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The Influence of Semantic Relationships on Older Adult Map Memory

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Research has shown that nonspatial features, including semantic categories, can bias younger adults' spatial location memory. For example, semantically related information is remembered as being closer in space than semantically unrelated information (Hirtle & Mascolo, 1986). These findings suggest that verbal information is concurrently encoded with spatial information and influences younger adults' spatial information retrieval. The present study explored whether older adults have a similar dependency between verbal and spatial information. In Experiment 1, older and younger adults learned maps depicting semantically categorizable landmarks. After learning, participants completed landmark free recall and distance estimation tasks. Younger adults recalled more landmarks from semantically organized maps compared with older adults. In addition, younger adults were more likely to underestimate the distance between semantically related landmarks than were older adults. Experiment 2 examined whether supportive instructions would influence older adults' use of verbal information when learning maps. When given instructions that encouraged semantic feature use, older adults remembered more landmarks, were more likely to cluster landmarks semantically, and demonstrated biases in distance estimation based on semantic relationships. These findings suggest that verbal influences on spatial/map learning in older adults depends on explicit instructions or environmental support at encoding.

Keywords: spatial memory, maps, older adults, semantic categories

Spatial memory research often focuses on how accurately younger adults remember individual landmarks, relative landmark locations, and distances between landmarks (e.g., McNamara, 1986; Thorndyke, 1981; Tversky, 1993). This work has determined that memory for environments is influenced by both spatial (actual physical distance and layout) and nonspatial factors. For example, Merrill and Baird (1987) found that when asked to recall information from maps, participants organized recall using semantic hierarchies. Research has also demonstrated that spatial memory organization is influenced by superordinate spatial regions (McNamara, 1986), semantic similarity of labels attached to location (Hirtle & Mascolo, 1986; Merrill & Baird, 1987), and pictorial similarity (Hirtle & Kallman, 1988). For example, Hirtle and Mascolo (1986) demonstrated that semantic labels associated with spatial clusters biased memory for distances between locations on maps. That is, semantically related information was remembered as being closer than unrelated information. Similarly, Hirtle and Kallman found that participants judged similar pictures, such as a ball field and a golf course, as being closer together in a spatial array compared with dissimilar pictures. More recently, Maddox, Rapp, Brion, and Taylor (2008) found that social categories paired with specific locations also affected spatial memory. When participants learned the race of a business owner associated with the

business location, they estimated same-racially owned businesses as closer together compared with equidistant businesses owned by individuals of difference races. The conclusion drawn from this research is that mental representations of environments incorporate both spatial and nonspatial features. Toward that end, nonspatial features can bias memory for spatial features.

The goal of the present research was to examine how nonspatial features influence spatial map memory in older adults. We investigated memory for landmarks and distances between landmarks in order to examine nonspatial effects on map memory in an aging population. Previous research has consistently shown that younger adults show distortions in map memory that are a direct result of nonspatial features. A similar distortion demonstrated by older adults would suggest that verbal information similarly influences spatial memory in older and younger adults, and that older adults are able to develop map representations that integrate nonspatial features. This is a particularly interesting theoretical question because previous research in verbal learning and map learning suggest competing hypotheses.

Verbal learning research has demonstrated that older adults rely more heavily on perceived semantic relationships when compared with younger adults. For example, older adults remembered more studied words when those words were studied in the context of categorizable lists compared with unrelated lists (Fernandes & Grady, 2008). In addition, semantic relationships have been shown to bias or distort verbal memory to a greater extent in older compared with younger adults. When presented with semantically related lists, both older and younger adults extracted a shared representation relating items within a category (Tun, Wingfield, Rosen, & Blanchard, 1998). However, at retrieval, older adults were more likely to rely on that shared representation to guide recollective processes than younger adults. This reliance resulted

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in memory errors. That is, older adults were more likely than younger adults to report the shared representation as having been studied. When the shared representation was obfuscated, older adults demonstrated a reduction in these kinds of memory errors, but at a cost to correct memory (Thomas & Sommers, 2005). Taken together, these results suggest that older adults use the organizational support that semantic relationships offer to facilitate memory. Without this organization tool, older adults remember less information in episodic memory tasks.

