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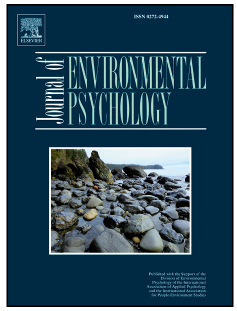

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Memory for route and survey descriptions across the adult lifespan: The role of verbal and visuospatial working memory resources

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Abstract

Spatial representations of an environment involve different perspectives and can derive from different inputs, including spatial descriptions. While it is well-established that memory of visually-encoded spatial representations declines with increasing age, less is known about age-related changes in recalling verbally-encoded spatial information. We examined the lifespan trajectories of memory recall for route (person-centred) and survey (object-centred) spatial descriptions and compared it to non-spatial verbal memory in a sample (N = 168) of young, middle-aged, young-old, and old-old adults. We also examined the mediating role of both verbal and visuospatial short-term and working memory capacity in accounting for age-dependent changes in non-spatial verbal and spatial-verbal (route and survey) memory recall. Age-related differences emerged across all memory recall tasks, however, the onset and rate of changes was earlier and steeper for spatial descriptions compared to non-spatial verbal recall. Interestingly, the age effect on route recall was partially mediated by age-related changes in both verbal and visuospatial working memory capacity, but survey recall was associated only with visuospatial working memory, while non-spatial verbal recall was associated only with verbal working memory resources. Theoretical and practical implications of these findings for spatial cognition and ageing models are discussed.

Keywords: Ageing; Spatial descriptions; Spatial memory; Working memory; Route; Survey

1 Introduction

Being able to spatially represent, remember, and navigate in the environment is essential for numerous everyday activities and important for maintaining autonomy and functional independence in older adults. While many studies have shown that navigational abilities, route learning, and spatial memory decline in typical ageing (for reviews see Colombo et al., 2017; Lester et al., 2017; Lithfous, Dufour, & Després, 2013), much less is known about age-related changes in memory for spatial descriptions. Yet spatial descriptions are a common means of communicating directions and is the preferred method of wayfinding and route planning in older adults (Marquez et al., 2017). The present study focuses on the effects of age on developing and maintaining spatial representations from route and survey descriptions across the adult-lifespan. It also examines whether putative age-related changes in memory recall for different types of descriptions are mediated by age-dependent changes in verbal and visuospatial working memory capacity.

Spatial mental representations can derive from different sources, including direct and indirect visuospatial inputs (navigation, maps) as well as verbal inputs, such as route- and survey-based spatial descriptions (Brunyé & Taylor, 2008; Krukar, Anacta, & Schweing, 2020; Taylor & Tversky, 1992). Route descriptions are based on a person-centred (or egocentric) perspective, with spatial relations defined by the changing viewpoint of an agent (e.g., *the Library is in front of you*). Route descriptions typically have a linear organization, provided by the order in which landmarks appear along the route itself (Taylor & Tversky, 1992). On the other hand, spatial relations in survey descriptions are based on an extrinsic (or allocentric) perspective, independent from the viewpoint of the perceiver (e.g., *the Library is opposite the Forum*), and they typically have a hierarchical organization (Taylor & Tversky, 1992). Spatial descriptions form a natural bridge between the verbal and visuospatial domains, because the format of the information encoded is verbal while the content of the information is visuospatial. It is thus particularly interesting to examine age-related changes in memory recall of spatial descriptions, because various visuospatial processes decline with increasing age (Klencklen, Després, & Dufour, 2012), whilst many aspects of verbal processing do not (Shafto & Tyler, 2014).

Age-related differences in navigation and environmental learning and memory have often been examined with respect to the perspective involved. As with spatial descriptions, encoding, maintaining and updating visuospatial information of an environment can be egocentric, whereby self-to-object relations are encoded and updated with the movement of the observer, or allocentric, involving stable object-to-object relations (Colombo et al., 2017). Older adults demonstrate a generalized deficit in the acquisition of allocentric knowledge and, overall, allocentric processing appears more age-sensitive than egocentric processing across the lifespan (Ruggiero, D'Errico, & Iachini, 2016). Nevertheless, there is robust evidence across different experimental paradigms indicating that older adults have difficulties in environmental learning regardless of encoding conditions and recall tasks. Several studies have found that route learning through navigation is impaired in older adults when assessed by either egocentric or allocentric recall tasks, including route repetition, route retracing, distance estimation, map drawing, and pointing tasks (Harris & Wolbers, 2014; Muffato, Meneghetti, & De Beni, 2016; O'Malley, Innes, & Wiener, 2018; Richmond, Sargent, Flores, & Zacks, 2018). Compared to younger adults, older individuals make more navigational errors (Head & Isom, 2010; Iaria, Palermo, Committeri, & Barton, 2009; Wiener, Kmecova, & de Condappa, 2012) and exhibit a reduced learning rate for new routes (Hilton et al., 2021; O'Malley et al., 2018). Age-related impairments in spatial memory have also been found in paradigms employing route-based video learning as well as survey-based map learning (Muffato, Meneghetti, & De Beni, 2019; Nemmi, Boccia, & Guariglia, 2017).

The evidence above highlights that older adults encounter difficulties in forming and maintaining egocentric and allocentric environmental representations derived from visual inputs. While older adults retain a preserved ability to construct and use spatial mental models from texts (Radvansky, Copeland, Berish, & Dijakstra, 2003), they show impairments when they have to integrate and maintain multiple spatial information streams (Copeland & Radvansky, 2007). Older adults have also been found to be less efficient than younger individuals in recalling spatial information encoded verbally from a route description (Meneghetti, Borella, Gyselinck, & De Beni, 2012; Meneghetti et al., 2016). In the current study, we examined the adult lifespan trajectories of memory recall for both route- and survey-based spatial descriptions, as well as recall for an analogous (non-spatial) verbal description. This approach allows complete age trends of memory recall to be contrasted across verbally-encoded material that involve different types of information (i.e., non-spatial verbal, spatial route, and spatial survey descriptions). Thus, this approach allows us to identify the onset and rate of the corresponding age-related memory recall lifespan changes, as well as which memory system (verbal vs spatial-verbal) and perspective (route vs survey) is most vulnerable to typical ageing effects. Given the well-documented age-dependent deficits in spatial cognition, we expected that memory for spatial descriptions would be more susceptible to age affects compared to non-spatial verbal memory, because previous studies have shown that linguistic and non-linguistic representations of space are closely connected and similarly influenced by the same governing parameters (Coventry, Griffiths, & Hamilton, 2014), supported by overlapping neural networks (Rocca et al., 2020), and that spatial language and non-linguistic spatial abilities change comparably and to a greater extent compared to non-spatial verbal abilities across the adult lifespan (Markostamou & Coventry, 2021).

