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Naming Spatial Relations Across the Adult Lifespan: At the Crossroads of Language and Perception

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Objective: Language abilities in adulthood remain relatively intact with increasing age, while spatial abilities decline. However, much less is known about ageing effects on spatial language (the ability to verbally describe where objects are located in relation to other objects). The primary goal of this study was to examine age-related changes in naming static and dynamic spatial relations across the adult lifespan. Moreover, we examined whether spatial naming is more closely associated with (non-spatial) verbal or (non-linguistic) visuospatial abilities. ***Method:*** Healthy adults aged between 18 and 85 years completed a newly developed Spatial Naming Test (SNT), as well as standard object and action naming tests and various visuospatial tasks. The psychometric properties of the novel SNT (inter-rater and test–retest reliability and convergent, divergent, and construct validity) were also examined. ***Results:*** The psychometric evaluation confirmed the reliability and validity of the SNT. Striking effects of ageing on naming of both static and dynamic spatial relations were found, as well as on visuospatial abilities, while object and action naming remained age invariant. Moreover, both (non-spatial) verbal and (non-linguistic) visuospatial abilities predicted static spatial naming, but only visuospatial abilities accounted for significant variance in dynamic spatial naming beyond age. ***Conclusions:*** These findings provide the first evidence that naming spatial relations declines in ageing as a function of changes in non-linguistic visuospatial abilities, indicating strong connections between linguistic and non-linguistic representations of space. Theoretical and practical implications of these findings are discussed.

Key Points

Questions: Does spatial naming (the ability to verbally describe where objects are located in relation to other objects) change in healthy ageing, and is this ability more closely associated with verbal or visuospatial abilities, or both? ***Findings:*** Using a large community-based adult-lifespan sample who completed a novel Spatial Naming Test as well as (non-spatial) naming and (non-linguistic) visuospatial tasks, we found that communicating about spatial relations becomes more challenging with increasing age, and that declines in spatial naming are associated with changes in visuospatial abilities more than individual differences in linguistic abilities. ***Importance:*** Apart from the theoretical implications of the findings supporting that linguistic and non-linguistic representations of space are closely connected, they help us better understand how typical ageing affects various cognitive abilities to maximise quality of life and also to detect cases of atypical ageing. ***Next Steps:*** The study opens new avenues for future research on language and spatial cognition in typical and atypical populations, including individuals with mild cognitive impairment and Alzheimer's disease.

Keywords: ageing, naming, semantics, spatial cognition, spatial language

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Language and visuospatial cognition are typically considered distinct cognitive systems that are supported by dissociable brain networks. Decades of research on ageing has mapped contrasting patterns of decline and stability in these cognitive domains across the adult lifespan. Yet, little is known about the category of language that most closely connects language to the spatial world—spatial language (Coventry & Garrod, 2004). Sharing spatial information with verbal means enables us to identify objects (*your cup is the one next to the teapot*), guide visual search and attention (*look at the picture on the top shelf*), describe directed actions (*put the pencils inside the drawer*), or exchange route instructions (*go straight down the road and then turn left*). Despite its importance, surprisingly, little is known about how this ability may change with increasing age and whether it is more closely related to verbal versus non-linguistic visuospatial abilities or to both of them. Moreover, theories of semantic representation typically make a distinction between concrete and abstract words/concepts (Meteyard, et al., 2012; Paivio, 2007; Pexman et al., 2007), often focussing on imagineability as a measure of concreteness (Connell & Lynott, 2012). Spatial prepositions, action verbs, and concrete nouns all fall under the rubric of concrete terms, yet the perceptual components of their distributed meaning may well rely on different mechanisms, with implications for ageing. The present work focuses on these issues.

Cognition in Ageing

Crystallized abilities and many aspects of verbal processing, including lexical–semantic knowledge, remain relatively intact with increasing age (Shafto & Tyler, 2014; Wierenga et al., 2008). In language production, while there have been reports of mild age-related word-finding difficulties during picture naming tasks for objects and actions (e.g., Kavé & Mashal, 2012; Verhaegen & Poncelet, 2013), several studies have reported null effects (Goulet et al., 1994; Mortensen et al., 2008; Schmitter-Edgecombe et al., 2000; Wierenga et al., 2008). In fact, conceptual knowledge and semantic processing remains well-preserved in typical ageing, with older adults exhibiting intact verbal semantic memory, lexical processing, and word recognition (Cohen-Shikora & Balota, 2016; Federmeier et al., 2003; Lien et al., 2006; Payne et al., 2012), and larger vocabularies than younger adults (Verhaeghen, 2003). Good language performance is largely underpinned by the same processes across adulthood (Shafto & Tyler, 2014) carried by a rich network of brain regions, which apart from left perisylvian areas include bilateral anterior temporal and frontal regions (Peelle et al., 2010; Rice et al., 2015), allowing sufficient compensation to verbally operate at a high level in older age (Kennedy et al., 2015; Wierenga et al., 2008; Wingfield & Grossman, 2006).

By contrast, different aspects of visuospatial abilities decline in older adults (Klencklen et al., 2012). Visuospatial abilities form a multifaceted aspect of cognition that enables us to encode, represent, organise, analyse, manipulate, and remember spatial information in the environment, as well as to physically navigate in the environment. Studies involving adult-lifespan samples have found significant age-related impairments in visuospatial organization tasks (Borella et al., 2014; Hoogendam et al., 2014), with prominent declines from the mid-50s (e.g., Borella et al., 2014) or mid-60s (e.g., Hoogendam et al., 2014). Moreover, older adults exhibit difficulties in visuospatial reasoning during tasks that require complex relational integration processing (Viskontas et al., 2005), even at a medium level of relational complexity (Viskontas et al., 2004). Cross-sectional studies have also associated increasing age with poorer mental imagery abilities involved in mental rotation (Borella et al., 2014; Devlin & Wilson, 2010). According to a meta-analysis by Techentin et al. (2014), negative age effects in spatial cognition are robust across studies investigating different spatial abilities, unaffected by factors, such as time limits, the specific task employed, and the medium of administration (paper-and-pencil, computerized). Age-related declines in spatial cognition have largely been linked to structural and functional neural changes, predominantly in hippocampal, striatal, and parietal regions (Jagust, 2013; Klencklen et al., 2012).

Spatial Language and Spatial Cognition

While the effects of ageing on verbal and visuospatial abilities have been well-described, much less is known about the effects of increasing age on spatial language. Spatial language forms a unique semantic category, as it requires effective coordination between linguistic and visuoperceptual processes onto a mental representation of space (Coventry & Garrod, 2004). Early in development, positive associations have been found between non-linguistic spatial learning and use of spatial prepositions in children aged between 16 and 24 months, indicating a close relation between the emergence of linguistic skills and non-linguistic skills that rely on shared representations of space (Balcomb et al., 2011). Studies showing that the quality of verbal information in children's descriptions of a route varies mostly with their visuospatial abilities and not with their verbal abilities (Nys et al., 2015) and that toddlers' production of spatial terms can predict their performance on non-linguistic spatial tasks (Pruden et al., 2011) further support the close relation between spatial language and spatial cognition in childhood.

Evidence across behavioural (Coventry et al., 2014; Hayward & Tarr, 1995), cross-linguistic (e.g., Munnich et al., 2001), neurodevelopmental (e.g., Landau & Hoffman, 2005), neuropsychological (Amorapanth et al., 2010; Göksun et al., 2013), and neuroimaging (e.g., Damasio et al., 2001; Rocca et al., 2020) investigations has also revealed a strong connection between linguistic and non-linguistic representations of space. For example, Coventry et al. (2014) in a series of experiments asked participants to either describe objects placed at varying distances from their body (using the spatial terms *this* or *that*; e.g., *this/that red triange*) or remember where the objects were placed. Both spatial description and memory for the object locations were affected by the same factors, namely, the located distance of the object and object parameters (including who owned the object, how familiar it was, etc.), suggesting linguistic representations for space mirror non-verbal perceptual spatial representations. Neuroimaging findings (Conder et al., 2017; Damasio et al., 2001; Rocca et al., 2020) have also demonstrated substantial overlaps in the neural correlates of non-linguistic spatial cognition and spatial language, notably in parietal areas, with spatial language engaging dorsal ("where") pathways as opposed to ventral ("what") pathways involved in object semantics (Landau & Jackendoff, 1993; Rocca et al., 2020). One of the first such studies (Damasio et al., 2001) found that naming spatial relations with the use of spatial prepositions was associated not only with activations in brain areas typically correlated with semantic retrieval, including inferotemporal and dorsolateral prefrontal areas of the left hemisphere, but also with bilateral activity in parietal regions that are typically associated with extra-linguistic visuospatial processing, especially in the right hemisphere for relations between abstract stimuli and in the left for naming spatial relations between concrete objects.

Additional Theoretical Considerations: On the Nature of Semantic Representation

Spatial semantics form a unique natural linkage between the linguistic and perceptual representation systems; thus, they provide a natural domain in which to examine the foundations of semantic processing. There has been an ongoing debate about the nature of semantic representations and the extent to which such representations are separate from, versus grounded in, non-linguistic processes. It has been noted that grounded approaches to semantic representation might be more applicable to concrete terms referring to the physical world (e.g., *tree*), whereas linguistic distributional models might better describe more abstract representations (e.g., *freedom*; Andrews et al., 2009; Meteyard et al., 2012). Taking into account the environmental context in which language is used, the pluralistic view proposed by Zwaan (2014) argues that the activation of abstract or grounded representations during language processing is subject to the level of its environmental embeddedness. In other words, the more the referential situation of a narrative maps onto the in progress communicative situation, the greater activation of embodied representations would be expected, and vice versa. Imagine, for example, a dance instructor explicitly describing the definite steps of a complex dance move while actually physically performing the dance move, a context in which perceptual and motor processes must dominate over abstract conceptualization, versus a philosophy lecturer describing to university students the steps of deductive reasoning based on Aristotelian syllogism, a context in which the recruitment of abstract symbols is arguably essential for successful communication.