Whereas research from the verbal episodic memory domain suggests that older adults will use semantic information to learn maps, spatial/map learning, processing speed, and working memory, research suggests an alternative hypothesis. Specifically, fluid cognitive resources, as defined by Baltes, Lindenberger, and Staudinger (2006) as speed of information processing and working memory capacity, have been shown to be instrumental for efficient map learning. As evidence, visuospatial working memory span correlates with map drawing skills (Coluccia, Bosco, & Brandimonte, 2007). In addition, participants with higher Corsi Block Test scores remembered route descriptions better than participants with lower scores (Pazzaglia & Cornoldi, 1999). More recently, Coluccia (2008) demonstrated the direct relationship between working memory and map learning. Engagement in a spatial secondary task impaired memory for landmark locations and specific routes within maps.

Older adults have consistently demonstrated age-related deficits in speed of processing (Salthouse, 1994) and in working memory (Bopp & Verhaeghen, 2005; Hasher & Zacks, 1988; Salthouse, 1994; Verhaeghen & Salthouse, 1997). The burden placed on these fluid resources may be such that older adults will be unable or unlikely to spontaneously use verbal information during map learning. If the role of nonspatial factors, such as semantic information, on spatial learning requires fluid cognitive resources, then older adults may not learn and organize map information in the same way as younger adults. That is, semantic information may not assist in encoding of and later access to spatial information.

The present study investigated how older and younger adults remembered spatial layouts. Participants studied maps that contained landmarks divided equally into environment-specific semantic categories. Semantically related landmarks were either spatially clustered (organized) or spatially distributed (unorganized). We tested memory using landmark free recall and distance estimation tasks. Landmark free recall examined memory for nonspatial map features. Distance estimation was used to examine both memory for spatial information (i.e., distances) and the influence of semantic information on spatial memory. Based on findings from the verbal learning literature, we predicted that semantic organization would positively affect landmark retrieval in both older and younger adults. Both groups would remember more landmarks and would be more likely to group recall by semantic categories after studying organized maps. In addition, consistent with previous research (i.e., Hirtle & Mascolo, 1986; Maddox et al., 2008), we predicted that semantic information would distort spatial memory. In particular, we expected that distance estimates between semantically related items would be judged smaller than those between semantically unrelated items, regardless of how semantic information was organized on the map. However, we expected that this distortion would be more evident in younger compared with older adults, as the map learning task is

cognitively demanding. Alternatively, if map learning places too great of a burden on required cognitive resources, older adults may not demonstrate the interaction between spatial and nonspatial, or semantic, features found in younger adults. Thus, semantic organization would not benefit landmark recall nor would it distort distance estimation.

In two experiments, we examined map learning in older adults. In Experiment 1, older and younger adults were presented with semantically organized and semantically unorganized maps. Our interest was in whether semantic organization would similarly influence landmark free recall and bias distance estimations in younger and older adults. Experiment 2 examined whether older adult performance could be improved through instructional support designed to facilitate semantic processing when presented with a spatial/map learning task.

Experiment 1

Participants

Twenty-three older and 24 younger adults completed this study. One older adult was dropped from this experiment for failing to comply with instructions. Younger participants were recruited from the Tufts Psychology Department Participant Pool; older adults were selected from a participant pool maintained by the first author. Older adults in this pre-established pool were screened for cognitive impairment with the Mini Mental State Exam (MMSE; Folstein, Folstein, & McHugh, 1975), provided information regarding general health, and gave a mood disorder history. Older participants were those that presented as cognitively healthy, not suffering from mood disorders, and not presently taking medication that might interfere with cognitive functioning. The MMSE was administered during initial screening and immediately preceding testing in the present experiment. Only older participants who scored greater than 27 on the MMSE at the time of the experiment were included in the sample. Participants were either paid \$15 or given course credit for their participation. Additional demographic information is presented in Table 1. Older and younger adults did not differ in years of education, $t < 1$. Furthermore, gender did not affect performance on the dependent measures of interest.

Design and Materials

The experiment used a 2 (Semantic Organization: *Organized*, *Unorganized*) \times 2 (Age: *Older*, *Younger*) mixed factorial design, with Age serving as a between-participants variables and Semantic Organization as a within-participant variable. The order of the organization conditions (i.e., Organized and Unorganized) was counterbalanced across participants. Dependent measures included landmark recall accuracy, recall order, and distance estimation accuracy.