In addition, we examined the extent to which individual differences in short-term and working memory capacity may explain putative age-related changes in memory recall for different types of verbally-encoded information, allowing us to better distinguish between the contributions of verbal and visuospatial resources in forming and maintaining spatial representations of an environment from different perspectives. Working memory – the ability to mentally store and manipulate information over a brief time period – is one of the core processes that are known to decline with ageing for both verbal and visuospatial information (D'Antuono et al., 2020; Fiore, Borella, Mammarella, & De Beni, 2012). Working memory decline is widespread, observed across simple visual storage tasks, as well as spatial-sequential and spatial-simultaneous tasks (Mammarella, Borella, Pastore, & Pazzaglia, 2013). Limited storage capacity coupled with a less efficient top-down updating and inhibitory control over working memory contents (Sander, Lindenberger, & Werkle-Bergner, 2012) may in turn aversively affect other high-order cognitive processes, such as episodic memory recall (Park et al., 2002).

The involvement of verbal and visuospatial working memory components in processing spatial descriptions has been examined in experiments that primarily employed dual-task paradigms (e.g., Brunyé & Taylor, 2008; Deyzac, Logie, & Denis, 2006). In these paradigms, participants perform a primary task of hearing or reading spatial descriptions while they concurrently perform secondary tasks that tax either their visuospatial (e.g., spatial tapping) or verbal (articulatory suppression) working memory resources. Using this kind of dual-task paradigm, previous studies with younger adults have shown that verbal and especially visuospatial components of working memory are involved in the memory for route descriptions (De Beni, Pazzaglia, Gyselinck, & Meneghetti, 2005; Deyzac et al., 2006; Meneghetti, De Beni, Gyselinck, & Pazzaglia, 2013; Meneghetti et al. 2016), while visuospatial working memory is involved in developing spatial mental models from survey descriptions (Brunyé & Taylor, 2008; Pazzaglia, Meneghetti, De Beni, & Gyselinck, 2010). Only one of these previous studies involved older adults and found that verbal and visuospatial working memory are associated with route recall performance, either when the route information is encoded through egocentric video-based navigation or a route description, both in younger and older adults (Meneghetti et al., 2016). Another study employing an individual-differences approach has also found associations between recall of route and survey spatial descriptions and working memory in young and older adults (Meneghetti, Borella, et al., 2014). We thus expected that individual differences in working memory resources would be associated with recall of spatial descriptions. Given the widespread age-related declines in working memory capacity for both verbal and visuospatial information (D'Antuono et al., 2020; Fiore et al., 2012) which may negatively influence episodic memory recall (Park et al., 2002), we expected that age-related changes in verbal and visuospatial working memory resources would mediate the putative age-dependent changes in recalling route descriptions. Moreover, visuospatial working memory resources were expected to play a more prominent role in forming and maintaining spatial representations derived from both route and survey perspectives.

To summarise, the main aim of the current study was to examine whether age effects on memory recall differ for verbally-encoded non-spatial verbal and spatial descriptions across the adult-lifespan, and whether the effects of age on recalling spatial descriptions are perspective-dependent (i.e., route or survey). Another aim was to examine the potentially differential role of verbal and visuospatial working memory resources in explaining putative age-dependent changes in recalling these different types of information through a series of mediation regression models. Samples of younger, middle-aged, young-old, and old-old individuals completed verbal free recall tasks after listening to non-spatial verbal, route and survey spatial descriptions, as well as tasks assessing verbal and visuospatial working memory. The adult-lifespan trajectories of memory recall for non-spatial verbal, and route- and survey-based spatial descriptions were directly compared. Given the greater vulnerability of spatial processing over verbal processes with increasing age and the difficulties in environmental learning from visuospatial inputs among older adults (Hilton et al., 2021; Muffato et al., 2016, 2019; O'Malley et al., 2018), we expected larger age effects on recalling spatial descriptions compared to non-spatial verbal information, with earlier and steeper declines in recalling route and survey descriptions across the adult-lifespan. Since previous studies have found that processing of egocentric (or route-based) spatial information is more accurate and faster than allocentric (or survey-based) processing (Ruggiero et al., 2016), we anticipated higher performance in recalling the route description compared to survey recall among all participants. Given that allocentric processing is particularly sensitive to ageing effects (Ruggiero et al., 2016), one might expect a steeper age-related decline in survey recall compared to route recall. However, previous studies have found comparable age-related spatial memory deficits of visually-encoded information from route and survey perspectives (Muffato et al., 2019; Nemmi et al., 2017), thus the effects of age may be perspective-invariant. Moreover, given that working memory resources are important in environmental learning through spatial descriptions in young adults (Brunyé & Taylor, 2008; De Beni et al., 2005; Pazzaglia et al., 2010), and that they are particularly sensitive to age-related declines (D'Antuono et al., 2020; Fiore et al., 2012; Mammarella et al., 2013), it was expected that they should explain, at least to some extent, potential age effects on memory recall (Meneghetti et al., 2016), with visuospatial working memory having a more salient role in recalling spatial descriptions (Meneghetti et al., 2013, 2015, 2017; Pazzaglia et al., 2010).

2 Methods

2.1 Participants

A sample of 173 adults were recruited for this study. Participants' age ranged from 18 to 85 years, forming four age groups of young (18 to 38 years old), middle-aged (40 to 55 years old), young-old (56 to 69 years old), and old-old (70 to 85 years old) adults. An a priori power analysis using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) with an alpha level of .05 and statistical power of .80 indicated that a sample size of 96 would be sufficient to obtain at least a conservative effect size (Cohen's f = .33).

All participants spoke English as their first language and had normal or corrected-to-normal vision and hearing. Exclusion criteria for all participants included prior history of head injury, alcohol and drug dependence, severe learning or intellectual disability, any active medical or neuropsychological condition resulting in cognitive dysfunction, and a formal subjective memory complaint (i.e., had sought professional assessment due to concerns about their memory). Inclusion criteria for participants aged 45 or older included a score ≥ 25 on the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), a brief screening test of general cognitive functioning. Five individuals were excluded for not meeting the eligibility criteria and the final sample consisted of 168 participants (96 females); 38 young (19 female), 38 middle-aged (24 female), 44 young-old (25 female), and 48 old-old (28 female) individuals.

Table 1 presents participants' characteristics within each age group and the results of one-way ANOVAs with Bonferroni-corrected *post hoc* multiple comparisons on background variables. A chi-squared test for frequency patterns of dichotomous variables showed that the four age groups were comparable with respect to gender (p = .710). With respect to education, the middle-aged group had significantly more years of formal schooling than the old-old group, while no other significant group differences emerged. The adequate cognitive functioning of our participants was also examined with the Mill Hill Vocabulary Test (MHVT; Raven & Court, 1998), which provides an index of crystallized intelligence.

