the stimuli used: in both Objects and Map, participants have to memorize the separate positions of familiar objects/landmarks (i.e. cat, table, pharmacy, school), whereas VPT involves patterns of black cells to memorize in a matrix.

From a theoretical standpoint, however, our results cannot be interpreted as indicating a total separation between VSWM and spatial orientation. Indeed, previous studies have demonstrated that working memory is involved in the performance of environmental tasks (Labate et al.2014). In this respect, the pattern of relations that emerged in our structural model between questionnaires, CBT and the Route task seems particularly interesting. Self-assessed orientation abilities were not predicted directly by a small-scale test like the CBT, although memory for sequences emerged as an important ability: it predicted performance in the Route learning test, which was a predictor of sense of direction and anxiety in performing environmental tasks.

Our results also showed differences – worth examining further in future studies - between scores for sense of direction (SOD-Q) and self-efficacy in environmental tasks (Efficacy-Q). Factor analysis showed that the two questionnaires loaded on two different factors: the SOD-Q loaded on factor 2, together with Route and CBT, whereas Efficacy-Q loaded on factor 3, together with Objects and Map. In the SOD-Q, respondents are asked to give a general impression of their sense of direction and to say what strategies they commonly use to orient themselves in everyday life. This measure was predicted by the CBT through the Route task. It may be that, in assessing their SOD people refer mainly to their ability to navigate through familiar routes, or to learn a new route in a familiar context, whereas in the Efficacy-Q questionnaire they are asked to think about several spatial tasks (some familiar, others less so) and to say how confident they feel about their ability to cope with them.

The results of our factor analysis also support the distinction between two different components of visuospatial working memory: simultaneous and sequential (Cornoldi and Vecchi, 2003). Specifically, we found Map and Objects (both tasks that involve learning a global spatial configuration) and Route (which consists of a sequential presentation of spatial locations to learn) grouped under different factors, pointing to the existence of different VSWM sub-components

(Mammarella et al., 2006). Our findings also sustain the impression that different types of memory are implicated in remembering the location of an object and in learning a new route (Piccardi et al., 2008).

Finally, our new tasks predicted non-cognitive dimensions of orientation ability, i.e. self-efficacy and anxiety. Earlier studies found that different way-finding strategies correlated differently with spatial anxiety in healthy (Lawton,1994) and pathological groups (Kallai et al., 1999). The affective dimension warrants further study, particularly in older people and those with disorientation issues. Individuals achieving lower scores in our tasks reported higher levels of anxiety and a lower estimated self-efficacy, suggesting that anxiety and a poor self-efficacy rating derived from their awareness of their weak orientation abilities in everyday life. It might be useful to analyze this relationship in reverse, however, to see whether and to what extent higher levels of anxiety and lower self-efficacy ratings may negatively influence an individuals' orientation skills. It is noteworthy that we also identified a positive direct effect of spatial ability on anxiety: participants with higher scores in the spatial tests reported higher levels of spatial anxiety. This was unexpected and the matter needs to be further investigated, but in the context of the present study it is additional proof that the psychometric spatial tests examine different abilities from those implicated in the performance of environmental tasks.

In conclusion, we can say that the new tasks and questionnaires presented here could be useful in assessing older people's orientation abilities. They enable a distinction between different competences, such as route learning and memory for object locations. They relate to working memory capacity, but at the same time they tap abilities closer to those needed in activities of everyday life. They are also able to predict emotional and motivational aspects (like the self-efficacy construct) of orientation behavior. Future studies should test their validity in predicting actual behavior in the performance of environmental tasks instead of self-report measures.

