Environment Learning from Spatial Descriptions: The Role of Perspective and Spatial Abilities in Young and Older Adults

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Abstract. The present study investigated age-related differences between young and older adults deriving mental representations from survey and route descriptions, and the involvement of spatial skills in their representation. A sample of 34 young (aged 20-30), 34 middle-aged (50-60) and 32 older (61-80) adults listened to survey and route descriptions of an environment and their recall was tested with a free recall task, a verification test, and a map drawing task; several spatial measures were also administered. The results showed that: i) middle-aged and older adults performed worse than young adults in all recall tasks; ii) all participants formed a perspective-dependent mental representation after learning a route description, but not after learning a survey description (as shown by the verification test); iii) age and spatial abilities predicted recall performance (in relation to type of task and the perspective learnt). Overall, spatial perspective and spatial skills influence the construction of environment representations in young, middle-aged and older adults.

Keywords: Spatial descriptions, Spatial abilities, Spatial self-assessments, Age-related differences, Aging.

1 Introduction

Knowledge of an environment can be learned directly (from sensorimotor experience) or indirectly, such as from maps, virtual displays [1,2 for a review], or descriptions [3 for a review]). The latter occurs in many real-life situations, such as when people unfamiliar with a place (e.g. someone visiting Bremen in Germany for the first time) read a description of how to reach a place of interest (to go from the train station to the historical city center, for instance) in a guidebook. When people read or hear descriptions of environments, they mentally represent them as resembling the state of affairs in the outside world [4], creating a so-called mental model, and this representation preserves its spatial properties [5].

Spatial descriptions typically convey environment information from one of two perspectives, i.e. route or survey, or a combination of the two [5]. Route descriptions represent a space from an egocentric perspective (a path view) and use an intrinsic

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frame of reference (“to your left”, “behind you”, etc.), while survey descriptions represent a space from an allocentric perspective (a bird's-eye view) and use an extrinsic frame of reference (like cardinal points).

There has been lengthy debate on the perspective (in)dependence of spatial mental representations derived from survey or route descriptions. Several studies found that mental representations became abstract, incorporating multiple views [5, 6], while others reported that they maintained the perspective encoded [7, 8, 9]. The typical finding in favor of perspective independence is that individuals asked to read a route or survey description and then say whether sentences testing spatial relations from survey and route perspectives are true or false (a task typically used to test mental models [5]) were equally accurate in verifying inferential sentences from both perspectives, irrespective of the one used in the description [5, 6]. In contrast, a finding that supports perspective dependence is that participants answer more accurately for sentences expressed from the same perspective as the one learned [7, 8, 9]. Research has now identified some factors that modulate perspective (in)dependence, some external like the number of times a text is read (perspective independence is reached after extended reading [6]), the type of recall task (survey descriptions are associated with a better performance in comparing distances between landmarks [10]), others internal, i.e. individual factors capable of modulating the formation of perspective (in)dependent mental models, such as gender (females are more perspective-dependent than males [8, 9]) and spatial competences.

Individual differences in spatial competences and their role in spatial representation have been analyzed in terms of: i) spatial cognitive abilities, distinguishing [11] between spatial perception (i.e. spatial relationships with respect to which way a person’s body is facing), spatial visualization (making multistep manipulations of complex stimuli; as measured with the Minnesota Paper Form Board – MPFB [12]), and mental rotation (rotating 3D stimuli; as measured in the Mental Rotations Test –MRT [13]); ii) visuospatial working memory (VSWM), i.e. the ability to retain and process spatial information [14]; and iii) self-assessed preferences for orientation and way-finding in an environment [15].

Concerning spatial abilities, when it comes to memorizing survey descriptions, individuals with strong spatial abilities (as measured with the MPFB [7] or MRT [16]) have a better recall (in verification test and map drawing task, for instance) than those with weaker spatial abilities. But the difference in their performance becomes negligible when route descriptions are memorized (and tested using various tasks). In some studies, like those focusing on VSWM [17], individuals with a high spatial span recalled a route text better than those with a low spatial span [18], while other studies found no difference between individuals with high and low spatial abilities (measured with the MPFB [7] or MRT [14]). Meneghetti, Pazzaglia and De Beni [19] recently analyzed individual spatial differences in spatial descriptions in terms of perspective-taking, a spatial ability that involves having to imagine adopting different positions from the observer’s view, which can be measured using the Object Perspective Test (OPT [20, 21]). They found that, after learning survey and route descriptions, spatial recall performance correlated with MRT and OPT scores, and sense of direction self-assessments, but the OPT was the best predictor of spatial recall performance.