Vocabulary was significantly better in middle-aged, young-old, and old-old participants compared to younger adults ($p_s < .001$), which ensured that any superiority in performance of the young group in the memory tasks was not likely to be due to differences in crystallised cognitive ability.

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Table 1

Participants' Characteristics by Age Group

	Age group (age range in years)					One-way ANOVA		
	Young (18-38)	Middle-Aged (40-55)	Young-Old (56-69)	Old-Old (70-85)	Total (18-85)	*F* value (3, 164)	Partial η^2	Post-hoc group comparisons
N	38	38	44	48	168			
Demographic data								
Age (years)	22.05 (4.43)	49.5 (4.28)	62.70 (3.97)	76.75 (4.59)	52.57 (20.99)			
Gender (% females)	50%	63.2%	56.8%	58.3%	59%			
Education (years)	14.16 (2.08)	15.58 (2.87)	14.02 (3.31)	12.71 (3.34)	14.15 (2.91)	6.79**	.10	Middle-aged > Old-old*
Cognitive data								
General cognitive functioning (MoCA; raw scores)	-	29.50 (.89)	28.13 (1.59)	27.02 (1.25)	28.07 (1.63)	36.12**	.37	Middle-aged > Young-old** Middle-aged > Old-old** Young-old > Old-old**
Vocabulary (MHVT; % correct)	50.99 (14.49)	62.66 (19.68)	70.66 (10.69)	70.77 (11.82)	64.43 (16.13)	15.52**	.22	Middle-aged > Young** Young-old > Young** Old-old > Young**

Note. Values represent means (and standard deviations). MoCA =. Montreal Cognitive Assessment; MHVT = Mill Hill Vocabulary Test.

*p < .05, **p < .01.

2.2 Materials

2.2.1 Verbal short-term and working memory

The forward (DSF) and backward (DSB) conditions of the Digit Span test were used for the assessment of verbal short-term and working memory capacity (Wechsler, 2010). Participants had to repeat random series of orally presented digits in the same or reverse order, respectively. In both conditions, the number of digits in each string progressively increased from 2 to 8, and there were two trials for each length. The task ended when the participant missed both trials of a particular string length, and memory capacity was defined as the maximum length of correctly recalled sequences in each condition (maximum score: 8).

2.2.2 Visuospatial short-term and working memory

The forward (SSF) and backward (SSB) conditions of the Spatial Span test were used for the assessment of visuospatial short-term and working memory capacity (Wechsler, 2010). In this task, the experimenter pointed to a series of blocks randomly placed on a board, and the participant had to repeat the sequence of blocks in the same or reverse order, respectively. The number of blocks progressively increased from 2 to 8, and there were two trials for each length. The task ended when the participant missed both trials of a particular sequence length, and memory capacity was defined as the maximum length of correctly recalled sequences in each condition (maximum score: 8).

2.2.3 (Non-spatial) Verbal memory

Episodic memory recall for verbal information was examined with the widely-used Logical Memory test (LM; Wechsler, 2010). Participants heard a short story containing 25 semantic units, and were asked to repeat it immediately after hearing it (immediate recall trial) and after a 25-minute delay (delayed recall trial). The story was about a woman who was robbed and reported it to the authorities who made up a collection to help her because she was experiencing difficult circumstances in her life (e.g., *She had four small children, the rent was due, and they had not eaten for two days*). Within each trial, each correctly recalled unit was scored one point, and performance was based on the total number of correctly recalled units (maximum score: 25).

2.2.4 Spatial-verbal memory

The Spatial-Verbal Memory test (SVM) was developed as an analogue of the LM test in order to assess episodic memory recall for spatial descriptions. Consequently, two spatial descriptions were developed containing spatial information presented from a person-centred (route description) or an object-centred (survey description) perspective, respectively (see Table A.1 in the Appendix). Both stories were matched in length to the LM test, containing 25 semantic units, 10 of which included spatial information with spatial prepositions. In the route description, locations of landmarks were described relative to the perspective of a protagonist taking a hike on a mountain (e.g., *He kept the lake on his right, until he passed under a large oak tree*). The route description followed a linear organisation, given by the order in which landmarks appeared along the route. In the survey description, locations of landmarks in a town centre were described from an object-centred perspective (e.g., *The library is situated in front of the church and to the right of the Town Hall*), following a hierarchical organisation.

Administration of the SVM test implemented the guidelines of the LM test. At the outset of the task, participants were instructed that they would hear a short story and they should try to remember it as closely to the original as possible because they would be asked to repeat it again later from memory. After hearing each story, participants were asked to verbally recall it immediately (immediate recall trial) and after a 25-minute delay (delayed recall trial). All free recall units were separately recorded during the immediate and delayed recall trials, and each correctly recalled unit was scored one point (maximum score in each description: 25). Additionally, each correctly recalled spatial information unit, described with spatial prepositions, was separately identified and scored one point for the immediate and delayed recall trials of the SVM route and survey descriptions (maximum score: 10).

2.3 General procedure

All research procedures were ethically approved by the University of East Anglia's School of Psychology Ethics Committee and were carried out in accordance with the 2013 Declaration of Helsinki. Most young adults were recruited from undergraduate and postgraduate university programmes through an online system and university advertisements, and were awarded course credits. All other participants were recruited from the community through advertisements in local media outlets and invitation leaflets, and received monetary compensation for their participation.

Participants were tested in a single individual (one-to-one) session in a quiet room on the university campus. Each participant provided written informed consent and demographic information at the outset of the testing session, followed by the administration of the MoCA. Next, participants completed all memory tasks in a random order (while ensuring that the delayed recall trial in each memory task took place approximately 25 minutes after the immediate recall trial to maintain consistent interval latencies). Participants' responses in each memory recall task were audio recorded and later transcribed for scoring.

3 Results

There were no missing points in the data sets. Data points exceeding 3.0 standard deviations from the mean of each variable were considered univariate outliers, however, no such points met this criterion. Cook's *D* was examined for multivariate outliers, however, there were no variables greater than 1.0 (Gravetter, Wallnau, Forzano, & Witnauer, 2020).

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The transcribed responses for the remembered texts from 30 randomly selected participants were scored independently by a second rater to assess the consistency of the scoring procedure. Inter-rater reliability between the raters was very high (Cohen's weighted $\kappa = .93$, $SE = 0.1$), and the analyses were run on the first rater's scores. Next, each episodic memory recall score was converted into proportion of correctly recalled units to allow comparisons across the measures. Given findings from factor analytic models do not support the structural separability of the immediate and delayed recall constructs for either verbal or non-verbal material in typically ageing populations (Holdnack, Zhou, Larrabee, Millis, & Salthouse; Millis et al., 1999; Price, Tulsky, Millis, & Weiss, 2002), we calculated composite memory recall scores for the (non-spatial) verbal, route-based and survey-based descriptions, respectively, by summing and averaging the scores of immediate and delayed recall trials in each test (Millis, Malina, Bowers, & Ricker, 1999). Data analysis is presented in two main sections. The first section focuses on the adult-lifespan trajectories of memory recall for (non-spatial) verbal, route- and survey-based (spatial-verbal) descriptions. The second section examines the role of individual differences in verbal and visuospatial short-term and working memory capacity on memory recall for verbal, route and survey descriptions.