Hence, semantic processing may employ different mental representations acquired either from the concrete perception and action systems or from arbitrary abstract concepts, depending on the semantic category in which a lexical term belongs as well as on the embeddedness of the environmental context in which the verbal communication unfolds. Theoretically, there has been an important move towards an integrative view in which language processing involves both symbolic and embodied representations (Andrews et al., 2009; Lynott & Connell, 2010; Pulvermüller, 2012). The present study aims to provide novel insights into the relative extent to which each account (symbolic/linguistic versus grounded/non-linguistic visuospatial representations) contributes to spatial semantics—a semantic category entailing robust environmental embeddedness by default. Furthermore, the abstract-concreteness distinction that dominates theories of semantics (see, Connell & Lynott, 2012, for discussion) may not be the most useful distinction when one considers semantics in ageing. Concrete nouns, action verbs, and spatial prepositions, for example, may all be regarded as scoring high on imagineability and concreteness, yet they are likely to recruit different extended brain networks for their instantiation (Pulvermüller, 2012; Tomasello et al., 2017). Hence, examining such word categories from an ageing perspective may help to refine models of semantics in terms of classification.

The Present Study

In the present study, we examined whether ageing affects the ability to name spatial relations with the use of spatial prepositions. Spatial prepositions (such as *in*, *above*, *in front of*, *toward*, etc.) are the primary means of communicating spatial relations (Landau & Jackendoff, 1993), requiring the integration of linguistic forms with extra-linguistic perceptual/visuospatial processing. Therefore, we can assess one's ability to verbally communicate relational information between objects by their use of spatial prepositions.

Building on earlier neuropsychological work, we developed a new task for the present study, the Spatial Naming Test (SNT), that requires the production of locative and directional/path prepositions to describe static and dynamic spatial relations, respectively. We evaluated the psychometric properties of the SNT in terms of test–retest and inter-rater reliability as well as convergent, divergent, and construct validity through factorial classification and a series of hypothesis-driven correlational analyses. Subsequently, we contrasted the adult-lifespan trajectories of static and dynamic spatial naming against the trajectories of analogous non-spatial naming and non-linguistic visuospatial abilities. Finally, we examined the extent to which individual differences in these verbal and visuospatial abilities contributed to spatial naming performance beyond putative age effects.

We expected that performance in processing representations that are gradually acquired throughout the lifespan, such as naming different objects and actions, would be well-preserved in typical ageing, while processes that require concurrent manipulation of novel representations that are independent of past knowledge, such as visuospatial organization, reasoning, and naming spatial relations, especially dynamic spatial relations, would be less efficient in older age. Thus, given the age-related changes in visuospatial cognition and the close relationship between spatial semantics and non-linguistic spatial cognition observed earlier in development, we expected stronger age effects on spatial naming and visuospatial abilities compared to non-spatial verbal abilities. This individual differences approach can provide novel information regarding the nature of spatial naming within a broad theoretical framework; if spatial naming and non-verbal visuospatial abilities are asymmetrically affected by typical ageing, then that dissociation would suggest a dual mode system of spatial cognitive processing, with linguistic and visuoperceptual representations of space being relatively independent of each other (Kemmerer & Tranel, 2000). If, on the contrary, both linguistic and non-verbal abilities of processing spatial information are comparably affected by ageing, then that would provide new evidence of a close relation between spatial language and non-verbal spatial cognition (Coventry et al., 2014; Damasio et al., 2001; Rocca et al., 2020).

Method

Participants

One hundred and sixty-four participants were recruited from the local community for the present study. Participants' age ranged from 18 to 85 years, forming five groups of younger, middle-aged, and older adults, stratified by 10-year age brackets (age groups: 18-28, 45-54, 55-64, 65-74, 75-85 years; $N = 30\text{-}34$ per age group). An a priori power calculation using G*Power (Faul et al., 2007) with an α level of .05 and statistical power of .80 indicated that a sample size of 115 would be sufficient to obtain at least a conservative effect size (Cohen's $f = .33$) on each measure separately and a sample of 152 to obtain a moderate-to-large interaction effect size (Cohen's $f = .35$). The selection of middle-aged and older participants was further stratified in half-decades (i.e., 45-49, 50-54, 55-59 years, and so on; $N = 15$-16 per age subgroup) to achieve optimum age distributions for each age group, and followed a balanced gender representation.

All participants spoke English as their first language and had normal or corrected-to-normal vision and hearing. Exclusion criteria for all participants included (a) prior history of head injury, (b) alcohol and drug dependence, (c) severe learning or intellectual disability, (d) any active medical, neurological, or psychiatric condition resulting in cognitive dysfunction, (e) a formal subjective memory complaint (i.e., having sought professional assessment due to concerns about their memory), and (f) a score ≤25 on the Montreal Cognitive Assessment test (MoCA; Nasreddine et al., 2005), a 30-point scale used as a brief measure of general cognitive functioning. Four participants were excluded from the study for not meeting all criteria, and therefore, the final sample consisted of 160 participants.

Participants' characteristics within each age group are presented in Table 1. There were no differences in sex distribution among the age groups, $\chi^2(4) = 2.63, p > .250$. There was a significant effect of age group on years of formal education, $F(4, 155) = 7.35, p < .001, \eta_p^2 = .16$, with the 45-54 and 55-64 groups having more years of formal schooling than those aged between 75 and 85 ($ps \leq .005$), and the 45-54 group having a higher educational level than the 65-74 group ($p = .005$).

We also examined the semantic processing ability of each participant with the Mill Hill Vocabulary Test (MHVT; Raven & Court, 1998), which provides an index of crystallized intelligence, to ensure that any impairment in spatial naming performance among older adults was not likely to be due to poorer vocabulary or diminished semantic processing. A significant effect of age group on MHVT score was found, $F(4, 155) = 11.89, p < .001, \eta_p^2 = .23$, with the 18-28 group performing worse than all other age groups ($ps < .001$), suggesting that crystallized abilities improve with increasing age (Cohen-Shikora & Balota, 2016; Verhaeghen, 2003). In addition, our participants were screened for depression with the self-report Patient Health Questionnaire (PHQ; Kroenke et al., 2001) and for anxiety with the self-report Generalized Anxiety Disorder scale (GAD; Spitzer et al., 2006) to ensure that any impairment in cognitive performance among older adults was not likely to be due to poorer emotional well-being. Depressive mood, $F(4, 155) = 7.9, p < .001, \eta_p^2 = .17$, and anxiety levels, $F(4, 155) = 8.86, p < .001, \eta_p^2 = .19$, were reliably higher in the 18-28 group compared to all other age groups ($ps \leq .026$), supporting the notion that increasing age is generally associated with better emotional well-being (Carstensen et al., 2011) and an intrinsic reduction in susceptibility to anxiety and depression (Jorm, 2000).

General Procedure

Ethical approval was obtained by the University of East Anglia's School of Psychology Ethics Committee and all procedures were carried out in accordance with the American Psychological Association and British Psychological Society guidelines and the Declaration of Helsinki. Each participant participated voluntarily and provided written informed consent for their participation. About two-thirds of the participants in the 18-28 age group received course credits for their participation, while the rest of the participants received monetary compensation.

Younger adults were recruited via fliers posted on university grounds and online advertisements on a participation pool. Middle-aged and older adults were recruited from East Anglia regions of the U.K. through advertisements in local media outlets and invitation leaflets. All participants attended a single testing session on campus on an individual (one-to-one) basis with the same experimenter (a trained neuropsychologist). Each testing session lasted approximately 2 hr. At the outset of each session, participants provided health and demographic information, followed by the MoCA administration in individuals aged 45 or more. Apart from the measures considered here, participants also completed tasks assessing different aspects of cognitive abilities (such as memory tasks; Markostamou & Coventry, 2021), beyond the scope of the present paper. All tasks were presented in a printed format and administered in a randomized order across all participants (with the exception of delayed memory recall trials that were always administered approximately 25 min after encoding). All neuropsychological tests were administered and scored using standard procedures. All participants' responses were verbal and were audio recorded and then transcribed verbatim for scoring.

Materials and Measures

Memory Measure

Episodic memory recall was examined with the widely used Logical Memory test (story A, LM; Wechsler, 2010). Participants heard a short story and were asked to verbally repeat it as accurately

Table 1
Participants' Characteristics Across All Age Groups

Measure	Age group (years)					Total
	18-28	45-54	55-64	65-74	75-85	
N	34	30	32	32	32	160
Age (years)	20.8 (2.19)	49.80 (3.26)	59.40 (2.57)	69.30 (2.40)	79.46 (2.90)	55.40 (20.60)
Education (years)	13.8 (1.94)	15.80 (3.07)	14.80 (3.52)	13.20 (2.62)	12.10 (3.32)	13.90 (3.16)
Gender (% females)	52.0%	68.0%	59.0%	53.0%	62.0%	59.0%
Handedness (% right)	94.1%	96.7%	87.5%	90.6%	93.8%	92.5%
General cognitive functioning (MoCA)	—	29.31 (1.05)	27.93 (1.92)	27.75 (1.54)	26.43 (1.50)	27.68 (1.82)
Vocabulary (MHVT)	18.00 (3.45)	22.60 (4.42)	22.75 (3.75)	23.47 (3.54)	23.37 (4.03)	21.98 (4.33)
Depression (PHQ)	6.00 (4.43)	3.33 (4.04)	3.16 (3.93)	2.19 (2.45)	1.59 (1.64)	3.29 (3.76)
Anxiety (GAD)	6.68 (4.63)	3.50 (3.97)	3.62 (3.51)	2.34 (2.79)	2.00 (2.51)	3.67 (3.92)

Note. Values represent means (and standard deviations).
MoCA = Montreal Cognitive Assessment; MHVT = Mill Hill Vocabulary Test; PHQ = Patient Health Questionnaire; GAD = Generalized Anxiety Disorder.

as possible immediately after hearing it (immediate recall trial) and after an interval of approximately 25 min (delayed recall trial). In the delayed recall trial, each correctly recalled unit was scored one point, and the percentage of correctly recalled units was calculated as the dependent variable.

Visuospatial Measures

We used three well-established visuospatial tasks to assess visuospatial organization, visuospatial reasoning, and mental rotation.