Spatial self-assessments influence environment learning (together with spatial abilities [1]), even when information is acquired from spatial descriptions [9]. For instance, Meneghetti et al. [9] found that individuals who reported preferring an extrinsic frame of reference to orient themselves (i.e. survey preference mode) formed more perspective-independent mental representations than people without this preference. The former were equally accurate in judging true/false sentences from both types of perspective, irrespective of the perspective learnt, but their preference for a survey recall format emerged from their better map-drawing performance.

Overall, these results indicate that spatial abilities – i.e. spatial visualization, mental rotation and perspective taking (measured with the MPFB, MRT and OPT, for instance) – VSWM, and spatial self-assessments are all relevant factors to take into account when analyzing the individual spatial skills needed to form good mental representations from spatial descriptions. It is worth noting that the role of such abilities may change, depending on the type of description (survey vs. route perspective) and the type of recall task (e.g. verification test or map drawing task).

Another important variable that may influence people's mental representations and spatial resources is age. People's ability to form mental representations of spatial settings as they grow older is a topic of increasing interest [22, 23] because it is crucial to their autonomy in everyday activities (e.g. reaching destinations). Analyzing age-related changes in this ability could also reveal whether certain environment learning skills are more or less sensitive to aging [24, 25]. More specifically, the question of how spatial representations formed from descriptions change with aging is particularly intriguing for several reasons. For a start, spatial descriptions are a particular case in which spatial information is expressed verbally and, since verbal skills such as vocabulary and text comprehension relate to crystallized abilities [26], and are consequently less sensitive to aging (whereas spatial skills like environment learning from visual input [22, 23, 27] are more liable to decline with age), it may be that using a verbal format to convey environment information would enable older adults to form more adequate mental representations of environments. The literature on aging that explores mental models derived from spatial descriptions shows that spatial features such as the layout of spatial locations and their relationships [28], and the effects of spatial distance [29] are maintained with aging. Although no studies involving older adults have investigated the role of spatial perspective directly, some data obtained with descriptions that presented spatial relations between objects with no reference to the person's point of view (resembling a survey perspective [28]), or referring to the person's movements [29]) showed that older adults did just as well as young adults in recall tasks (verification of spatial sentences, or recognition of elements in a layout [28]). No studies have focused as yet on the differences between young and older adults' mental representations derived from spatial descriptions presented from a survey or route perspective, and this was the first aim of the present study.

There is some initial evidence of the involvement of spatial competences (recorded in terms of VSWM, spatial abilities and spatial self-assessments) in elderly people's environment learning abilities. The few studies examining the relationship between age, spatial competences and environment learning [30, 31] indicate that the influence of age on environment learning performance is mediated by people's spatial competences. In a study across the adult lifespan, for instance, Meneghetti et al. [31] showed that both spatial self-assessments (a factor concerning sense of direction and pleasure in visiting new places) and spatial abilities (measured with the MRT and OPT) mediate the relationship between age and environment orientation performance. Studies conducted with spatial descriptions found that older adults' spatial recall performance related to their working memory (WM) and spatial abilities (tested with the MRT, for instance) [32], but no research has simultaneously examined the involvement of different spatial competences in sustaining young and older adults' spatial representations acquired from survey and route descriptions. This was the second aim of the present study.

This study thus aimed to assess: 1) age-related differences, comparing young with middle-aged and older adults, in mental representations derived from survey and route descriptions, exploring their perspective (in)dependence; and 2) to what extent this representation is sustained by spatial competences. A middle-aged adult group was included because spatial learning from visual input is liable to decline early [33], [25] so worsening spatial mental representations derived from spatial descriptions might be detectable already in middle age too.

A sample of young, middle-aged and older adults completed a series of objective spatial tasks measuring spatial abilities and self-assessments. Then they listened to survey and route descriptions. Their recall of the descriptions was measured with a verification test (using filler, paraphrased and survey or route inference sentences, as in mental model studies [5]), and free recall and map drawing tasks (both sensitive measures used to test mental representation [14]).

Regarding the first aim (age-related differences in mental representations derived from survey and route descriptions), we expected the young and old groups to reveal either a similar recall performance (as suggested by studies on older adults [28]), or a worse performance in the older adults, given their poor performance in environment learning from visual inputs (e.g. maps [32], or navigation [23]), which prompt the formation of mental representations with some features resembling those formed from spatial descriptions [3]. Given the known early decline in spatial learning skills in the middle-aged [25], [33], we tested whether they resembled the older adults in terms of spatial recall performance. We also examined whether our results suggested a perspective dependence (as shown in [8, 9]) or independence [as in 5, 6]. The latter type of result might also relate to the type of recall measure used, so we aimed to see whether older (and middle-aged) adults had difficulty in switching perspective (as moving from egocentric to allocentric information [34, 35]); or whether they found it difficult to form mental representations with spatial features [22], irrespective of the type of recall task used.