3.1 Adult-lifespan trajectories of memory recall

Figure 1 presents the overall memory recall performance in each task (left panel) as well as memory recall of spatial information units in the route and survey spatial descriptions (right panel) across all age groups.

First, a 4×3 mixed analysis of variance was employed to examine the effects of Age Group (between-subjects variable with four levels: young, middle-aged, young-old, and old-old) and Information Type (within-subjects variable with 3 levels: verbal, route, and survey), and their possible interaction effect on memory recall. Mauchly's test of sphericity was not significant, $W(2) = .98$, $p = .158$. There was a large main effect of Information Type on memory recall, $F(2, 328) = 122.32$, $p < .001$, $\eta_p^2 = .43$. The difference in memory recall was significant across all Bonferroni-corrected post hoc pairwise comparisons ($p_s < .001$), with higher recall rates obtained for non-spatial verbal information ($M = 58.02$, $SE = 1.04$), followed by route-based information ($M = 47.14$, $SE = 1.09$), and lower recall rates for survey-based information ($M = 41.79$, $SE = 1.16$). A large main effect of Age Group was also found, $F(3, 164) = 10.9$, $p < .001$, $\eta_p^2 = .17$. Bonferroni-corrected post hoc comparisons showed that the old-old and the young-old groups performed significantly poorer compared to the middle-aged ($p = .011$) and young groups ($p = .005$), while there were no significant differences between the young and middle-aged groups ($p = 1.000$) nor between the young-old and old-old groups ($p = 1.000$) (younger: $M = 54.37$, $SE = 1.92$; middle-aged: $M = 53.74$, $SE = 1.92$; young-old: $M = 45.47$, $SE = 1.78$; old-old: $M = 42.36$, $SE = 1.7$). The interaction effect between Age Group and Information Type was not significant, $F(6, 328) = 1.29$, $p = .261$, $\eta_p^2 = .02$. There were no intrusions from one description to the other. In most cases, participants correctly recalled parts of the descriptions (for example, the landmarks, especially those presented in the first and last parts of the descriptions) but were not able to recall other parts or details of the descriptions (for example, locative information and details from the middle parts of the descriptions). The addition of education and crystallised intelligence as covariates in the analyses did not change the effects found. There was a small effect of education on memory recall, $F(1, 162) = 5.21$, $p = .024$, $\eta_p^2 = .03$, while the effect of crystallised intelligence was not significant, $F(1, 162) = 1.65$, $p = .201$, $\eta_p^2 = .01$, and there were no significant interaction effects involving the covariates (Information Type × Education: $F(2, 324) = .46$, $p = .629$, $\eta_p^2 = .00$; Information Type × Crystallized intelligence: $F(2, 324) = 2.79$, $p = .063$, $\eta_p^2 = .01$).

Subsequently, we conducted a series of separate ANOVAs with Age Group as the between-subjects variable (with four levels: young, middle-aged, young-old, and old-old) to better examine the presence of group differences on each dependent variable as well as to compare the specific effect sizes of age on each memory recall measure.

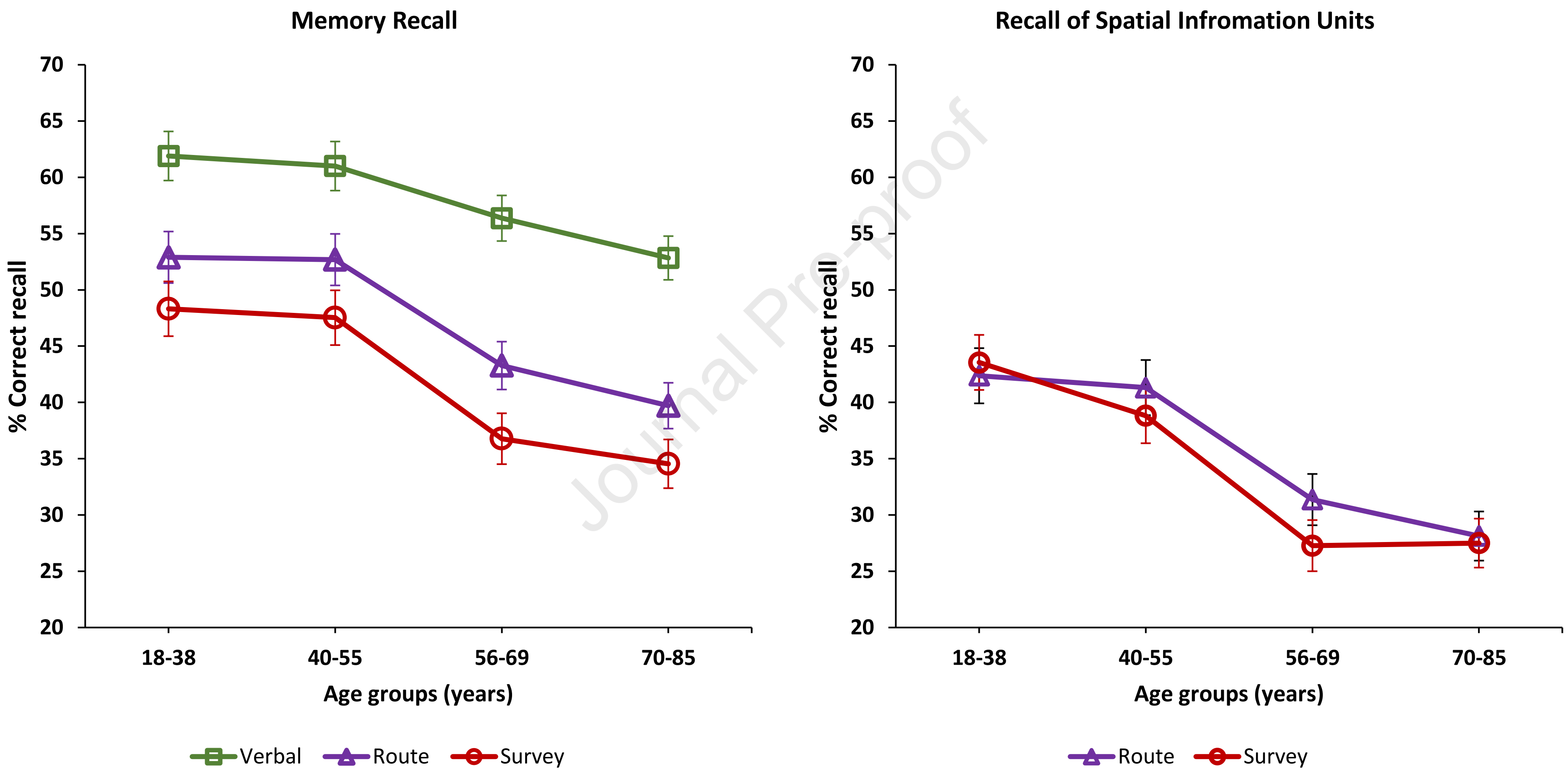
A significant effect of Age Group was found for memory recall of (non-spatial) verbal information, $F(3, 164) = 4.23$, $p = .006$, $\eta_p^2 = .07$. Post hoc group comparisons with Bonferroni correction showed that the old-old group performed poorer than the young ($p = .014$) and middle-aged ($p = .035$) groups, while no other significant group differences were revealed (Figure 1, left panel).