Visuospatial Organization. Hooper's Visual Organization Test (HVOT; Hooper, 1983) was used to assess visuospatial integration abilities. HVOT consists of 30 line-drawings of common objects that are fragmented into two or more pieces, requiring mental rearrangement of the pieces to identify the item. Administration and scoring followed the manual's guidelines. Each picture was presented one at a time and the participant was asked to identify the item. Correct responses were scored one point, while a less accurate but not incorrect response was scored half point. The percentage of correct responses was calculated as the dependent variable.

Mental Rotation. The Mental Rotation Test (MRT; Phillips, 1979) consists of 20 pairs of depictions of three-dimensional cube figures. In each pair, the two images are either identical (rotated by a number of degrees) or dissimilar (mirror images). Each pair was presented one at a time and participants were asked to decide whether the images were the same or different. Each correct response was scored one point, and the percentage of correct responses was calculated as the dependent variable. Time limit for completing the task was 5 min.

Visuospatial Reasoning. The Matrix Reasoning test (MR; Wechsler, 2010) was used to examine non-verbal intelligence. Administration and scoring followed the manual's guidelines. Each participant viewed an incomplete matrix of geometric figures and was asked to select the response option that completed the matrix from six choice options. Each correct response was scored one point, and the percentage of correct responses was calculated as the dependent variable. Time limit for completing the task was 5 min.

Object and Action Naming Measures

The widely used Boston Naming Test (BNT; Kaplan et al., 2001) was used for the assessment of object naming, while the Action Naming Test (ANT; Obler & Albert, 1979) was used for action naming.

Object Naming. The BNT consists of 60 simple line-drawings of objects of graded naming difficulty. We used a shorter 30-item version of the BNT which has been found to be equivalent of the original 60-item version in psychometric properties (Graves et al., 2004). Each item was presented one at a time to the participant, who was asked to name it with the appropriate noun. Correct responses were scored one point, and the percentage of correct responses was calculated as the dependent variable.

Action Naming. The ANT consists of 55 line-drawings of actions of graded naming difficulty. Participants were shown each item and were asked to name the action depicted with the appropriate verb. Correct responses were scored one point, and the percentage of correct responses was calculated as an index of action naming accuracy.

Spatial Naming

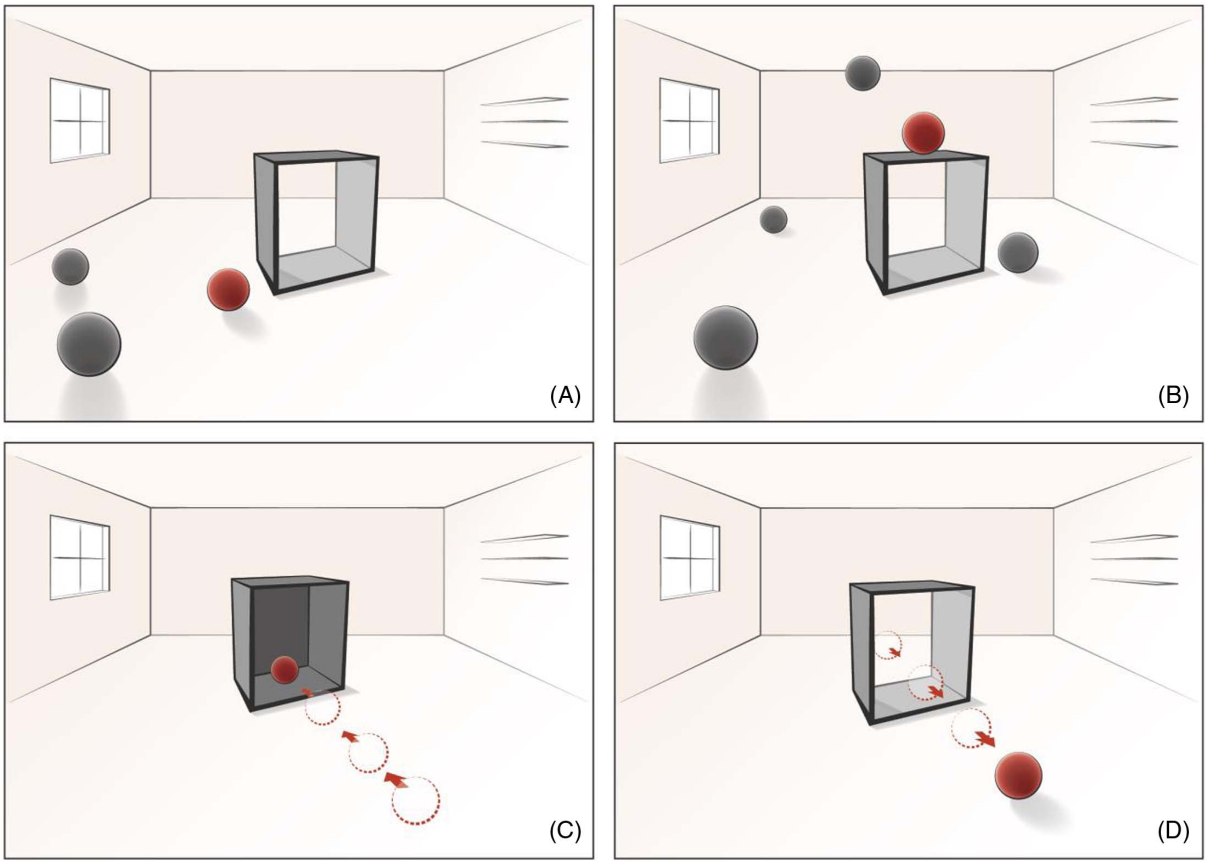
The SNT was specifically developed to assess naming abilities for static and dynamic spatial relations between objects, with locative and directional/path prepositions, respectively. It was designed as an analogue of the BNT for naming of objects (Kaplan et al., 2001). The SNT was designed to tap geometry-based spatial relations, excluding functional relationships between objects (Coventry & Garrod, 2004; Landau & Jackendoff, 1993). Therefore, geometrical shapes were deliberately chosen instead of everyday concrete objects to avoid biased responses based on typical descriptions of commonly encountered spatial relations (e.g., "the cat is *on* the mat"). Furthermore, the use of abstract geometric objects was chosen to limit language-specific conventionalized descriptions of spatial relations, as in "the bird is *in* the tree" or "the fly is *on* the ceiling," or conventionalized differences, such as "being *in* the car" versus "being *on* the bus," or "the food *in* the dish" versus "the food *on* the plate," and so on.

Stimuli. The SNT consists of 30 line drawings of simple geometrical shapes depicting different types of spatial relations, with a red ball as the located object and a cube as the reference object (or more cubes when necessary, as in cases of *between*, *in the middle*, *among*). The test was divided into two parts: Part A consisted of 15 pictures containing static spatial relations, requiring the production of locative/relational prepositions to describe locations (e.g., *inside*, *among*, *near*; see Figure 1, panels A and B). Black balls were also depicted to create a set of different spatial relations, in an attempt to elicit the most suitable response for the target spatial relation in a way that is distinguishable from the non-target relations. Part B consisted of 15 pictures containing dynamic spatial relations, requiring the production of directional/path prepositions to describe a change of locations (e.g., *through*, *onto*, *away from*; see Figure 1, panels C and D). Additional lined parallelograms of dotted red balls and arrows were depicted in the dynamic spatial relations to represent the movement of the located object. Having additional images and action lines superimposed on an image is the most commonly used technique to represent motion in still pictures in science and has been identified as the most efficient way of evoking motion representations clearly and precisely in still pictures (Cutting, 2002). Static spatial relations required the production of simple (e.g., *on*, *in*), complex (e.g., *between*, *among*) and proximal (e.g., *near*, *far*) topological prepositions, as well as projective (e.g., *in front of*, *below*, *to the right of*) prepositions. Dynamic spatial relations included goal- (e.g., *into*, *onto*), source- (e.g., *down off*, *out of*, *away from*), and via-based (e.g., *through*, *around*) paths to be named. Each target item corresponded to a single spatial preposition or prepositional phrase, although in some cases, more than one preposition was appropriate (e.g., *under*, *underneath*, *below*; all SNT items along with the scoring guidelines can be found in the Appendix and at https://osf.io/4xprc/).

Procedure. Participants were explained that their task to was to name as accurately as possible the red ball's location (Part A) or its change of location (Part B) in relation to the cube, in a way that identifies its location uniquely, distinguishing it from the black ball(s)' location(s). Participants were also explicitly instructed to use spatial prepositions to describe where the red ball is (Part A) or

Figure 1

Stimuli Samples of the Spatial Naming Test (SNT) Across Static (a: Near; B: on) and Dynamic (C: Into; D: Through) Spatial Relations



Note. See the online article for the color version of this figure.

moving (Part B) in relation to the cube. At the outset of each part, participants were given one example trial (one static and one dynamic, not used as test items), and were instructed once again that they should name where the red ball is (Part A) or moving (Part B) in relation to the cube, in a way that would be distinguishable from the non-target spatial relations between the black ball(s) and the cube. Before administering each example trial, participants were first asked to point to each different element of the drawings (i.e., red ball, black ball, cube, arrows) to ensure that they could clearly see and identify the visual stimuli. Next, the test items were presented, one at a time. If a participant provided a response that violated the task instructions (responding without using spatial prepositions or without describing the target spatial relation in a way that is distinguishable from the non-target relations), the task instructions were repeated once again and, when necessary, the participant was further instructed to avoid using themselves as the reference object (e.g., *The red ball is near me* or *The red ball is moving towards me*), a clock face system (e.g., *The red ball is at three o'clock*), or compass directions (e.g., *The red ball is North of the cube*) to describe the spatial relations. These additional instructions could be provided up to two times upon violation of the task instructions. However, such violations were rare (three cases in total) and it was never necessary to repeat the additional instructions twice in our sample of healthy adults.