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Table 1. Descriptive statistics and Cronbach's alpha for variables in the study

	Mean	SD	Range	Kurtosis	Skewness	*Cronbach's* alpha
Spatial tasks						
Object Location Task-a (Objects-a)	3.73	1.39	1-6	-0.84	-0.02	0.39
Object Location Task-b (Objects-b)	7.79	2.38	1-12	-1.17	-0.20	0.60
Map Learning Task (Map)	8.73	3.42	2-16	-0.66	0.34	0.74
Route Learning Task (Route)	17. 23	2.70	8-22	0.58	-0.53	0.75
Spatial questionnaires						
Sense of Direction Scale (SOD-Q)	49.81	8.01	25-65	0.26	-0.40	0.83
Spatial Anxiety Scale **(**Anxiety-Q)	15.91	3.48	9-28	1.44	0.85	0.71
Self-Efficacy Scale (Efficacy-Q)	12.70	3.80	4-22	-0.10	0.21	0.90
Spatial Tests						
Minnesota Paper Form Board (MPFB)	7.44	2.86	1-15	0.26	0.50	0.73
Embedded Figures Test (EFT)	4.24	2.61	1-13	3.21	1.76	0.85
Mental Rotations Test (MRT)	1.24	1.35	0-7	2.91	1.41	0.46
Visuo-spatial Working Memory Tests						
Corsi's Block Test (CBT)	5.00	1.09	1-7	-0.78	0.32	_
Visual Pattern Test (VPT)	19.53	3.92	13-31	-0.12	0.50	_

Note: The scoring procedure did not enable Cronbach's alpha to be calculated for CBT and VPT.

Table 2. Univariate correlations between variables in the study. The upper part of the table shows the correlations with MMSE and age partialled out.

Variable	1	2	3	4	5	6	7	8	9	10
1.Object Location Task (Objects)	/	.41**	.36**	.28**	-.27**	.22*	.33**	.20	.14	.16
2.Map Learning Task (Map)	.47**	/	.33**	.10	-.10	.29**	.14	.19	-.16	.12
3.Route Learning Task (Route)	.36**	.34**	/	.32**	-.25*	.29**	.23*	.27**	.34**	.38**
4.Sense of Direction Scale (SOD-Q)	.23*	.07	.33**	/	-.39**	.36**	.03	.11	.19	.27*
5.Spatial Anxiety Scale **(**Anxiety-Q)	-.25*	-.09	-.24*	-.39**	/	-.16	.20	.01	-.23*	-.17
6.Self-Efficacy Scale (Efficacy-Q)	.28**	.38**	.28**	.32	-.15	/	.06	.16	-.01	.18
7.Minnesota Paper Form Board (MPFB)	.37**	.19	.24*	.01	.20	.10	/	.47**	.01	.31**
8.Embedded Figures Test (EFT)	.24*	.23*	.27**	.09	.01	.19	.49**	/	.08	.36**
9.Corsi's Block Test (CBT)	.14	-.14	.34**	.19	-.23*	-.01	.01	.09	/	.16
10.Visual Pattern Test (VPT)	.23*	.20	.40**	.25*	-.16	.22*	.34**	.38**	.15	/

Note: *p ≤ .05; **p ≤ .01

Table 3 Factor analysis: rotated matrix

Variable	Factor 1	Factor 2	Factor 3
Spatial tasks			
Object Location Task (Objects)	.36	.25	**.58**
Map Learning Task (Map)	.19	.03	**.81**
Route Learning Task (Route)	.45	**.54**	.26
Spatial questionnaires			
Sense of Direction Scale (SOD-Q)	.02	**.69**	.23
Spatial Anxiety Scale **(**Anxiety-Q)	.20	**-.74**	-.19
Self-Efficacy Scale (Efficacy-Q)	.08	.25	**.65**
Spatial Tests			
Minnesota Paper Form Board (MPFB)	**.81**	-.20	.14
Embedded Figures Test (EFT)	**.76**	-.01	.13
Visuo-spatial Working Memory Tests			
Corsi's Block Test (CBT)	.27	**.64**	-.41
Visual Pattern Test (VPT)	**.61**	.32	.12

Note: Extraction: eigenvalue > 1, varimax rotation. Loadings higher than .50 (in bold) are used to interpret the factors.