A large effect of Age Group was obtained for route recall, $F(3, 164) = 9.51$, $p < .001$, $\eta_p^2 = .15$. The results of Bonferroni-corrected post hoc comparisons showed that the old-old group performed significantly poorer than the middle-aged and young groups ($p_s < .001$), while the young-old group also performed poorer than the young ($p = .015$) and middle-aged ($p = .018$) groups (Figure 1, left panel). Moreover, a separate analysis on spatial information units recall revealed a similar Age Group effect, $F(3, 164) = 9.37$, $p < .001$, $\eta_p^2 = .15$, with young-old and old-old individuals recalling significantly less spatial information units from the route description than young ($p_s \leq .007$) and middle-aged ($p_s \leq .02$) individuals (Figure 1, right panel).

A large effect of Age Group as also observed on memory recall of the survey description, $F(3, 164) = 9.55$, $p < .001$, $\eta_p^2 = .15$, and for memory recall of survey-based spatial information units, $F(3, 164) = 12.25$, $p < .001$, $\eta_p^2 = .18$, whereby the young and middle-aged individuals exhibited a significantly higher memory performance compared to the young-old and old-old groups ($p_s \leq .009$; Figure 1, left panel) and recalled a significantly higher number of survey-based spatial information units ($p_s \leq .004$; Figure 1, right panel).

To further compare the overlap of age-dependent changes across verbal memory recall for different types of information (i.e., non-spatial verbal, route spatial-verbal, and survey spatial-verbal), the 95% confidence intervals of regression analyses were compared for the slopes and intercepts for each dependent variable, using age (continuous) as the predictor variable. For each comparison, half of the average of the overlapping confidence intervals was calculated and added to the lower bound estimate of the first slope, and then we examined whether the upper bound estimate of the second slope would exceed that value; if the confidence intervals overlapped by less than 50%, the slopes were considered significantly different from each other (Cumming, 2009). The results of these analyses are presented in Table 2. The slope of non-spatial verbal memory recall was significantly different from the slopes of route-based (Δb = .017; p = .005) and survey-based (Δb = .024; p = .002) spatial-verbal memory recall, with steeper slopes for spatial-verbal memory recall scores.

Figure 1. *Lifespan Trajectories of Memory Recall for (Non-Spatial) Verbal, Route, and Survey Descriptions (left panel) and for Route and Survey Spatial Information Units (right panel)*



Note. Error bars represent 95% confidence intervals. N = 168.

Table 2

Slope Comparisons Across all Memory Recall Measures

Measure	Slope (SE)	Intercept (SE)	R^2	Bonferroni CIs for slope LL	Bonferroni CIs for slope UL
Non-spatial verbal memory recall	-.046 (.013)	16.92 (.73)	.075*	-.071	-.021
Spatial-verbal route memory recall	-.063 (.013)	15.08 (.78)	.112*	-.090	-.037
Spatial-verbal survey memory recall	-.070 (.014)	14.09 (.83)	.127*	-.098	-.042

Note. N = 168; *p < .001.

3.2 The role of short-term and working memory capacity

Correlations between all memory measures are presented in Table 3. We employed a series of mediation regression models with Preacher and Hayes's (2008) bias-corrected bootstrapping procedure for models with multiple mediators (based on 1000 bootstrap resamples) to examine whether short term and working memory capacity for verbal and visuospatial information account for the age effects on memory recall for different types of information. These models simultaneously examined direct and indirect age effects whereby age predicted each of the four short-term and working memory measures, which in turn predicted memory recall for (non-spatial) verbal, route, and survey descriptions, respectively. Age was entered as a continuous variable in all models.

Table 3

Bivariate Correlations Between Memory Measures

Variable	1	2	3	4	5	6	7
1. Non-spatial verbal memory recall	–	.57**	.53**	.10	.31**	.16	.23
2. Spatial-verbal route memory recall		–	.67**	.19	.33**	.26*	.37**
3. Spatial-verbal survey memory recall			–	.13	.27**	.27**	.43**
4. Verbal short term memory capacity				–	.47**	.18	.09
5. Verbal working memory capacity					–	.36**	.36**
6. Visuospatial short term memory capacity						–	.49**

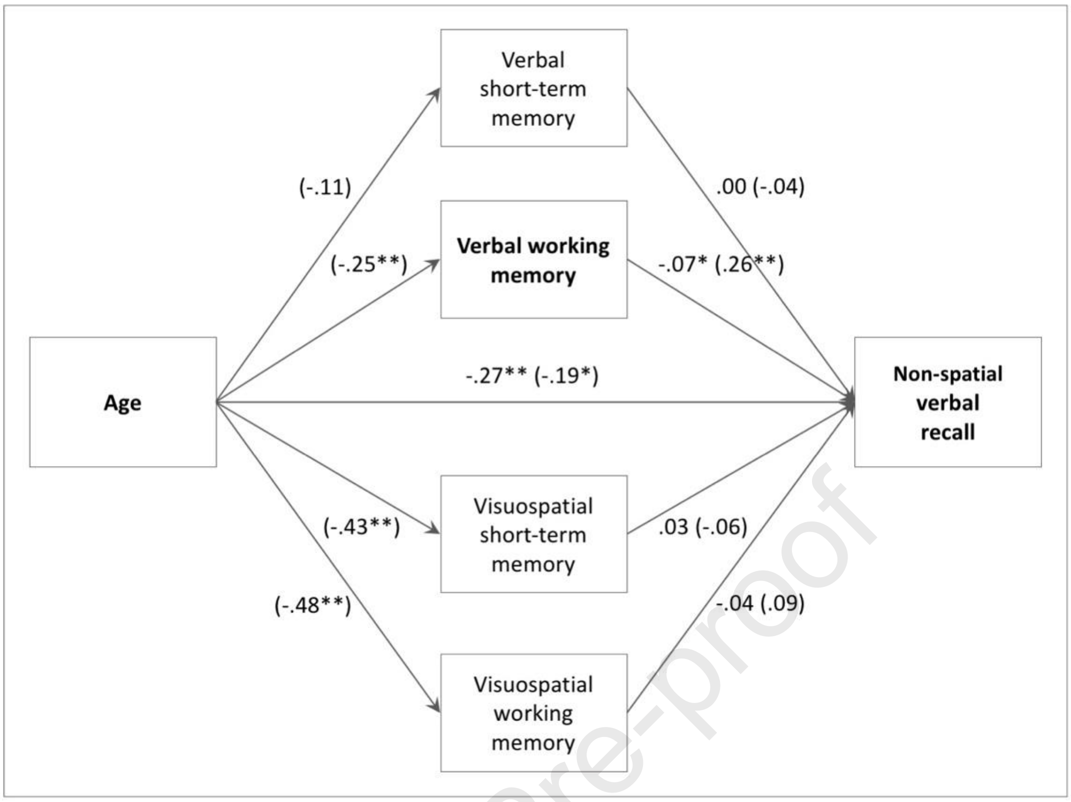
7. Visuospatial working memory capacity	–