Scoring. To establish consistent scoring guidelines for the SNT, all responses provided by participants for each test item were gathered and a group of 15 academic staff from the Faculty of Arts and Humanities and the Faculty of Social Sciences of the University of East Anglia rated how accurately each spatial preposition corresponded to each spatial relation depicted in the SNT on a 3-point scale (1 = accurate, 2 = less accurate but acceptable, 3 = not accurate; see Appendix). All raters were native speakers of English and had expertise in various language-related disciplines (including linguistics, psycholinguistics, applied linguistics, literature, creative writing, communication studies, etc.) Based on the ratings, optimal responses were scored one point (e.g., *into* for the relation depicted in Figure 1C), whereas a less accurate but not incorrect response was scored as a half point (e.g., *towards* for the relation depicted in Figure 1C). Responses that did not conform to the task instructions, including responses that were not distinguishable from the non-target spatial relations, were considered incorrect (e.g., *left* for the relation depicted in Figure 1A). The percentages of correct responses were calculated as indices of spatial naming accuracy.

Data Analysis

Data analysis is presented in three main sections. In the first section, we examined the psychometric properties of the SNT. More specifically, we inspected the performance distribution of the SNT, and we assessed its test–retest and inter-rater reliability and practice effects, as well as its convergent, divergent, and construct validity with a series of correlations and factor analysis. The second main section focused on the adult-lifespan trajectories of all abilities examined. We examined age as both a continuous and categorical variable. We compared accuracy rates of spatial naming, non-spatial naming, and non-verbal visuospatial measures among the five groups of younger, middle-aged, and older adults to examine the onset of potential age-related changes in all measures considered, as well as the mapping between spatial naming and non-spatial verbal and non-linguistic visuospatial trajectories across the adult lifespan. Finally, hierarchical multiple regressions were computed to examine the extent to which individual differences in non-spatial naming abilities and non-verbal visuospatial abilities contributed to spatial naming performance above and beyond age effects.

Results

Data Screening

All statistical analyses were conducted using Statistical Package for the Social Sciences 27.0 (International Business Machines Corp., Armonk, NY). There were no missing points in the data sets. We considered univariate outliers any data points exceeding 3.0 standard deviations from the corresponding age group mean of each variable. Only two points met this criterion (from an older individual in HVOT and a younger individual in BNT). Two multivariate outliers were identified by means of the Mahalanobis distance statistic, with the criterion set at χ^2 (6) > 21.53 at $p = .001$. Given that removing them did not affect the results, we retained them in the data set.

Psychometric Properties of the Spatial Naming Test

Distribution of Performance

We inspected the distribution of performance of the adult-lifespan sample on the SNT to determine the presence of floor or ceiling effects. Descriptive statistics for the SNT scores are presented in Table 2. Results showed that the skewness and kurtosis values ranged well within acceptable limits of ±2.0 for normally distributed data obtained from large samples (i.e., $N > 150$; Gravetter et al., 2020).

Inter-Rater Reliability Assessment

To assess the consistency of the scoring procedure, a second rater independently scored the SNT responses from 30 randomly selected participants. Analysis established that the inter-rater reliability between the raters was very high (Cohen's weighted $\kappa = .89$, $SE = .01$).

Test–Retest Reliability Assessment and Practice Effects

A subgroup of 34 adults (19 females), ranging in age from 19 to 63 years (age: $M = 38.05$, $SD = 14.14$ years; years of formal education: range = 12–21, $M = 16.29$, $SD = 2.64$ years), completed the SNT on a second, separate occasion, with a testing interval of between 2 and 24 weeks. Change indices across time were calculated by subtracting the means and standard deviations from Session 1 scores from Session 2 scores (Attix et al., 2009). Two-way mixed effects intra-class correlation coefficients and 99% confidence intervals were calculated to determine the test–retest reliability of the SNT (McGraw & Wong, 1996). A restrictive confidence interval was used ($\alpha = .01$) to control for Type I errors related to multiple comparisons. SNT test–retest scores with their corresponding correlation values are presented in Table 3. Correlation coefficients between test and retest scores ranged from .84 to .95, suggesting that the SNT achieved high levels of temporal stability over 2-24 weeks. Paired-samples *t*-tests comparing the mean scores across the two sessions showed no practice effects ($p > .250$), providing further evidence for the SNT's test–retest reliability.

Convergent, Divergent, and Construct Validity Assessment

The convergent validity of the SNT was determined by the calculation of the Pearson's correlation coefficients (*r*) between the SNT and established measures of both naming (i.e., the BNT and ANT) and visuospatial (i.e., the HVOT, MR, and MRT) abilities. Evidence of divergent validity consisted of lower correlations between the SNT and a dissimilar memory recall measure (i.e., the LM). Results (Table 4) showed strong correlations between the SNT and visuospatial measures (*r*s ranging from .39 to .54), while spatial naming was also significantly correlated with object and action naming (*r*s ranging from .31 to .36). In addition, the correlation between the SNT and the memory recall task (LM) was weaker ($r = .22$), providing evidence of discriminant validity. Partial correlations among all measures, controlling for age effects, were also calculated to ensure that the associations between the measures were not inflated by age-related coupled changes.

Table 2
Descriptive Statistics for the Spatial Naming Test (SNT)

Measure	*M*	*SD*	Min	Max	Distribution: Skewness	Distribution: Kurtosis
Spatial naming (composite)	87.33	7.50	40.00	100.00	−.645	.090
Static spatial naming	86.67	7.93	40.00	100.00	−.809	.520
Dynamic spatial naming	88.00	9.26	43.33	100.00	−.797	.518

Note. $N = 160$.

Table 3
Descriptive Data and Correlation Values for the Test–Retest Reliability Assessment of the Spatial Naming Test (SNT)

Measure	Session 1	Session 2	Change indices and correlations			
	M (SD)	*M (SD)*	*M* Diff. (*SD*)	ICC	Lower 99% CI	Upper 99% CI
Spatial naming (composite score)	92.84 (4.37)	93.08 (4.12)	0.24 (|.25|)	.92*	.80	92.84 (4.37)
Static spatial naming	91.47 (4.73)	91.57 (4.80)	0.1 (|.07|)	.84*	.75	91.47 (4.73)
Dynamic spatial naming	94.21 (5.52)	94.70 (4.99)	0.49 (|.52|)	.95*	.88	94.21 (5.52)

Note. *M* = mean; *SD* = standard deviation; Diff = difference (Session 2—Session 1); ICC = intra-class correlation coefficient; CI = confidence interval; *N* = 34.
* $p < .001$.

The age-controlled correlational analyses between the measures of interest yielded similar patterns of results (Table 4).

To further examine the construct-related validity of the SNT, we submitted all measures to an exploratory factor analysis with principal axis factoring as the extraction method. A scree test and the empirical Kaiser criterion (Braeken & van Assen, 2017) were used to determine the number of factors to retain for rotation. As the factors were expected to be correlated, an oblimin rotation method with Kaiser Normalization was selected. Pattern coefficients ≥.50 were predetermined to be salient (Stevens, 2002). Results from Barlett's Test of Sphericity indicated that the correlation matrix was not random, $\chi^2 = 229.85$, $df = 15$, $p < .001$, and the Kaiser-Meyer-Olkin measure of sampling adequacy was .791, indicating the suitability of the data for factor analysis (Stevens, 2002). The model yielded a two-factor solution with eigenvalues greater than 1, which was also confirmed with a visual scree test. The resulting solution accounted for 64.04% of the total variance. Factor loadings are presented in Table 5. Factor 1 accounted for the largest proportion of the variance (46.43%) and was interpreted as reflective of visuospatial abilities, as the HVOT, MR, and MRT loaded highly on it. Factor 2 accounted for 17.62% of the variance and appeared to reflect naming abilities, as the BNT and ANT loaded most highly on it. Importantly, spatial naming (SNT) loaded highly on Factor 1 along with the visuospatial measures, but also had a strong loading on Factor 2 along with the non-spatial naming measures, which indicates that spatial naming is closely related to both visuospatial and verbal abilities. This two-factor solution was robust across extraction (principal axis factoring, principal components) and rotation (oblimin, varimax) methods.

Adult-Lifespan Trajectories

First, age was analysed as a continuous variable in a series of linear regression analyses. The results of the regression analyses (Table 6) showed that age was a significant predictor of static and dynamic spatial naming, as well as visuospatial organization, mental rotation, and visuospatial reasoning, but not object or action naming. Subsequently, we examined differences in performance based on age group. Figure 2 shows the performance on each measure across all age groups. Mixed factorial analysis of variance was employed to examine the effects of age group (between-subject variable) and naming category (within-subject variable with four levels: static spatial relations, dynamic spatial relations, objects, and actions), and their possible interaction effects on naming performance. Significant main effects were followed-up with Bonferroni-corrected post hoc group comparisons. Significant main interaction effects were followed-up with tests of simple effects with Bonferroni correction, to allow comparisons between age groups at any given naming category.

There was a significant main effect of category on naming accuracy, $F(3, 465) = 83.91$, $p < .001$, $\eta_p^2 = .35$. Post hoc pairwise comparisons with Bonferroni correction revealed that naming accuracy for static spatial relations was significantly lower than for objects and actions ($ps < .001$), dynamic spatial naming was significantly lower than action naming ($p < .001$), and object naming was significantly lower than action naming ($p < .001$), for all participants (naming accuracy for static spatial relations: $M = 86.74\%$, $SE = .58$; dynamic spatial relations: $M = 88.02\%$, $SE = .63$; objects: $M = 89.92$, $SE = .60$; actions: $M = 96.29$, $SE = .29$).

A significant main effect of age group was also found, $F(4, 155) = 11.28$, $p < .001$, $\eta_p^2 = .22$, which was qualified by a significant Age group × Category interaction, $F(12, 465) = 6.34$, $p < .001$, $\eta_p^2 = .14$. Follow-up Bonferroni-corrected analyses of simple effects showed that the effect of age on naming accuracy was significant for objects, $F(4, 155) = 2.87$, $p = .025$, $\eta_p^2 = .07$, but not for actions, $F(4, 155) = 2.32$, $p = .059$, $\eta_p^2 = .05$. Bonferroni-corrected pairwise comparisons indicated that the age effect on object naming was due to the 18-28 group performing significantly worse than the 45-54 age group ($p = .037$), while no other significant group differences were revealed.