Figure 1 Object location task (Objects): a) picture of the room shown to participants with items to remember; b) picture where participants located the previously-memorized objects. The original dimensions of the pictures were 42 cm x 30 cm.

a) b)

Figure 2 Map Learning Task: a) map showing landmarks to be remembered; b) empty map for locating the previously-memorized landmarks. The original dimensions of the maps were 21 cm x 30 cm.

a) b)

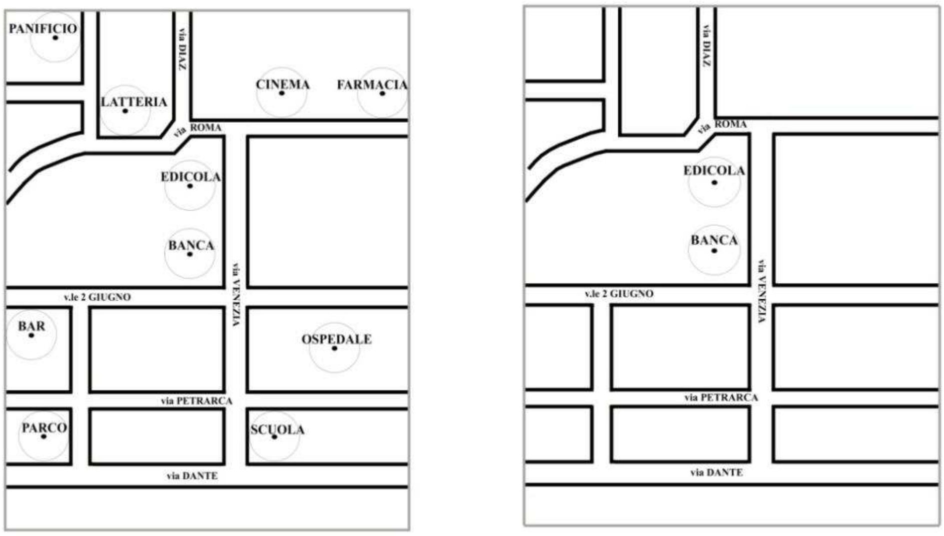
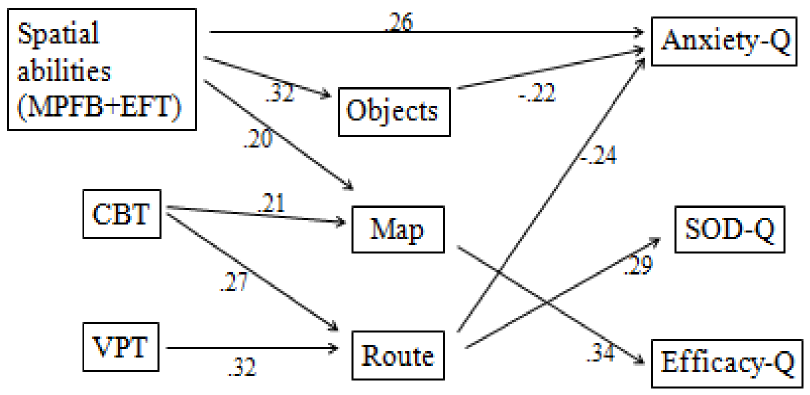


Figure 4 Results of structural equation modeling analysis showing all significant path coefficients among three types of variable: 1. a spatial abilities variable (MPFB + EFT) and two VSWM tests (CBT, VPT), in the left portion of the figure; 2. three new spatial tasks assessing, memory for object location (Objects), route learning (Route), and map learning (Map), respectively, in the central portion; 3. three new questionnaires on orientation ability, assessing spatial anxiety (Anxiety-Q), Sense of direction (SOD-Q), and spatial self-efficacy (Efficacy-Q), in the right portion of the figure. Parameter estimates of the final mode are shown. The numbers refer to standardized path coefficients.



Note: MPFB (Minnesota Paper Form Board); EFT (Embedded Figures Test); CBT (Corsi's Block Test); VPT (Visual Pattern Test); Objects (Object Location Task); Map (Map Learning Task); Route (Route Learning Task); Anxiety-Q (Spatial Anxiety Scale); SOD-Q (Sense of Direction Scale); Efficacy-Q (Self-Efficacy Scale).