We created eight maps depicting four environments: an office supply store, a small town, a zoo, and a mall. Each environment contained 12 landmarks evenly divided between three perceptually distinct sections delineated by paths. The landmarks could be classified into three environment-specific semantic categories. For example, the Small Town map included categories of Public Places, Religious Places, and Residences. Pretesting insured proper location categorization for each environment. Of the two

Table 1
Demographic Information for Experiments 1 and 2

Variable	Age	Education	Handedness		Gender	
			Right	Left	Male	Female
Experiment 1						
Younger	19.2 (1.5)	13.7 (1.6)	22	2	10	14
Older	74.4 (6.2)	15.1 (3.1)	20	3	12	11
Experiment 2						
Older	76.5 (5.2)	14.4 (2.4)	82	17	32	67

maps for each environment, one had semantically related landmarks randomly dispersed (unorganized map) and the other had them clustered within a section. The maps contained systematically named paths/streets and each map used a different naming convention (seasons/weather, alphabet letters, numbers, or colors). Maps were printed on 8.5" × 11" sheets of paper. Map presentation was counterbalanced across participants such that 12 younger and 12 older adults studied each environment.

Preliminary analyses confirmed that the different environments did not yield differences in any of the dependent measures of interest. Specifically, a separate group of 20 younger adult participants at Tufts University completed a sorting task in which they were presented with 120 landmark labels and asked to sort into as many categories as they saw fit. All participants developed 24 categories. Only landmark labels that fell into those 24 categories were included in the experiment. A hierarchical cluster analysis (Johnson, 1967) was performed to determine clusters of four or

more items for use in the experiment. A single-linkage solution resulted in the 24 predicted clusters. An example of an organized and unorganized map can be seen in Figure 1.

Procedure

Instructions informed participants that they would study maps. Following study, memory for information contained in the maps was assessed. For each map, participants were instructed to "Pay attention to the general layout of the map as well as the locations of landmarks relative to other landmarks." Before beginning the experiment, participants were presented with one map to orient them to the stimuli and to allow for practice on the distance estimation task. Participants estimated the Euclidian distance between 5 practice landmark pairs by moving a Graphic User Interface (GUI) slider. Sliders are useful controls for choosing a value in a range of values.