Table 4
Bivariate (and Partial) Correlations Between All Measures

Measure	1	2	3	4	5	6	7
1. Spatial naming	—	.31* (.36*)	.36* (.36*)	.53* (.45*)	.39* (.31*)	.54* (.45*)	.21 (.18)
2. Object naming		—	.39* (.40*)	.22 (.27)	.17 (.19)	.23 (.27)	.17 (.18)
3. Action naming			—	.22 (.21)	.15 (.13)	.17 (.16)	.13 (.13)
4. Visuospatial organization				—	.36* (.31*)	.48* (.37*)	.20 (.17)
5. Mental rotation					—	.52* (.45*)	.15 (.12)
6. Visuospatial reasoning						—	.25 (.23)
7. Memory recall							—

Note. Values in parentheses represent partial correlations between measures, after controlling for age effects; *N* = 160.
* $p < .001$.

Table 5
Factor Loadings Derived From Principal Axis Extraction With Oblimin Rotation

Measure	Factor 1	Factor 2
Spatial naming	**.71**	**.57**
Object naming	.30	**.52**
Action naming	.34	**.72**
Visual organization	**.63**	.33
Mental rotation	**.60**	.27
Visuospatial reasoning	**.81**	.35
Eigenvalues	2.79	1.06
Interpretation	Visuospatial abilities	Naming abilities

Note. Salient loading values are in bold; $N = 160$.

In sharp contrast, the effect of age group on naming accuracy was significant for static, $F(4, 155) = 7.62$, $p < .001$, $\eta_p^2 = .16$, and for dynamic, $F(4, 155) = 16.11$, $p < .001$, $\eta_p^2 = .29$, spatial relations. Bonferroni-corrected pairwise comparisons indicated that the 75-85 group was significantly less accurate in naming static spatial relations compared to the younger (18-28; $p = .019$) and middle-aged (45-54 and 55-64; ps $\leq .001$) groups. Moreover, the 65-74 and 75-85 groups performed significantly poorer in naming dynamic spatial relations compared to younger (18-28; ps $\leq .036$) and middle-aged (45-54 and 55-64; ps $\leq .033$) groups, while, in addition, the 75-85 group exhibited a significantly lower performance compared to the 65-74 group ($p = .001$).

Another series of analyses of variance were executed to determine the effect of age on performance on visuospatial tasks with post hoc Bonferroni-corrected pairwise comparisons. A significant effect of age group was found for all visuospatial measures, including visuospatial organization (HVOT), $F(4, 155) = 14.58$, $p < .001$, $\eta_p^2 = .27$, mental rotation (MRT), $F(4, 155) = 6.03$, $p < .001$, $\eta_p^2 = .14$, and visuospatial reasoning (MR), $F(4, 155) = 12.97$, $p < .001$, $\eta_p^2 = .25$. Post hoc comparisons showed that older adults aged 75-85 performed significantly worse than all other age groups in visual organization (ps $< .001$), indicating a sharp decline in advanced age. Mental rotation was significantly poorer in older adults aged 75-85 compared to adults aged 18-28 ($p < .001$) and 45-54 ($p = .001$). Finally, visuospatial reasoning started to significantly decline from the mid-60s, as the 65-74 group performed significantly worse than the 18-28 ($p = .012$) and 45-54 ($p = .048$) groups, while the 75-85 group's MR performance was significantly poorer compared to all other groups (ps $\leq .035$).

Regression Analyses

To determine the contribution of (non-spatial) verbal abilities and (non-verbal) visuospatial abilities to spatial naming variance above and beyond the influence of age, we conducted a series of hierchical regression analyses. To this end, composite scores for (non-spatial) naming and (non-linguistic) visuospatial measures were calculated; the composite naming score was calculated as the mean percentage of correct responses in the BNT and ANT, and the composite visuospatial score as the mean percentage of correct responses in the HVOT, MR, and MRT. With spatial naming accuracy indices as the dependent variables, in these regressions, age was entered in the first block of predictors as a continuous variable and the naming and visuospatial variables were entered simultaneously in the second block. The results of the regression models for overall spatial naming, as well as for static and dynamic spatial naming, are presented in Table 7.

Age was highly predictive of spatial naming, $F(1, 158) = 16.76$, $p < .001$, and accounted for 9.6% of the variance in naming performance. Introducing the naming and visuospatial abilities variables in step two significantly increased the model's predictive value, $F(2, 156) = 32.48$, $p < .001$, which explained an additional 26.6% of the variance. Spatial naming was significantly predicted by both naming and visuospatial factors, although visuospatial abilities held a higher predictive power, while age did not remain a significant predictor in the second step of the model.

A separate similar model indicated that age significantly predicted static spatial naming, $F(1, 158) = 5.77$, $p = .017$, accounting for 3.6% of the variance. More importantly, adding naming and visuospatial abilities to the model substantially increased its predictive value, $F(2, 156) = 32.51$, $p < .001$, which explained an additional 28.4% of the variance. In step two of the model, age was no longer a significant predictor of static spatial naming, while naming and visuospatial abilities held a comparable predictive power for naming static spatial relations.

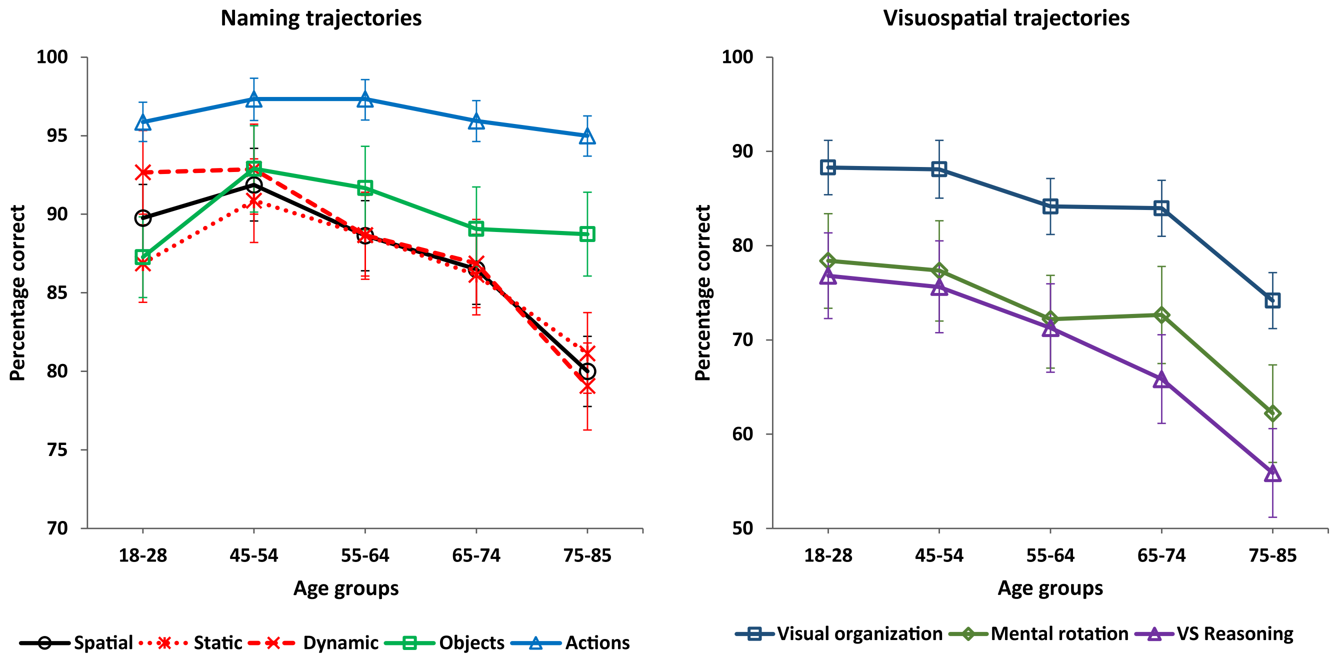
The results of another separate similar model showed that age significantly contributed to dynamic spatial naming, $F(1, 158) = 18.65$, $p < .001$, accounting for 10.6% of the variance. Importantly, the addition of naming and visuospatial abilities in step two significantly increased the model's predictive value, $F(2, 156) = 7.92$, $p = .001$, and explained an additional 8.2% of the variance in dynamic spatial naming. However, while visuospatial abilities were found to be a significant predictor of naming dynamic spatial

Table 6
Regression Summaries for All Measures as Predicted by Age

Measure	Model summary	*B* (*SE*)	β	*t*-value
Static spatial naming	$F(1,158) = 6.76$, $p = .01$, $R^2 = .04$	−.08 (.03)	−.20	−2.60*
Dynamic spatial naming	$F(1,158) = 40.40$, $p < .001$, $R^2 = .20$	−.20 (.03)	−.45	−6.36**
Object naming	$F(1,158) = .54$, $p > .250$, $R^2 = .00$	.02 (.03)	.06	.73
Action naming	$F(1,158) = .86$, $p > .250$, $R^2 = .00$	−.01 (.01)	−.07	−.93
Visual organization	$F(1,158) = 33.70$, $p < .001$, $R^2 = .18$	−.20 (.03)	−.42	−5.80**
Mental rotation	$F(1,158) = 16.52$, $p < .001$, $R^2 = .09$	−.23 (.06)	−.31	−4.06**
Visuospatial reasoning	$F(1,158) = 36.10$, $p < .001$, $R^2 = .19$	−.32 (.05)	−.43	−6.01**

Note. $N = 160$.
* $p < .01$. ** $p < .001$.

Figure 2
Adult-Lifespan Trajectories of Naming and Visuospatial Abilities



Note. Error bars represent 95% confidence intervals. See the online article for the color version of this figure.

relations along with age, naming abilities failed to account for significant variance in dynamic spatial naming over and above age.