Regarding our second aim (age-related differences in mental representations derived from survey and route descriptions in relation to spatial competences), we assumed that spatial competences related to spatial recall accuracy in young and in middle-aged and older adults (as suggested by other studies on age-related differences [30, 31]). We also explored the different role of spatial competences as a function of the perspective learnt (survey vs. route), and of the tasks used to test spatial recall.

Indeed, certain spatial abilities, VSWM, and possibly spatial self-assessments too (as studied in young adults [9], [14]), would be more strongly involved in tasks requiring an active reproduction of the information memorized (free recall and map drawing) than in the verification test.

2 Method

2.1 Participants

The study involved 34 young adults (17 females, age range 20-30), 34 middle-aged adults (18 females, age range 50-60) and 32 older adults (16 females, age range 61-80) and, within each group, all the various ages were fairly equally represented (see mean ages in Table 1). They were all native Italian speakers, healthy and living independently, and they all volunteered for the study. The groups differed in years of formal education, $F(2,99) = 20.04$, $\eta^2 = .29$, $p < .001$, young adults having had more schooling than the others (all groups had attended school for at least 13 years). The adequate cognitive functioning of our participants (particularly for the middle-aged and older groups) was tested by administering the Vocabulary test of Wechsler Adult Intelligence Scale - Revised (WAIS–R) and Reading Comprehension tasks (RCT; [36]), which showed no differences between the three age groups ($F < 1$; $F= 2.04$ $p = .14$). All participants reached the cutoff for their age in the WM tasks (backward digit span and Corsi blocks; see description below [37]), though the middle-aged and older adults fared worse than the young adults -$F(2, 97) = 7.03/9.92$ $p <.001$- (see Table 1).

Table 1. Means (*M*) and standard deviations (*SD*) for demographic variables by age group

	Young adults		Middle-aged		Old adults	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age	25.12	1.90	53.74	3.09	67.94	5.49
Years of education	16.91	2.73	13.12	2.83	13.47	2.59
Vocabulary (WAIS–R)	47.91	6.70	44.76	6.50	47.16	6.90
Reading comprehension task (RCT)	8.76	1.23	8.06	1.67	8.03	1.77
Backward digit span	5.38	0.95	4.76	1.10	4.50	0.88
Backward Corsi blocks	6.00	1.18	4.91	1.24	4.88	1.10

2.2 Materials

Experimental Tasks

Spatial texts. Four descriptions of two fictitious outdoor environments were used (a tourist center and a holiday farm, adapted from [9]), two from a route and two from a survey perspective. Both descriptions contained 14 landmarks and were of similar length (between 302 and 309 words). In the survey version, the description first outlined the layout of the environment, then defined the relationship between landmarks using canonical terms ("north", "south-east"). In the route version, a person imagined walking along a route and the landmarks' position was presented as seen by the person using egocentric terms ("left", "right") (see Table 2). Each description was recorded in an MP3 file lasting 3 minutes.

Verification test. Thirty-two true/false sentences were used (half of them true, adapted from [9]) for each spatial text, i.e. 8 filler sentences on non-spatial information, 8 paraphrased sentences drawn from the description learnt, 8 route and 8 survey inferential sentences on spatial relations between landmarks not mentioned explicitly (the number of sentences in each category was consistent with previous studies [5, 6]; see Table 2).

Table 2. Examples of route and survey descriptions and verification test (tourist center)

Route description	Survey description
"[…] Go straight ahead and you will soon see the tennis courts, which are used for a number of local competitions, on your left at the end of the oak wood. Keep going as the road bends slightly to the right and, beyond the bend, you will see the hills on your left, which surround the whole area."	"[…] a dense oak wood, famous for its many centuries-old trees, stretches from north to south. This dense oak wood extends to the south as far as the tennis courts. At the southernmost tip of the lake there are hills stretching from east to west across the whole area of the tourist center."

Verification test sentences	Example
Filler	The tennis courts are used for a number of local competitions.
Paraphrased for route texts	You will find the hills on your left beyond the bend.
Paraphrased for survey texts	The hills stretch from east to west across the area of the tourist center.
Route inference	Going towards the hills, you will find the oak wood on your right.
Survey inference	The tennis courts are to the south of the hills.

Spatial Measures

Working memory tasks. The Backward Corsi blocks task [17] and the Backward digit span task [37] involve repeating in reverse order increasingly long sequences of blocks/numbers presented by the experimenter. The final score is the longest correctly-repeated sequence.