Note. N = 168; *p < .01, **p < .001.

3.2.1 Verbal recall

The model for non-spatial verbal memory (Figure 2) showed that approximately 15% of the variance in memory recall was explained by the predictors (R^2 = .144). Age predicted all memory capacity measures except verbal short-term memory. Age remained a significant predictor of memory recall for non-spatial verbal information when short-term and working memory capacity measures were taken into account, although its predictive power was reduced. In addition, the model revealed a significant indirect effect of age on non-spatial verbal recall through verbal working memory capacity, *ab* = -.066, BCa 95% CI [-.127 to -.017]. No other indirect age effects on verbal memory recall were observed (verbal short-term memory capacity: *ab* = .004, 95% BCa CI [-.020 to .034]; visuospatial short-term memory capacity: *ab* = .026, 95% BCa CI [-.043 to .102]; visuospatial working memory capacity: *ab* = -.045, 95% BCa CI [-.137 to .042]).

Figure 2. *Path Diagram Showing the Effect of Age on Non-Spatial Verbal Recall as Mediated Through Verbal and Visuospatial Short-Term and Working Memory Capacity*

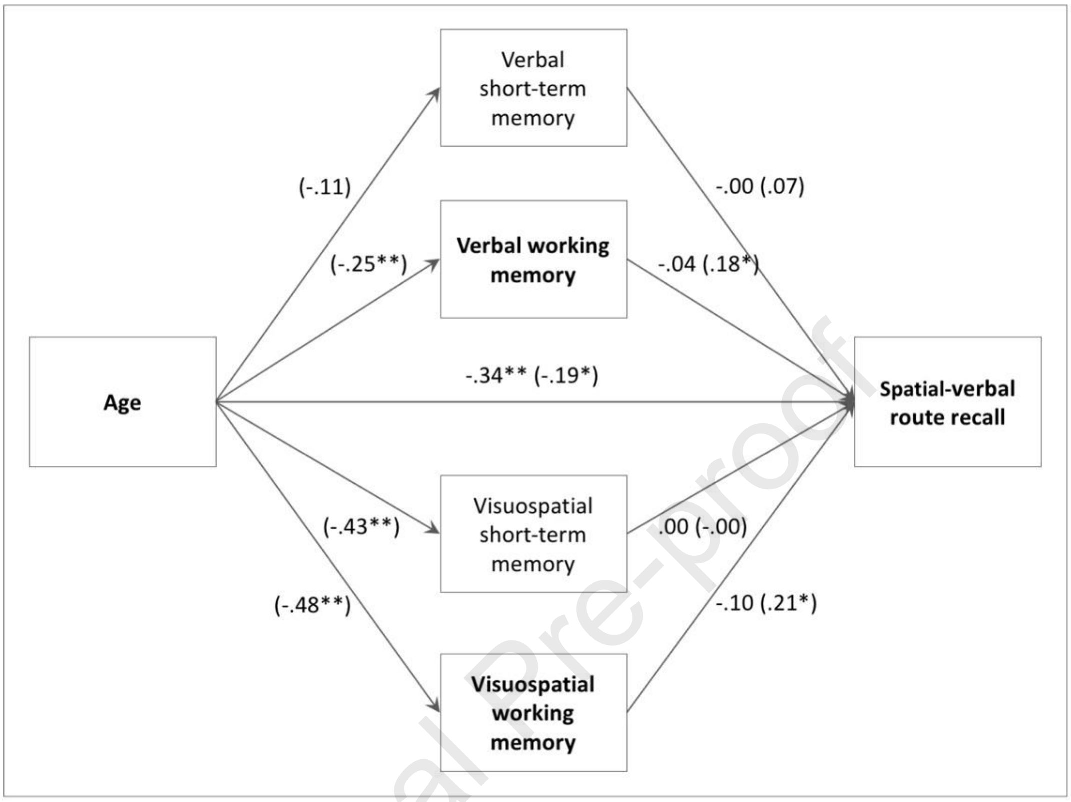


Note. All scores are standardized beta weights. The direct effects between variables are presented in parentheses; $*p < .05$; $**p < .01$.

3.2.2 Route recall

A separate similar model was carried out for memory recall of the route description (Figure 3), which showed that approximately 14% of the variance in memory was accounted for by the predictor variables ($R^2 = .144$). Age still predicted route recall when short term and working memory measures were taken into account, but its predictive power was reduced. Moreover, the model yielded significant indirect effects of age on route recall through verbal, *ab* = -.045, BCa 95% CI [-.103, -.004], and visuospatial, *ab* = -.102, BCa 95% CI [-.205, -.016], working memory capacity, but not through short-term memory capacity (verbal short-term memory capacity: *ab* = -.007, 95% BCa CI [-.033 to .009]; visuospatial short-term memory capacity: *ab* = .002, 95% BCa CI [-.086 to .085]).