Discussion

In the present study, we identified the adult-lifespan trajectories of naming static and dynamic spatial relations for the first time and directly contrasted them against the trajectories of (non-spatial) object and action naming, as well as (non-linguistic) visuospatial abilities. Results showed divergent patterns of naming performance across the lifespan, depending on the semantic category involved, with significant age-related declines in spatial naming but not in object or action naming. More specifically, the ability to accurately describe static spatial relations with the appropriate spatial

Table 7
Regression Summaries for Spatial Naming Performance

Predictors	R	R^2	ΔR^2	B (SE)	β	t-value
Spatial naming						
Step 1	.31	.10	.10***			
Age				−.12 (.03)	−.31	−4.09***
Step 2	.60	.36	.27***			
Age				−.04 (.03)	−.11	−1.47
(Non-spatial) naming abilities				.35 (.10)	.23	3.50***
(Non-verbal) visuospatial abilities				.34 (.06)	.45	5.94***
Static spatial naming						
Step 1	.19	.04	.04*			
Age				−.07 (.03)	−.19	−2.4**
Step 2	.57	.32	.28***			
Age				−.02 (.03)	−.04	−0.51
(Non-spatial) naming abilities				.51 (.10)	.35	5.09***
(Non-verbal) visuospatial abilities				.26 (.06)	.35	4.52***
Dynamic spatial naming						
Step 1	.33	.11	.11***			
Age				−.19 (.04)	−.32	−4.32***
Step 2	.43	.19	.08***			
Age				−.12 (.05)	−.20	−2.45**
(Non-spatial) naming abilities				.23 (.16)	.11	1.45
(Non-verbal) visuospatial abilities				.29 (.09)	.27	3.13***

Note. $N = 160$.
* $p < .05$. ** $p < .01$. *** $p < .001$.

prepositions remains stable until the mid-60s and declines sharply in the mid-70s, while naming dynamic spatial relations starts to mildly drop as early as from the mid-50s and begins to significantly decline from the mid-60s. Declines in non-linguistic visuospatial abilities, including visual organisation, mental rotation, and visuospatial reasoning, were also apparent from the mid-60s with a more pronounced impairment in late adulthood, in line with previous reports (Borella et al., 2014; Hoogendam et al., 2014; Techentin et al., 2014; Viskontas et al., 2005).

By contrast, we found that naming objects slightly improves in midlife and remains intact until late adulthood, while there were no significant age-related changes in action naming. These findings contribute to the mixed literature regarding age effects on naming. Consistent with our findings, several studies with neurologically unimpaired individuals have also reported that performance in picture-confrontation naming tasks is generally well-preserved in ageing (e.g., Schmitter-Edgecombe et al., 2000; Wierenga et al., 2008), and although there have also been reports of mild declines in late adulthood (Kavé & Mashal, 2012; Verhaegen & Poncelet, 2013), it has been suggested that differences between younger and older adults usually pertain to naming speed rather than naming accuracy (Goulet et al., 1994; Mortensen et al., 2008) and that mild word-finding difficulties among older adults are attributed to impaired executive control processes related to the manipulation and effortful retrieval of information rather than diminished semantic knowledge per se (Facal et al., 2012; Wierenga et al., 2008).

The key result of divergent lifespan trajectories of naming performance can be interpreted in several ways. Although all three categories are usually regarded as concrete, one could argue that they may, nevertheless, vary in concreteness, and this variability in concreteness may account for age-related differences. Specifically, objects may be regarded as the most concrete (with their fixed sensory attributes), with actions less concrete, and spatial relations the least concrete. Therefore, it is possible that the least concrete terms may be subject to greater age-related effects. However, existing evidence points to a reduction of the concreteness effect in semantic processing in ageing (Borghi & Setti, 2017), with retrieval of concrete words being impaired by ageing to a greater degree than memory of abstract words (Peters & Daum, 2008). We think a more plausible explanation is that these distinct semantic categories are supported by at least partially dissociable neural networks (Damasio et al., 2001; Rocca et al., 2020) that are differentially affected by typical ageing processes. In fact, patient and neuroimaging investigations have previously shown that word production for nouns and verbs is underpinned by overlapping neural networks that include left prefrontal and anterior temporal regions (Havas et al., 2015; Liljeström et al., 2008), while the production of spatial prepositions is additionally supported by an extended network of parietal regions (Amorapanth et al., 2010; Damasio et al., 2001), which are typically associated with visuospatial processes.

The parallel trajectories of change in spatial semantics and non-linguistic spatial cognition across the adult lifespan provide novel evidence of the strong connection between linguistic and non-linguistic representations of space (Amorapanth et al., 2010; Coventry et al., 2014; Landau & Hoffman, 2005). These findings are in line with the notion that these representational systems share underlying structural similarities and comparable cognitive operations (Hayward & Tarr, 1995), that are supported, at least to some extent, by overlapping brain networks (Damasio et al., 2001; Rocca et al., 2020) which are sensitive to typical ageing.

More broadly, these results have important implications for theories of language on one hand and potential applications for atypical populations on the other. As discussed earlier, there is much debate regarding the extent to which semantic processes are derived from distributional abstract symbols versus grounding in the systems of perception and action (Meteyard et al., 2012). Our results provide an important addition to this debate and also to theoretical accounts focusing on the distinction between concrete and abstract conceptual representations (cf. Andrews et al., 2009; Barsalou et al., 2018). Even among semantic categories that may all be regarded as concrete (i.e., objects, actions, and spatial relations), there is significant variation in naming as a function of reliance on non-linguistic systems. The central result that spatial naming declines in ageing, while naming of actions and objects does not, speaks to the need to consider semantic change not just in early learning, but also in terms of relative change at the other equally important end of the lifespan.

The current findings offer an important window regarding how verbal versus visuospatial abilities modulate spatial naming performance and, more broadly, determine spatial semantics. Both non-spatial naming and non-linguistic visuospatial abilities accounted for a significant variance in spatial naming above and beyond age effects. These findings are consistent with the view that language as a whole might be underpinned by both grounded and symbolic representations (Andrews et al., 2009; Lynott & Connell, 2010). However, the two sets of items—static and dynamic relations—do produce different loadings with respect to verbal resources. While naming performance for static spatial relations was predicted by both non-spatial naming measures and visuospatial resources, the latter was the only predictor of naming dynamic spatial relations, suggesting a higher reliance of dynamic spatial semantics on grounded representations from the visuospatial domain. Differences between static and dynamic spatial abilities have been largely neglected (Sanchez & Wiley, 2014); however, some existing evidence suggests that these two dimensions may be relatively distinct (Contreras et al., 2003; D'Oliveira, 2004). Naming dynamic spatial relations, and, more broadly, forming dynamic spatial representations, requires the perceptual monitoring and analysis of moving elements and their sequential locative changes. In language comprehension as well as in perceptual paradigms, representing events that involve changing locations requires further strategic use and monitoring of perceptual and motor representations which is computationally costly (Richmond & Zacks, 2017). The higher reliance of dynamic spatial naming on non-linguistic visuospatial abilities would also explain the demonstrated higher performance of younger adults in dynamic spatial naming compared to static spatial naming. Although knowledge about the age-related changes in static versus dynamic visuoperceptual processing is limited, past research has shown that older adults are less sensitive to motion perception and direction identification compared to younger individuals (Bennett et al., 2007; Conlon & Herkes, 2008), processes tightly yoked to dynamic spatial processing. In a previous study examining static versus dynamic spatial naming in patients with hemispheric lesions and matched controls, no effects of task type were identified in either group (Göksun et al., 2013); however, the number of the targeted spatial relations was limited in that study, and the stimuli used were everyday objects with rich situational knowledge that could have elicited object-knowledge effects or biased responses based on overlearned descriptions of commonly encountered spatial relations (e.g., *The apple in the bowl*), which has been shown to significantly influence spatial preposition selection (Coventry & Garrod, 2004; Coventry et al., 2010).

From a practical standpoint, the psychometric evaluation of the SNT resulted in excellent test–retest reliability, confirming that it provides consistent results over time, as well as inter-rater reliability, and established its concurrent and construct validity with analogous (non-spatial) naming and (non-linguistic) visuospatial tests, as well as its divergent validity relatively to a memory test. This brief and simply administered new test can provide a useful and reliable means of assessing this important facet of cognition that, so far, has not been thoroughly investigated in typically developing populations. Although there exists a rich literature on the acquisition of spatial semantics early in development, previous studies have typically employed observational paradigms or focused on a limited range of spatial concepts at a time. Thus, an interesting avenue for future work would be to employ the SNT to identify the developmental trajectories of static and dynamic spatial naming early in life, especially in comparison to (non-spatial) verbal and (non-verbal) visuospatial abilities. Given the positive associations between spatial language and (non-linguistic) spatial cognition that have previously been observed in children (Balcomb et al., 2011; Nys et al., 2015; Pruden et al., 2011), we would expect a similarly strong relationship between SNT performance and spatial cognition in children. Further research in larger samples of different age groups is required to consolidate the SNT's psychometric properties as well as its appropriateness for use in children. The SNT also offers potential for application to a range of clinical populations where visuospatial abilities are known to be compromised relative to typical controls, from individuals with Williams syndrome early in development (Landau & Hoffman, 2005) to mild cognitive impairment and early Alzheimer's disease in later life (Coughlan et al., 2018). Given the reliance on visuospatial processes in spatial naming, disproportionate deficits on naming spatial relations should be observed among these patients, while the SNT may also offer potential as a means for the early detection of atypical ageing.

Conclusions

In conclusion, the results of the present study demonstrate that naming static and dynamic spatial relations declines with increasing age, as measured by the new SNT, a test with robust psychometric properties. Moreover, how the pattern of decline maps onto (non-linguistic) visuospatial and (non-spatial) linguistic abilities has been illuminated, providing several theoretical and practical applications. The parallel trajectories of spatial language and non-linguistic visuospatial abilities across the adult lifespan point to strong links between linguistic and non-linguistic spatial representation. The present findings also illustrate that performance in processing representations acquired throughout the lifespan, such as naming different objects and actions, is well-preserved in ageing, while processing that involves concurrent manipulation of novel representations that are independent of past knowledge, such as visuospatial organization, reasoning, and naming spatial relations, particularly dynamic spatial relations, is less efficient in the later years of life.