Spatial objective tasks. Short (s) versions of the following tried and tested spatial tasks [24] were used: Embedded Figures Test (sEFT; adapted from [38]), Minnesota Paper Form Board (sMPFB; adapted from [12]), Mental Rotations Test (sMRT; adapted from [13]), Object Perspective Test (sOPT; adapted from [21], for the psychometric features see [24, 25]). The sEFT (10 items) involves finding simple elements (listed separately) embedded in a complex overall figure. In the sMPFB (16 items) respondents choose a figure (from among five options) obtainable by arranging a set of fragments. The sMRT (10 items) requires the identification of two 3D cube-objects that match a target object in a rotated position. The sOPT (6 items) involves imagining standing at one object in a configuration, facing another, and pointing in the direction of a third; the answer is given by drawing an arrow from the center towards the edge of a circle. All these short spatial tasks have a time limit of five minutes. The number of correct answers (for the sEFT, sMPFB and sMRT) and the absolute degrees of error (for the sOPT) were considered as dependent variables.

Sense of Direction and Spatial Representation questionnaire (SDSR [15]). This comprises 11 items measuring general sense of direction, knowledge and use of cardinal points, and preference for survey, route or landmark-centered representations (see psychometric features in [24, 25]). All scores (using Likert scale 1 "not at all" -5 "very much") were added together (found to be a sensitive method in older adults [25]) and the total score was considered as a dependent variable.

2.3 Procedure

Participants were tested individually in two sessions lasting an hour each. In the first, participants completed the Vocabulary test and RCT, then performed the spatial measures (presented in balanced order across participants). In the second, they listened twice (for six minutes in all) to a description from one perspective (survey or route; the type of perspective combined with a given type of environment was balanced across participants), then they performed the following, in the same order as listed: the free recall test (orally reporting everything they could remember about the environment), the verification test (on filler, paraphrased, route inference or survey inference sentences, presented in random order), and the map-drawing task (depicting the layout and the location of the landmarks)1. Then participants heard the description from the other perspective twice and performed the recall tasks.

3 Results

3.1 Scoring

In the verification test, one point was awarded for each correct answer for each type of sentence (maximum score: 8). For the free recall and map drawing tasks, we examined first whether landmarks were recalled, irrespective of their position (obtaining a 'landmarks mentioned' score, one point for each landmark), and then whether landmarks were located correctly ('landmark location' score), a measure used to test the spatial features of the participants' mental representations [14]; in this latter case, in free recall a point was awarded for each landmark verbally reported in the correct position relative to others nearby (e.g. the tennis court is on the left of the path and at the edge of the oak wood; see Table 2). In map drawing, a point was awarded for each landmark written or drawn in the correct position on the map in relation to others nearby (e.g. the tennis court was drawn to the bottom right of the sheet of paper and the oak wood was further to the right). No points were awarded for wrong or partly wrong information. The scores awarded by two independent judges correlated closely (r = .98, r = 93; p < .001), so the analyses were run on the scores awarded by the first judge.

3.2 Age-related Differences in Mental Representations Derived from Survey and Route Descriptions (Aim 1)

Verification Test. A 3 (Age: young vs. middle-aged vs. old adults) as a between-participants factor – x 2 (Type of description: route vs. survey) x 4 (Type of sentence: filler vs. paraphrased vs. route inference vs. survey inference) as within-participant

[1] Map drawing was chosen as the final task to avoid the visual layout influencing the free recall and verification test. The free recall and verification tests assessed verbal recall (the first without and the second with anchoring information).

factors, mixed ANOVA was carried out. The results showed the following main effects: Age, $F(2, 97) = 12.27$, $\eta_p^2 = .20$, $p < .001$ – where young adults performed significantly better than the middle-aged ($p < .01$) or older adults ($p < .001$), while the latter two were similar ($p = .29$; see Table 3); Type of sentence, $F(3, 97) = 60.83$, $\eta_p^2 = .39$, $p < .001$ – where accuracy was similar for filler sentences ($M = 6.85$, $SD= 1.14$) and paraphrased ones ($M = 7.03$, $SD = 1.04$, $p = .32$), and higher for both ($p < .001$) than for route ($M = 5.62$, $SD = 1.42$) or survey sentences ($M = 5.36$, $SD = 1.95$), and the latter two were similar ($p = .17$). Only the Type of description x Type of sentence interaction was significant, $F(3, 97) = 7.30$, $\eta_p^2 = .07$, $p <.001$ (see Table 3). The comparisons within each type of description (using Bonferroni's correction, differences where $p \leq .001$ were considered significant) showed that: in route descriptions, accuracy was similar for filler and paraphrased sentences ($p = .96$), and higher than for route or survey inference sentences ($p < .001$), and responses were more accurate for route inference sentences than for survey inference sentences ($p < .001$); in survey descriptions, accuracy was the same for filler and paraphrased sentences ($p = .73$) and higher ($p < .001$) than for route or survey inference sentences; the latter two did not differ ($p = 1.00$). The comparisons between survey and route descriptions showed that survey inference sentences were answered more accurately for survey than for route descriptions ($p < .01$), and there was no difference in the proportion of correct answers concerning filler, paraphrased and route inference sentences between the route and survey descriptions were found ($p > .63$).