Figure 3. *Path Diagram Showing the Effect of Age on Spatial-Verbal Route Recall as Mediated Through Verbal and Visuospatial Short-Term and Working Memory Capacity*

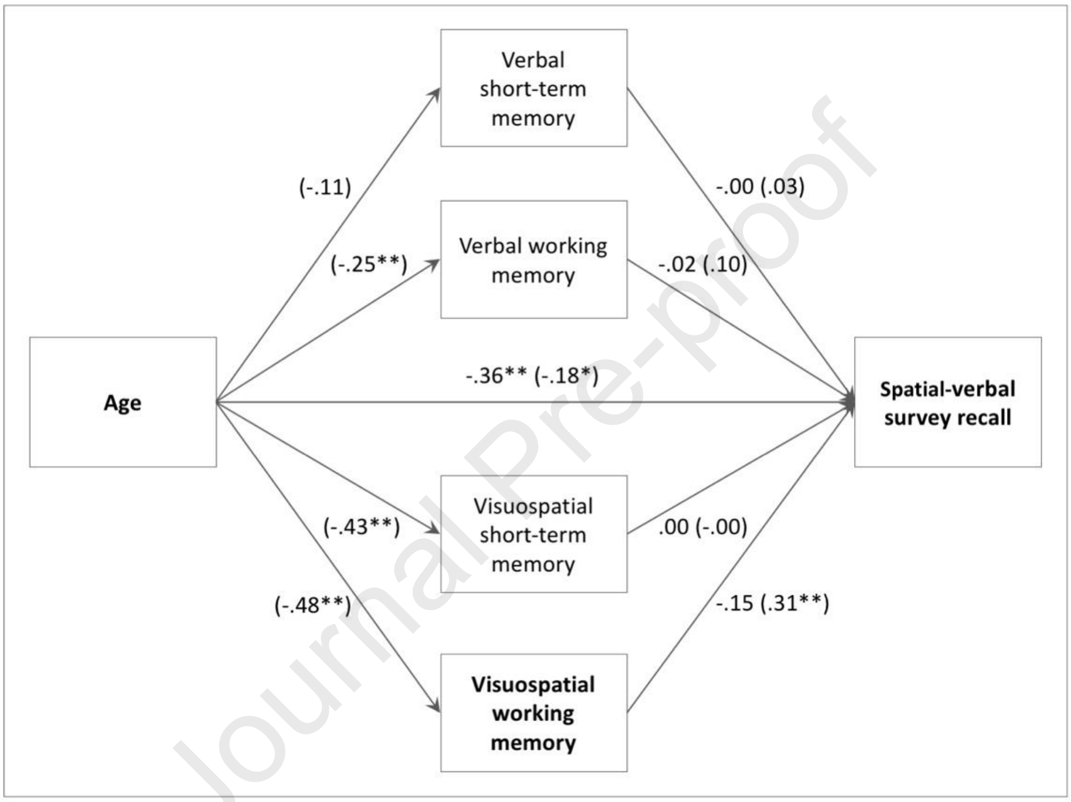


Note. All scores are standardized beta weights. The direct effects between variables are presented in parentheses; *$p < .05$; **$p < .01$.

3.3.3 Survey recall

A third similar model was carried out for the survey description (Figure 4), which showed that approximately 23% of the variance in memory recall was accounted for by the predictors ($R^2 = .229$). Age remained a significant predictor of recalling the survey description when short term and working memory capacity measures were taken into account, although its predictive power was reduced. In addition, there was a significant indirect effect of age on survey recall through visuospatial working memory capacity, *ab* = -.146, BCa 95% CI [-.236 to -.045]. No other indirect effects of age were found (verbal short-term memory capacity: *ab* = -.004, 95% BCa CI [-.033 to .018]; verbal working memory capacity: *ab* = -.025, 95% BCa CI [-.070 to .018]; visuospatial short-term memory capacity: *ab* = .001, 95% BCa CI [-.075 to .069).

Figure 4. *Path Diagram Showing the Effect of Age on Spatial-Verbal Survey Recall as Mediated Through Verbal and Visuospatial Short-Term and Working Memory Capacity*



Note. All scores are standardized beta weights. The direct effects between variables are presented in parentheses; *p < .05; **p < .01.

4 Discussion

The present study aimed to examine and compare the onset and rate of age-related decline in memory recall for route and survey spatial descriptions in contrast to a non-spatial verbal description, across the adult lifespan. Another important aim was to investigate the mediating role of verbal and visuospatial working memory resources in the ability to form and retain route- and survey-based spatial representations. To address these aims, four groups of young, middle-aged, young-old, and old-old adults listened to route and survey descriptions as well as a non-spatial description and then freely recalled them. In addition, all participants completed tasks assessing verbal and visuospatial short-term and working memory capacity.

The first set of findings showed reliable age effects upon all measures of episodic memory recall, although, importantly, the effects of age were markedly larger in memory recall for spatial descriptions than in the non-spatial verbal recall. With respect to the onset of age-related changes, while a significant decline in memory recall for (non-spatial) verbal information was observed only in old-old adults (between 70-85 of age), memory recall for both route and survey descriptions started to decline considerably earlier, as both the young-old (aged between 56-69) and old-old groups performed worse than the middle-aged and young groups. Moreover, separate analyses revealed steeper slopes of age-related changes in spatial-verbal memory recall compared to (non-spatial) verbal memory recall.

These findings highlight the importance of examining age differences across the lifespan in memory research, or at least further sub-dividing older participants into younger- and older-old groups, instead of having two groups of younger and older adults. More importantly, these results establish different patterns of age-associated decline in memory recall of verbally encoded information, depending on the type of information involved, supporting a modular, rather than a generalised model of age-associated memory decline. Verbal processing of sentences containing spatial information activates brain regions associated with extra-linguistic visuospatial processing, such as temporal-occipital-parietal networks and parahippocampal areas (Wallentin et al., 2005; Rocca et al., 2020), suggesting substantial overlaps in the neural and mental organization of linguistic and perceptual representations of space. Given that the brain areas involved in visuospatial cognition are particularly vulnerable to ageing effects (Colombo et al., 2017; Lester et al., 2017; Klencklen et al., 2012), our findings of this higher age-related sensitivity in recalling spatial than non-spatial descriptions may be partially attributable to age-dependent neural changes in areas associated to visuospatial processing.

The significant main effect of information type we found suggests that recalling verbally-encoded spatial information, especially presented from a survey perspective, was more challenging compared to recalling non-spatial verbal information across all age groups. We also found that the effect of perspective on recalling spatial descriptions was similar across the age groups, as all participants retained significantly more route-based than survey-based information, regardless of their age. This absence of interaction is in line with previous reports that examined age effects on memory recall of spatial information encoded through navigation from route and survey perspectives (Muffato et al., 2019, 2020; Nemmi, Boccia, & Guariglia, 2017). In fact, while differential age effects have previously been observed in spatial navigation, with allocentric processing being less efficient among older adults compared to egocentric processing (Ruggiero et al., 2016; Wiener et al., 2012), the effects of ageing on visuospatial memory do not appear to be frame-specific (Muffato et al., 2019, 2020; Nemmi et al., 2017). The results of the present study replicate these past findings and extend them by revealing a similar pattern of age effects on recalling verbally-encoded spatial information within different perspectives. It should be noted, however, that, although matched in length and the number of spatial information units they contained, the two spatial descriptions involved different environments (rural route vs urban survey descriptions), to minimise the risk of intrusions from one description to the other during recall. Therefore, future studies should additionally consider examining age effects on recalling route- and survey-based descriptions from the same environments (possibly across two separate sessions to minimise intrusions and practice effects). Moreover, future studies should also directly compare the effects of ageing on both verbal and non-verbal memory recall of spatial information within different perspectives, as previous studies have found that the learning input combined with the type of recall might affect spatial learning and memory (Meneghetti et al., 2016; Muffato et al., 2019). Finally, given that the descriptions in the current study were quite short and simple in terms of their content complexity, future studies should also examine potential effects of text difficulty in memory recall.