References

Amorapanth, P. X., Widick, P., & Chatterjee, A. (2010). The neural basis for spatial relations. *Journal of Cognitive Neuroscience*, *22*(8), 1739–1753. https://doi.org/10.1162/jocn.2009.21322

Andrews, M., Vigliocco, G., & Vinson, D. (2009). Integrating experiential and distributional data to learn semantic representations. *Psychological Review*, *116*(3), 463–498. https://doi.org/10.1037/a0016261

Attix, D. K., Story, T. J., Chelune, G. J., Ball, J. D., Stutts, M. L., Hart, R. P., & Barth, J. T. (2009). The prediction of change: Normative neuropsychological trajectories. *The Clinical Neuropsychologist*, *23*(1), 21–38. https://doi.org/10.1080/13854040801945078

Balcomb, F., Newcombe, N. S., & Ferrara, K. (2011). Finding where and saying where: Developmental relationships between place learning and language in the first year. *Journal of Cognition and Development*, *12*(3), 315–331. https://doi.org/10.1080/15248372.2010.544692

Barsalou, L. W., Dutriaux, L., & Scheepers, C. (2018). Moving beyond the distinction between concrete and abstract concepts. *Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences*, *373*(1752), Article 20170144. https://doi.org/10.1098/rstb.2017.0144

Bennett, P. J., Sekuler, R., & Sekuler, A. B. (2007). The effects of aging on motion detection and direction identification. *Vision Research*, *47*(6), 799–809. https://doi.org/10.1016/j.visres.2007.01.001

Borella, E., Meneghetti, C., Ronconi, L., & De Beni, R. (2014). Spatial abilities across the adult life span. *Developmental Psychology*, *50*(2), 384–392. https://doi.org/10.1037/a0033818

Borghi, A. M., & Setti, A. (2017). Abstract concepts and aging: An embodied and grounded perspective. *Frontiers in Psychology*, *8*, Article 430. https://doi.org/10.3389/fpsyg.2017.00430

Braeken, J., & van Assen, M. A. L. M. (2017). An empirical Kaiser criterion. *Psychological Methods*, *22*(3), 450–466. https://doi.org/10.1037/met0000074

Carstensen, L. L., Turan, B., Scheibe, S., Ram, N., Ersner-Hershfield, H., Samanez-Larkin, G. R., Brooks, K. P., & Nesselroade, J. R. (2011). Emotional experience improves with age: Evidence based on over 10 years of experience sampling. *Psychology and Aging*, *26*(1), 21–33. https://doi.org/10.1037/a0021285

Cohen-Shikora, E. R., & Balota, D. A. (2016). Visual word recognition across the adult lifespan. *Psychology and Aging*, *31*(5), 488–502. https://doi.org/10.1037/pag0000100

Conder, J., Fridriksson, J., Baylis, G. C., Smith, C. M., Boiteau, T. W., & Almor, A. (2017). Bilateral parietal contributions to spatial language. *Brain and Language*, *164*, 16–24. https://doi.org/10.1016/j.bandl.2016.09.007

Conlon, E., & Herkes, K. (2008). Spatial and temporal processing in healthy aging: Implications for perceptions of driving skills. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, *15*(4), 446–470. https://doi.org/10.1080/13825580701878008

Connell, L., & Lynott, D. (2012). Strength of perceptual experience predicts word processing performance better than concreteness or imageability. *Cognition*, *125*(3), 452–465. https://doi.org/10.1016/j.cognition.2012.07.010

Contreras, M. J., Colom, R., Hernández, J. M., & Santacreu, J. (2003). Is static spatial performance distinguishable from dynamic spatial performance? A latent-variable analysis. *The Journal of General Psychology*, *130*(3), 277–288. https://doi.org/10.1080/00221300309601159

Coughlan, G., Laczó, J., Hort, J., Minihane, A. M., & Hornberger, M. (2018). Spatial navigation deficits - overlooked cognitive marker for preclinical Alzheimer disease? *Nature Reviews. Neurology*, *14*(8), 496–506. https://doi.org/10.1038/s41582-018-0031-x

Coventry, K. R., & Garrod, S. C. (2004). *Saying, seeing and acting; The psychological semantics of spatial prepositions*. Psychology Press. https://doi.org/10.4324/9780203641521

Coventry, K. R., Griffiths, D., & Hamilton, C. J. (2014). Spatial demonstratives and perceptual space: Describing and remembering object location. *Cognitive Psychology*, *69*, 46–70. https://doi.org/10.1016/j.cogpsych.2013.12.001

Coventry, K. R., Lynott, D., Cangelosi, A., Monrouxe, L., Joyce, D., & Richardson, D. C. (2010). Spatial language, visual attention, and perceptual simulation. *Brain and Language*, *112*(3), 202–213. https://doi.org/10.1016/j.bandl.2009.06.001

Cutting, J. E. (2002). Representing motion in a static image: Constraints and parallels in art, science, and popular culture. *Perception*, *31*(10), 1165–1193. https://doi.org/10.1068/p3318

D'Oliveira, T. C. (2004). Dynamic spatial ability: An exploratory analysis and a confirmatory study. *The International Journal of Aviation Psychology*, *14*(1), 19–38. https://doi.org/10.1207/s15327108ijap1401_2

Damasio, H., Grabowski, T. J., Tranel, D., Ponto, L. L., Hichwa, R. D., & Damasio, A. R. (2001). Neural correlates of naming actions and of naming spatial relations. *NeuroImage*, *13*(6), 1053–1064. https://doi.org/10.1006/nimg.2001.0775

Devlin, A. L., & Wilson, P. H. (2010). Adult age differences in the ability to mentally transform object and body stimuli. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, *17*(6), 709–729. https://doi.org/10.1080/13825585.2010.510554

Facal, D., Juncos-Rabadán, O., Rodríguez, M. S., & Pereiro, A. X. (2012). Tip-of-the-tongue in aging: Influence of vocabulary, working memory and processing speed. *Aging Clinical and Experimental Research*, *24*(6), 647–656.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Federmeier, K. D., Van Petten, C., Schwartz, T. J., & Kutas, M. (2003). Sounds, words, sentences: Age-related changes across levels of language processing. *Psychology and Aging*, *18*(4), 858–872. https://doi.org/10.1037/0882-7974.18.4.858

Göksun, T., Lehet, M., Malykhina, K., & Chatterjee, A. (2013). Naming and gesturing spatial relations: Evidence from focal brain-injured individuals. *Neuropsychologia*, *51*(8), 1518–1527. https://doi.org/10.1016/j.neuropsychologia.2013.05.006

Goulet, P., Ska, B., & Kahn, H. J. (1994). Is there a decline in picture naming with advancing age? *Journal of Speech and Hearing Research*, *37*(3), 629–644. https://doi.org/10.1044/jshr.3703.629

Graves, R. E., Bezeau, S. C., Fogarty, J., & Blair, R. (2004). Boston naming test short forms: A comparison of previous forms with new item response theory based forms. *Journal of Clinical and Experimental Neuropsychology*, *26*(7), 891–902. https://doi.org/10.1080/13803390490510716

Gravetter, F., Wallnau, L., Forzano, L. A. B., & Witnauer, J. E. (2020). *Essentials of statistics for the behavioral sciences* (10th ed.). Wadsworth.

Havas, V., Gabarrós, A., Juncadella, M., Rifa-Ros, X., Plans, G., Acebes, J. J., de Diego Balaguer, R., & Rodríguez-Fornells, A. (2015). Electrical stimulation mapping of nouns and verbs in Broca's area. *Brain and Language*, *145-146*, 53–63. https://doi.org/10.1016/j.bandl.2015.04.005

Hayward, W. G., & Tarr, M. J. (1995). Spatial language and spatial representation. *Cognition*, *55*(1), 39–84. https://doi.org/10.1016/0010-0277(94)00643-Y

Hoogendam, Y. Y., Hofman, A., van der Geest, J. N., van der Lugt, A., & Ikram, M. A. (2014). Patterns of cognitive function in aging: The Rotterdam study. *European Journal of Epidemiology*, *29*(2), 133–140. https://doi.org/10.1007/s10654-014-9885-4

Hooper, E. H. (1983). *The hooper visual organization test manual*. Western Psychological Services.

Jagust, W. (2013). Vulnerable neural systems and the borderland of brain aging and neurodegeneration. *Neuron*, *77*(2), 219–234. https://doi.org/10.1016/j.neuron.2013.01.002

Jorm, A. F. (2000). Does old age reduce the risk of anxiety and depression? A review of epidemiological studies across the adult life span. *Psychological Medicine*, *30*(1), 11–22. https://doi.org/10.1017/S0033291799001452

Kaplan, E., Goodglass, H., & Weintraub, S. (2001). *Boston naming test*. Pro-Ed.

Kavé, G., & Mashal, N. (2012). Age-related differences in word-retrieval but not in meaning generation. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, *19*(4), 515–529. https://doi.org/10.1080/13825585.2011.638975

Kemmerer, D., & Tranel, D. (2000). A double dissociation between linguistic and perceptual representations of spatial relationships. *Cognitive Neuropsychology*, *17*(5), 393–414. https://doi.org/10.1080/026432900410766

Kennedy, K. M., Rodrigue, K. M., Bischof, G. N., Hebrank, A. C., Reuter-Lorenz, P. A., & Park, D. C. (2015). Age trajectories of functional activation under conditions of low and high processing demands: An adult lifespan fMRI study of the aging brain. *NeuroImage*, *104*, 21–34. https://doi.org/10.1016/j.neuroimage.2014.09.056

Klencklen, G., Després, O., & Dufour, A. (2012). What do we know about aging and spatial cognition? Reviews and perspectives. *Ageing Research Reviews*, *11*(1), 123–135. https://doi.org/10.1016/j.arr.2011.10.001

Kroenke, K., Spitzer, R. L., & Williams, J. B. (2001). The PHQ-9: Validity of a brief depression severity measure. *Journal of General Internal Medicine*, *16*(9), 606–613. https://doi.org/10.1046/j.1525-1497.2001.016009606.x

Landau, B., & Hoffman, J. E. (2005). Parallels between spatial cognition and spatial language: Evidence from Williams syndrome. *Journal of Memory and Language*, *53*(2), 163–185. https://doi.org/10.1016/j.jml.2004.05.007

Landau, B., & Jackendoff, R. (1993). "What" and "where" in spatial language and spatial cognition. *Behavioral and Brain Sciences*, *16*(2), 217–238. https://doi.org/10.1017/S0140525X00029733