To clarify the role of age in relation to Type of description and Type of sentence, the older adults were divided into 60-69 year-olds (n = 22) and 70-80 year-olds (n = 12)[2]. The 2 (Age) x 2 (Type of description) x 4 (Type of sentence) mixed ANOVA showed a significant Age x Type of sentence interaction, $F\ (3, 96) = 2.68$, $\eta_p^2 = .08$, $p =.05$. Further comparisons showed that 70-80 year-olds performed worse with survey sentences ($M = 3.96$, $SD = 1.26$) than with route sentences ($M = 5.29$, $SD = 0.81$; $p < .001$), while the 60-69 year-olds' performance did not differ between survey ($M = 4.71$, $SD = 1.61$) and route sentences ($M = 4.68$, $SD = 1.60$; $p =.54$). Both older adult subgroups performed better with filler and paraphrased sentences than with inferential ones (no differences in sentence accuracy were found between the two subgroups, $F < 1$ to $F = 1.90$ $p = .12$).

Free Recall and Map-Drawing. Preliminary it was ascertained the recall of landmarks (independently of the location reported): all participants recalled most of the landmarks (in free recall and map drawing young adults mentioned 90% of the landmarks, the middle-aged 73%, and the older adults 70%). The 3 (Age) x 2 (Type of description) mixed ANOVA on the scores for landmarks correctly located showed only a main effect of Age for both free recall, $F(2, 97) = 45.98$, $\eta_p^2 = .49$, $p < .001$, and map drawing, $F(2, 97) = 35.48$, $\eta_p^2 = .42$, $p < .001$: young adults performed better ($p < .001$) than the middle-aged or older adults, with no difference between the latter two ($p > .35$; see Table 3). In free recall, all participants used language expressions consistent with the perspective learnt. The lower scores obtained by the middle-aged and older adults were due to mistakes in positioning the landmarks. The analyses on the 60-69 and 70-80 year-old subgroups showed no significant differences between the two ($F_s < 1$).

[2] This procedure was suggested by the Reviewer 4 of the paper

Table 3. Means (*M*) and standard deviations (*SD*) for accuracy in the verification test (by Type of sentence, Type of description, and Age), free recall and map drawing (by Type of description and Age)

Type of recall task	Type of description	Type of sentence	Young adults		Middle -aged		Old adults		Total	
			M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Verification test	Route	Filler	6.94	1.04	6.47	1.19	6.41	1.43	6.61	1.24
		Paraphrased	7.15	1.02	6.26	1.31	5.69	1.45	6.38	1.39
		Route inference	5.65	1.61	5.35	1.43	5.06	1.37	5.36	1.48
		Survey inference	4.97	2.01	4.56	2.03	3.94	1.63	4.50	1.93
	Survey	Filler	6.76	1.23	6.56	0.99	6.41	1.24	6.58	1.16
		Paraphrased	6.91	1.06	6.03	1.53	6.13	1.41	6.36	1.39
		Route inference	5.59	1.23	4.88	1.65	4.72	1.44	5.07	1.49
		Survey inference	5.74	1.88	5.24	1.65	4.72	1.33	5.24	1.68
	Total		6.21	1.39	5.67	1.47	5.38	1.41		
Free recall			10.77	2.62	5.81	2.75	4.73	2.86		
Map drawing			9.66	2.84	5.13	2.77	4.36	2.74		

3.3 Age-Related Differences in Mental Representations Derived from Survey and Route Descriptions in Relation to Spatial Competences (Aim 2)

Correlations. Correlations between all variables (only inferential sentences were considered for their role in testing spatial mental models [5]) showed that Age correlated negatively with WM (Backward digit span and Corsi blocks tests), with all the spatial objectives tasks (but not with the SDSR), and with all the recall tasks (except for the route and survey inference sentences in the route descriptions and the route inference sentences in the survey descriptions). The correlations between spatial measures and recall tasks showed that: i) accuracy in free recall and map drawing, in either route or survey description conditions (which correlated quite closely with one another), correlated strongly with WM and all objective spatial tasks. In contrast, true/false sentences, which correlated modestly within each other, did not correlate significantly with spatial objective tasks, the SDSR or WM tasks (see Table 4).