A number of novel insights were also revealed with respect to the role of individual differences in working memory resources in memory recall for different, verbally-encoded information. First, we found increasing age to be associated with declines in both verbal and visuospatial working memory capacity as well as visuospatial short-term memory, in accordance with previous reports (D'Antuono et al., 2020; Fiore et al., 2012), although the effects of age on visuospatial working memory resources were markedly larger than on verbal resources. As expected, we found that verbal working memory capacity is directly associated with memory recall performance for non-spatial verbal information, and that it partially mediates the relevant age effects on verbal episodic memory recall. More importantly, we found that the contribution of working memory resources on memory recall for spatial descriptions varied depending on the perspective involved. Both verbal and visuospatial working memory capacity had a direct effect on the ability to recall a route description from memory, and they both partially mediated the age-dependent decrements in route recall, although the role of visuospatial working memory appeared to be more prominent. This finding accords well with the results of a previous study that employed dual-task paradigms that showed that both verbal and visuospatial working memory are involved in route learning in both young and older adults (Meneghetti et al., 2016). Conversely, only visuospatial working memory capacity directly affected the memory recall of a survey description, while the age-related decline in survey recall was partially mediated solely by the age-dependent limitations in maintaining and manipulating visuospatial information in the working memory system.

Overall, these findings demonstrate that distinct working memory systems are involved in recalling different types of verbally-encoded information, and that the type-dependent discrepancies in memory recall across the adult-lifespan are linked to age-related changes in core cognitive operations like working memory. This suggests that people engage diverse cognitive resources in order to efficiently process, maintain, and recall different types of information. Individual differences in basic cognitive processes like processing speed and working memory have often been identified as sources accounting for large proportions of age-related variance on free recall episodic memory tasks (Park et al., 2002). Moreover, previous studies involving young adults have shown in dual-task paradigms that both verbal and visuospatial components of working memory are associated with spatial memory after verbal encoding through spatial descriptions (Brunyé & Taylor, 2008; De Beni et al., 2005; Pazzaglia et al., 2010), with visuospatial working memory emerging as playing a more prominent role (Meneghetti et al., 2013, 2014, 2015, 2017). In fact, research with blind individuals indicates that spatial mental models can be effectively generated from verbal descriptions in the absence of visual experience, but less efficiently when the descriptions are presented from a survey compared to a route perspective (Noordzij, Zuidhoek, & Postma, 2006), suggesting that processing survey descriptions might require additional integration operations that draw from visuoperceptual abilities to a greater extent than the operations involved in processing route descriptions.

Age-related differences in visuospatial abilities and strategy use have also been identified as important factors that modulate navigation and memory recall of environmental representations derived from visual inputs (Harris, Wiener, & Wolbers, 2012; Muffato et al., 2019, 2020; Segen, Avraamides, Slattery, & Wiener, 2021; Wiener, de Condappa, Harris, &

Wolbers, 2013). While strategy use has additionally been found to influence recall of spatial descriptions among younger adults (Meneghetti et al., 2013, 2014), future studies should also examine the potential presence of age-related differences in the selection and use of strategies in recalling route and survey descriptions. Spatial descriptions can be processed either verbally, focusing on the propositional information of the description, or using imagery strategies, which entail transforming spatial descriptions into spatial mental images. In younger adults, the use of imagery strategies appears to be more efficient than the use of verbal strategies in constructing and maintaining a spatial mental model from route descriptions (Gyselinck, Meneghetti, De Beni, & Pazzaglia, 2009; Meneghetti et al., 2014) and can improve memory performance among individuals with poorer spatial abilities (Meneghetti et al., 2013). A similar employment of imagery-based strategies could also characterise efficient encoding and retrieval of survey descriptions. Thus, in addition to the observed decrements in working memory resources, age-related differences in strategy use may also contribute to the deficits in recalling spatial descriptions. Moreover, future studies should also examine whether older adults' performance in recalling route and survey spatial descriptions might benefit from extensive learning. Previous studies have established that older adults' recall of navigational information improves following extensive training (Nemmi et al., 2017) and that certain age-related deficits in route learning, such as landmark knowledge, are ameliorated (Hilton et al., 2021), although deficits in other aspects of spatial learning, such as landmark sequence knowledge, persist (Hilton et al., 2021).

4.1 Conclusions

In conclusion, the findings demonstrate that the onset and the rate of age-related changes in episodic memory recall of verbally-encoded information varies depending on the type of information involved. Compared to recalling (non-spatial) verbal information, we found an earlier and steeper memory decline for spatial descriptions, either from a (person-centred) route perspective or from an (object-centred) survey perspective, suggesting a more modular, rather than a generalised model of age-associated memory changes. Second, the current empirical evidence suggests that individual differences in working memory resources play an important role in episodic memory recall and partially account for the age-related memory declines. Importantly, however, different working memory sub-systems support episodic memory for different types of verbally-encoded information. As expected, verbal working memory capacity was found to be pivotal in non-spatial verbal recall. In contrast, the influence of working memory resources on recalling spatial descriptions varied depending on the perspective involved – both verbal and visuospatial working memory capacity were found significant for memory recall of a route description, while only visuospatial working memory was associated with memory recall of a survey description. Overall, these findings suggest that forming and recalling spatial representations of an environment through language depends on extra-linguistic processing resources, such as visuospatial working memory.

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Appendix

Table A.1

The Route and Survey Descriptions in the Spatial Verbal Memory Task

Route description

Alex was **on** the main path **at** the Great Mountain, and started walking **towards** the peak. When he saw the blue lake **in front of** him, he turned **left**. He kept the lake **on his right**, until he passed **under** a large oak tree. He then crossed **over** a wooden bridge, leaving the lake **behind** him. He continued walking **straight on** and after a while he reached the peak.

Survey description

The Town Hall is **in the centre of** the town. **Around** the Town Hall are a number of buildings. The library is situated **in front of** the church and **to the right of** the Town Hall. The market is just **behind** the Town Hall, **next to** the museum. The gardens are **nearby**, located **to the left of** the Town Hall. **On** the main avenue, which runs **along** the Town Hall, there are many pubs and restaurants.

Note. Terms providing spatial information are in bold.

Highlights

- A lifespan sample recalled non-spatial verbal, route, and survey descriptions.
- Age-related memory decline was earlier and steeper for spatial descriptions.
- Both verbal and visuospatial working memory were associated with route recall.
- Only visuospatial working memory was associated with survey recall.