Lien, M. C., Allen, P. A., Ruthruff, E., Grabbe, J., McCann, R. S., & Remington, R. W. (2006). Visual word recognition without central attention: Evidence for greater automaticity with advancing age. *Psychology and Aging*, *21*(3), 431–447. https://doi.org/10.1037/0882-7974.21.3.431

Liljeström, M., Tarkiainen, A., Parviainen, T., Kujala, J., Numminen, J., Hiltunen, J., Laine, M., & Salmelin, R. (2008). Perceiving and naming actions and objects. *NeuroImage*, *41*(3), 1132–1141. https://doi.org/10.1016/j.neuroimage.2008.03.016

Lynott, D., & Connell, L. (2010). Embodied conceptual combination. *Frontiers in Psychology*, *1*, Article 212. https://doi.org/10.3389/fpsyg.2010.00212

Markostamou, I., & Coventry, K. (2021). Memory for route and survey descriptions across the adult lifespan: The role of verbal and visuospatial working memory resources. *Journal of Environmental Psychology*, *78*, Article 101712. https://doi.org/10.1016/j.jenvp.2021.101712

McGraw, K. O., & Wong, S. P. (1996). Forming inferences about some intraclass correlation coefficients. *Psychological Methods*, *1*(1), 30–46. https://doi.org/10.1037/1082-989X.1.1.30

Meteyard, L., Cuadrado, S. R., Bahrami, B., & Vigliocco, G. (2012). Coming of age: A review of embodiment and the neuroscience of semantics. *Cortex*, *48*(7), 788–804. https://doi.org/10.1016/j.cortex.2010.11.002

Mortensen, L., Meyer, A. S., & Humphreys, G. W. (2008). Speech planning during multiple-object naming: Effects of ageing. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, *61*(8), 1217–1238. https://doi.org/10.1080/17470210701467912

Munnich, E., Landau, B., & Dosher, B. A. (2001). Spatial language and spatial representation: A cross-linguistic comparison. *Cognition*, *81*(3), 171–207. https://doi.org/10.1016/S0010-0277(01)00127-5

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

Nys, M., Gyselinck, V., Orriols, E., & Hickmann, M. (2015). Landmark and route knowledge in children's spatial representation of a virtual environment. *Frontiers in Psychology*, *5*, Article 1522. https://doi.org/10.3389/fpsyg.2014.01522

Obler, L. K., & Albert, M. L. (1979). *The action naming test*. VA Medical Center.

Paivio, A. (2007). *Mental representations: A dual coding approach*. Oxford Univeristy Press.

Payne, B. R., Gao, X., Noh, S. R., Anderson, C. J., & Stine-Morrow, E. A. (2012). The effects of print exposure on sentence processing and memory in older adults: Evidence for efficiency and reserve. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, *19*(1-2), 122–149. https://doi.org/10.1080/13825585.2011.628376

Peelle, J. E., Troiani, V., Wingfield, A., & Grossman, M. (2010). Neural processing during older adults' comprehension of spoken sentences: Age differences in resource allocation and connectivity. *Cerebral Cortex*, *20*(4), 773–782. https://doi.org/10.1093/cercor/bhp142

Peters, J., & Daum, I. (2008). Differential effects of normal aging on recollection of concrete and abstract words. *Neuropsychology*, *22*(2), 255–261. https://doi.org/10.1037/0894-4105.22.2.255

Pexman, P. M., Hargreaves, I. S., Edwards, J. D., Henry, L. C., & Goodyear, B. G. (2007). Neural correlates of concreteness in semantic categorization. *Journal of Cognitive Neuroscience*, *19*(8), 1407–1419. https://doi.org/10.1162/jocn.2007.19.8.1407

Phillips, R. (1979). *Phillips Shepard & Metzler test*. NFER-NELSON.

Pruden, S. M., Levine, S. C., & Huttenlocher, J. (2011). Children's spatial thinking: Does talk about the spatial world matter? *Developmental Science*, *14*(6), 1417–1430. https://doi.org/10.1111/j.1467-7687.2011.01088.x

Pulvermüller, F. (2012). Meaning and the brain: The neurosemantics of referential, interactive, and combinational knowledge. *Journal of Neurolinguistics*, *25*(5), 423–459. https://doi.org/10.1016/j.jneuroling.2011.03.004

Raven, J. C., & Court, J. H. (1998). *Raven's progressive matrices and vocabulary scales*. Oxford Psychologists Press.

Rice, G. E., Lambon Ralph, M. A., & Hoffman, P. (2015). The roles of left versus right anterior temporal lobes in conceptual knowledge: An ALE meta-analysis of 97 functional neuroimaging studies. *Cerebral Cortex*, *25*(11), 4374–4391. https://doi.org/10.1093/cercor/bhv024

Richmond, L. L., & Zacks, J. M. (2017). Constructing experience: Event models from perception to action. *Trends in Cognitive Sciences*, *21*(12), 962–980. https://doi.org/10.1016/j.tics.2017.08.005

Rocca, R., Coventry, K. R., Tylén, K., Staib, M., Lund, T. E., & Wallentin, M. (2020). Language beyond the language system: Dorsal visuospatial pathways support processing of demonstratives and spatial language during naturalistic fast fMRI. *NeuroImage*, *216*, Article 116128. https://doi.org/10.1016/j.neuroimage.2019.116128

Sanchez, C. A., & Wiley, J. (2014). The role of dynamic spatial ability in geoscience text comprehension. *Learning and Instruction*, *31*, 33–45. https://doi.org/10.1016/j.learninstruc.2013.12.007

Schmitter-Edgecombe, M., Vesneski, M., & Jones, D. W. R. (2000). Aging and word-finding: A comparison of spontaneous and constrained naming tests. *Archives of Clinical Neuropsychology*, *15*(6), 479–493. https://doi.org/10.1093/arclin/15.6.479

Shafto, M. A., & Tyler, L. K. (2014). Language in the aging brain: The network dynamics of cognitive decline and preservation. *Science*, *346*(6209), 583–587. https://doi.org/10.1126/science.1254404

Spitzer, R. L., Kroenke, K., Williams, J. B., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine*, *166*(10), 1092–1097. https://doi.org/10.1001/archinte.166.10.1092

Stevens, J. P. (2002). *Applied multivariate statistics for the social sciences* (4th ed.). Erlbaum.

Techentin, C., Voyer, D., & Voyer, S. D. (2014). Spatial abilities and aging: A meta-analysis. *Experimental Aging Research*, *40*(4), 395–425. https://doi.org/10.1080/0361073X.2014.926773

Tomasello, R., Garagnani, M., Wennekers, T., & Pulvermüller, F. (2017). Brain connections of words, perceptions and actions: A neurobiological model of spatio-temporal semantic activation in the human cortex. *Neuropsychologia*, *98*, 111–129. https://doi.org/10.1016/j.neuropsychologia.2016.07.004

Verhaegen, C., & Poncelet, M. (2013). Changes in naming and semantic abilities with aging from 50 to 90 years. *Journal of the International Neuropsychological Society*, *19*(2), 119–126. https://doi.org/10.1017/S1355617712001178

Verhaeghen, P. (2003). Aging and vocabulary scores: A meta-analysis. *Psychology and Aging*, *18*(2), 332–339. https://doi.org/10.1037/0882-7974.18.2.332

Viskontas, I. V., Holyoak, K. J., & Knowlton, B. J. (2005). Relational integration in older adults. *Thinking & Reasoning*, *11*(4), 390–410. https://doi.org/10.1080/13546780542000014

Viskontas, I. V., Morrison, R. G., Holyoak, K. J., Hummel, J. E., & Knowlton, B. J. (2004). Relational integration, inhibition, and analogical reasoning in older adults. *Psychology and Aging*, *19*(4), 581–591. https://doi.org/10.1037/0882-7974.19.4.581

Wechsler, D. (2010). *Wechsler Adult Intelligence Scale–IV UK*. Pearson.

Wierenga, C. E., Benjamin, M., Gopinath, K., Perlstein, W. M., Leonard, C. M., Rothi, L. J. G., Conway, T., Cato, M. A., Briggs, R., & Crosson, B. (2008). Age-related changes in word retrieval: Role of bilateral frontal and subcortical networks. *Neurobiology of Aging*, *29*(3), 436–451. https://doi.org/10.1016/j.neurobiolaging.2006.10.024

Wingfield, A., & Grossman, M. (2006). Language and the aging brain: Patterns of neural compensation revealed by functional brain imaging. *Journal of Neurophysiology*, *96*(6), 2830–2839. https://doi.org/10.1152/jn.00628.2006

Zwaan, R. A. (2014). Embodiment and language comprehension: Reframing the discussion. *Trends in Cognitive Sciences*, *18*(5), 229–234. https://doi.org/10.1016/j.tics.2014.02.008

(*Appendix follows*)

Appendix

Table A1
General Scoring of Acceptable Responses in the Spatial Naming Test (SNT)

Test item	Score: 1 point	Score: ½ point
Part A – Static spatial relations		
Example A	to the left of	
A1	in; inside; within	
A2	to the right of	
A3	on; on top of	
A4	above; over	up high from the cube
A5	behind; at the back of	
A6	under; underneath; beneath; below	
A7	below; under; underneath; beneath	
A8	in front of	
A9	far; far to the left of; furthest left; away; distant left	
A10	near; near left; nearer; close(r) to	
A11	next to; beside; alongside; adjacent to; by the side; touching the left side; attached to the left side; adjoining the left side	near; nearer; nearest close, closer, closest
A12	between; in the middle of; in the centre of	
A13	among; amongst	
A14	in the middle of; in the centre of	
A15	opposite of; in front of on the other side	right in front; in front of
Part B – Dynamic spatial relations		
Example B.1	left	
B1	downwards; down	
B2	upwards; up	
B3	right	
B4	across; all along (from the left to the right)	right
Example B.2	towards, at	
B5	into; towards inside	towards; at
B6	out of; outside of	away from
B7	away from	
B8	around; round	
B9	over; above	
B10	under; underneath; beneath; below	
B11	through	
B12	onto; on top of	over and up
B13	down off; off of; away from the top of	from the top of
B14	along; past; parallel to; across the front; across right to left	left in front of; right to left of
B15	towards the side of; to the side of; next to; beside	towards; to; at; near

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