Regression Analyses. Hierarchical regression analyses were run to estimate the percentage of variance explained by age, processing resources (WM), spatial abilities and self-assessments for route and survey descriptions in map drawing, free recall and the verification test (distinguishing between the survey and route inference sentences). The order in which the variables were entered, based on their theoretical importance judging from the literature, was: Age (Step 1), WM (Step 2) as a basic cognitive ability [31], Spatial abilities (Step 3) as higher cognitive abilities [25], and spatial self-assessments (Step 4). Cook's distance was computed to check for outliers on the criterion and predictor variables (Cook's distance >1), and the variance inflation factor values and tolerance criterion showed no significant multicollinearity.

Map drawing. The predictors explained 38% of the overall variance for route descriptions and 45% for survey ones. For both types of description, when age was entered in the regression, it accounted for a significant part of the variance (route: 27%; survey: 34%); in subsequent steps, for both route and survey descriptions the spatial objective tasks explained another 7% and 9% of the variance, respectively. In the final step, Age ($\beta = -.52$, $p < .0001$) and the sOPT ($\beta = -.26$, $p < .05$)

Table 1. Correlations between age and the measures of interest

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Age	1.00													
2. WM	-0.41**	1.00												
3. sEFT	-0.34**	0.52**	1.00											
4. sMPFB	-0.50**	0.30**	0.29**	1.00										
5. sMRT	-0.44**	0.38**	0.45**	0.31**	1.00									
6. sOPT	0.39**	-0.43**	-0.63**	-0.30**	-0.45**	1.00								
7. SDSR	0.10	-0.02	-0.17	0.03	0.05	-0.11	1.00							
8. Route D. - Free recall	-0.59**	0.26**	0.31**	0.42**	0.40**	-0.36**	0.20	1.00						
9. Route D. – Map drawing	-0.53**	0.33**	0.27**	0.37**	0.39**	-0.43**	0.13	0.74**	1.00					
10. Route D. - Route inference sentence	-0.13	0.08	0.16	0.01	0.12	-0.16	0.01	0.35**	0.45**	1.00				
11. Route D. - Survey inference sentence	-0.21	0.24	0.05	0.08	-0.02	-0.14	-0.07	-0.03	0.20	0.30**	1.00			
12. Survey D. - Free recall	-0.69**	0.32**	0.33**	0.39**	0.39**	-0.45**	0.07	0.72**	0.64**	0.24	0.06	1.00		
13. Survey D. - Map drawing	-0.59**	0.37**	0.41**	0.36**	0.41**	-0.52**	0.02	0.56**	0.62**	0.27**	0.10	0.80**	1.00	
14. Survey D. - Route inference sentence	-0.21	0.13	0.26	0.02	0.12	-0.15	-0.11	0.27**	0.31**	0.43**	0.27**	0.33**	0.30**	1.00
15. Survey D. - Survey inference sentence	-0.29**	0.11	0.06	0.21	0.01	-0.08	-0.12	0.12	0.29**	0.14	0.32**	0.30**	0.32**	0.25

Note (for Tables 4 and 5). N = 100, only $p < .01$ was considered significant (**); WM: working memory; the mean z score was calculated for the Backward digit span and Corsi blocks tests); sEFT: short Embedded Figure Test; sMPFB: short Minnesota Paper Form Board; sMRT: short Mental Rotations Test; sOPT: short Object Perspective Test; SDSR: Sense of Direction and Spatial Representation scale; D: Descriptions.

significant predictors for both route and survey descriptions, Age (β = -.58, p < .0001) and sOPT (β = -.27, p < .05).

Free recall task. The predictors explained 44% of the overall variance in the route description condition and 53% in the survey one. In both types of description, age accounted for a significant part of the variance (route: 34%; survey: 47%). In subsequent steps, spatial self-assessments explained another 5% of the variance for route descriptions, and spatial objective tasks another 5% for survey descriptions. In the last step, the only significant predictors were: Age (β = -.58, p < .0001) and SDSR (β = .24, p < .01) for route descriptions; and Age (β = -.69, p < .0001) and sOPT (β = -.20, p < .05) for survey descriptions.

Verification test. For route descriptions and route inference sentences the model explained 5% of the overall variance; for the other conditions (route descriptions - survey inference sentences, survey descriptions - route inference sentences, route descriptions - survey inference sentences), the predictors explained 14%, 14% and 12% of the overall variance, respectively. Age accounted for a significant part of the variance (4% for route descriptions - survey inference sentences; 4% for survey descriptions - route inference sentences; 9% for survey descriptions - survey inference sentences). Any additional variance for the route descriptions - survey inference sentences, and survey descriptions - survey inference sentences was explained by the other measures in subsequent steps, and Age was the only significant predictor in the final step (route descriptions - survey inference sentences β = -.20, p < .05; survey descriptions - survey inference sentences β = -.30, p < .0001). For the survey descriptions - route inference sentences condition, the spatial objective tasks explained another 10% of the variance in subsequent steps; in the final step, Age (β = -.20, p < .05) and sEFT (β = .38, p < .001) were the only significant predictors (see Table 5).

Table 5. Hierarchical regression analyses with age and measures of interest for map drawing, free recall and verification test by type of description (route vs. survey)

		Map drawing		Free recall		Route inference sentences		Survey inference sentences	
Type of description	Predictors	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Route	Age	.27***	-.52***	.34***	-.58***	.02	-.12	.04*	-.20*
	WM task	.02	.14	.001	.03	.00	.04	.03	.20^
	Spatial objective tasks	.07*		.05		.02		.06	
	sEFT		-.15		.02		.11		-.06
	sMPFB		.11		.16		-.05		-.19
	sOPT		-.26*		-.07		-.07		-.09
	sMRT		.13		.11		.03		-.19
	Spatial self-assessments	.01				.01		.01	
	SDSR	.01	.12	.05*	.24**		.04		-.07
	Total R^2	**.38**		**.44**		**.05**		**.14**	
Survey	Age	.34***	-.58***	.47**	-.69***	.04*	-.20*	.09*	-.30***
	WM task	.02	.16	.001	.05	.00	.07	.00	-.02
	Spatial objective tasks	.09*		.05*		.10*		.02	
	sEFT		.03		-.03		.38*		.01
	sMPFB		.07		.12		.18		-.10
	sOPT		-.27*		-.20*		.10		-.03
	sMRT		.07		.02		-.02		-.15
	Spatial self-assessments	.01		.001		.00		.00	
	SDSR		.03		.10		-.02		-.06
	Total R^2	**.45**		**.53**		**.14**		**.12**	

4 Discussion and Conclusions

The present study aimed to investigate age-related differences in young, middle-aged and older adults' mental spatial representations derived from learning environments described from a survey or a route perspective. In particular, we explored age-related differences in perspective (in)dependence, and to what extent mental representations are sustained by spatial competences, in relation to the type of description and the type of recall task used. Previous studies had indicated that: i) spatial representation in young adults may [6] or may not [8] be perspective-independent, and individual differences (in spatial competences, for instance) can influence the final features of the representation [9]; ii) older adults retain the ability to form mental models from spatial descriptions [28] though studies using visual input found older adults impaired in forming environment representations [22]. No studies had investigated whether older adults (and the middle-aged too, since spatial learning abilities decline early across the adult lifespan [33]) are susceptible to a perspective (in)dependence effect, and whether their mental representations are sustained by spatial competences.

Concerning the age-related differences for survey and route descriptions (Aim 1), our results showed that middle-aged and older adults performed less well than young adults in all recall tasks (free recall, verification test and map drawing). Our findings contrast with previous studies showing no age-related differences (young vs. older adults) in the recall of spatial descriptions [28], but said studies did not examine mental representations derived from survey and route descriptions. Our results are consistent, on the other hand, with findings obtained using visual inputs (maps and navigation tools) showing that older adults were more impaired than younger ones [22]. This suggests that mental representations derived from spatial descriptions have spatial features to a similar extent to those formed from visual input [3].

The verification test results specifically showed that mental representations derived from route descriptions are perspective-dependent, while those derived from survey descriptions are perspective-independent. Indeed, after learning route descriptions, participants gave answers that were more accurate for route inference than for survey inference sentences, whereas, after learning survey descriptions, they showed a similar performance in survey and route inference sentences (though they performed better with survey inference sentences after hearing a survey description than after hearing a route description). These results indicate that mental representations are perspective-dependent when derived from route descriptions, and perspective-independent after learning survey descriptions. These findings are consistent with studies showing that route descriptions require more extensive learning to generate perspective independence properties [6], and the strong support of cognitive resources [14], [39], while it was easier to generate perspective-independent mental models after learning survey descriptions.

Although this result at least partially confirms previous findings in young adults, it is novel as regards the age-related differences: all age groups had a similar pattern of performance when the types of sentence and perspective were analyzed (although middle-aged and older adults were generally less accurate than younger ones).

Taken together the results of all recall tasks indicated that middle-aged and older adults generally had more difficulty in forming spatial mental representations derived from spatial descriptions. Their performance was worse in all recall tests, i.e. tasks preserving the same format and based on active reproduction (free recall), or on identifying true/false spatial relations (verification test), or involving a change of format and based on active reproduction (map drawing). Our results thus support the assumption of a general difficulty in managing spatial information [22] to correctly locate landmarks and infer spatial relations, not only in people over 60, but even in those over 50 (as suggested by studies using visual input [25], [33]). This decline in spatial description learning ability – judging from our results, at least - was not attributable to difficulties in switching, for instance, from an egocentric to an allocentric view [34,35], but to a more general difficulty in forming mental representations with spatial features. Our comparison between 60-69 year-olds and 70-80 year-olds brought out the type of difficulty encountered with aging: the old-old performed worse with survey sentences than with route sentences (whatever the type of description learnt). Although further studies are needed to confirm it, this result suggests that the old-old are impaired in their ability to manage allocentric information, i.e. to form a survey representation (a finer level of environment representation according to Siegel & White [40]), as seen in studies on age-related differences using visual input [22], [27]. On the other hand, aging has a less severe effect on people's ability to manage egocentric information (as seen from the person's point of view), which is more commonly needed to process environment information in everyday situations.

Concerning how age-related differences in coping with survey and route descriptions were influenced by spatial competences (Aim 2), the correlations and regression analyses showed that the spatial competences (assessed using different measures) play a part in supporting spatial text recall accuracy – also depending on the type of recall task used and the type of perspective learnt. Our results indicate that age and spatial competences have a stronger influence on active recall tasks (map drawing and free recall) than on tasks that involve judging the truthfulness of sentences (verification test). This is consistent with studies on young adults showing a clear involvement of cognitive and spatial resources in tasks requiring an active reproduction of the information memorized [14], [39]. Accuracy in active recall tasks was found to correlate with WM and with objective measures of spatial abilities (while the verification test correlated only modestly with these measures of individual differences). Regression analyses showed, however, that only one spatial task – the sOPT – significantly predicted survey and route description recall (as shown with map drawing for both types of description, and with free recall for survey descriptions). The sOPT assesses the ability to adopt an imaginary perspective misaligned with the observer's view, which is plausibly involved in learning route descriptions since the listeners' view changes as they move along their imaginary path (and this was only detected with the map drawing task). At the same time, the sOPT proved the best predictor of survey description learning (as tested with map drawing and free recall): although this type of description does not entail a change in the person's imaginary point of view, the sequence in which the spatial information is presented may induce listeners to imagine moving and changing their perspective, so their perspective-taking ability sustains their recall of a survey description. This interpretation is an intriguing possibility, but further studies will be needed to better elucidate the strategies used by participants in recall tasks. Although the role of perspective-taking proved important in supporting mental representations derived from survey and route descriptions, it should be noted that performance in the sOPT correlated with the scores obtained in tasks measuring other spatial skills, so these resources must have some aspects in common [25]. Performance in free recall after hearing a route description was also predicted by spatial self-assessments on sense of direction, confirming the relationship between self-assessments and environment description learning [9]. In the verification test, the contribution of the predictors was minimal and age accounted for most of the variance (it was only after learning survey descriptions and saying whether route inference sentences were true or false that an additional variance was accounted for by the sEFT).

On the whole, our results suggest that similar underlying cognitive mechanisms are at work across the age groups examined when mental representations are derived from survey and route descriptions. Spatial abilities, particularly in perspective-taking, have an important role in sustaining the active reproduction of memorized spatial information in any age group, so spatial competences are needed to support the construction of a reliable mental representation of an environment not only in the young, but also in middle-aged and older adults [31].

Our results seem interesting, but further studies will need to better elucidate how the ability to generate representations from spatial descriptions develops across the adult lifespan. Future research should pay attention to several aspects, such as: age range (preferably considering evenly-distributed samples ranging from 20 to 80 years old); type of input (other types of environment); types of recall task (e.g. using sensitive measures to identify the type of difficulty encountered in spatial learning); and the order of their presentation (to avoid effects of one task on another).

In conclusion, our results suggest that: i) middle-aged and older adults both find it more difficult (than younger adults) to recall environment descriptions conveyed from route or survey perspectives; ii) all age groups are equally liable to a perspective independence effect (after learning from survey descriptions, at least); and iii) spatial competences sustain mental representations derived from spatial descriptions based on both route and survey perspectives (especially when active recall tasks are used).

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