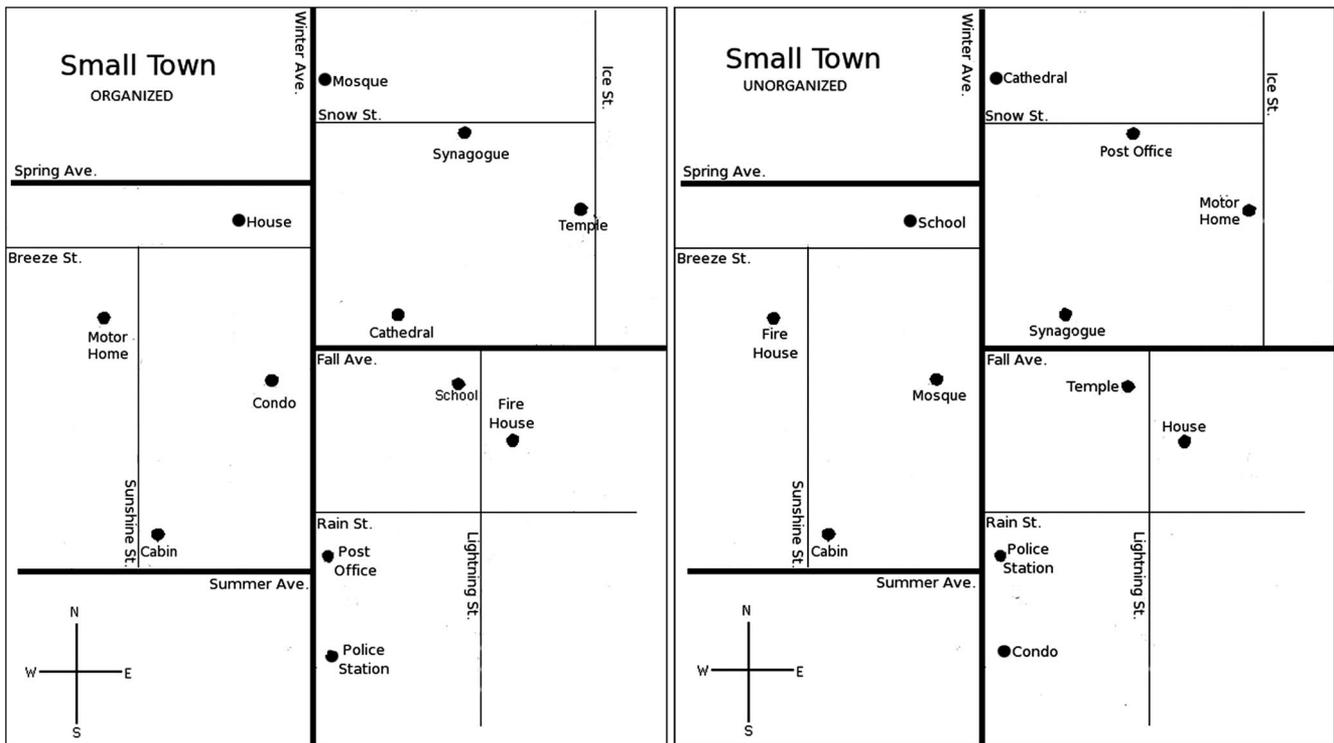


Figure 1. Sample organized and unorganized map of a small town.

After practice, participants studied two of the possible eight maps, one organized and one unorganized. Participants were instructed to learn the layout and relative locations of landmarks within an environment (Taylor, Naylor, & Chechile, 1999). To aid in map study, participants listened to narratives describing the general map layout and relative landmark locations. Narratives were based on those used in prior map learning research (i.e., Taylor & Tversky, 1992; Brunyé & Taylor, 2008). Descriptions conveyed perspective organization, vantage point, and spatial terminology. In addition to the locative information, each description contained nonlocative information that provided elaborative details about the environments. Narratives were approximately 350 words in length and were designed to aid encoding of all elements within a map.

Following each map study phase, participants completed a landmark free-recall test and then estimated distances between landmark pairs. Both tests were completed in a self-paced manner. For landmark free-recall, participants listed as many of the studied landmarks as they could in any order. For distance estimations, participants saw 9 same-category and 9 different-category landmark-landmark pairs, randomly presented. They estimated the Euclidian distance between the landmarks by moving, with a mouse, a computer based GUI slider. Participants then repeated the procedure for a second map with a different organization condition than the first. After testing of the second map, participants completed the demographic questionnaire that assessed age, gender, education, handedness, and handedness of immediate family members. The questionnaire also asked whether participants prefer a verbal description or a map when getting travel directions. Finally, participants rated their general memory ability using a 1 (*poor*) to 7 (*excellent*) Likert scale. Neither map preference nor assessment of general memory ability impacted the results, and will not be discussed further.

Results

Landmark Recall

A 2 (Age: Younger, Older) \times 2 (Organization: Unorganized, Organized) analysis of variance (ANOVA) performed on average landmark free recall found main effects for both Age, $F(1, 45) = 17.62, p < .01$, and Organization, $F(1, 45) = 23.56, p < .01$. As can be seen in Table 2, older adults ($M = .59$) recalled fewer landmarks than younger adults ($M = .77$). In addition, participants recalled more landmarks when maps were semantically organized ($M = .74$) as opposed to unorganized ($M = .63$). Finally, Age interacted with Organization, $F(1, 45) = 7.42, p < .05$. Younger adults benefitted more from map organization than did older adults, $t(23) = 5.10, d = 1.38$. In fact, map organization did not affect older adult performance in the landmark recall task, $t < 1$.

Organization can be considered one of the most effective tools to improve free recall in the absence of external support (i.e., cue). Experimental studies on clustering and recall quantify the spontaneous use of organization strategies by computing clustering indices associated with different organizing properties (e.g., adjusted ratio clustering, ARC; Roenker, Thompson, & Brown, 1971). The ARC score assumes chance clustering to be 0 and perfect clustering to be 1 and is computed according to the following formula: $ARC = [R - E(R)]/[maxR - E(R)]$, where R is the total number of

Table 2
Means and SDs for Performance in Experiment 1

	<i>M (SD)</i>	
	Younger	Older
Landmark recall		
Organized	.86 (.17)	.62 (.16)
Unorganized	.68 (.04)	.57 (.16)
Semantic cluster: ARC values		
Organized	.62 (.49)	.29 (.55)
Unorganized	.08 (.46)	.16 (.71)
Spatial cluster: ARC values		
Organized	.62 (.49)	.29 (.55)
Unorganized	.20 (.41)	-.13 (.57)
Distance estimation: ARC values		
Organized same	-47.05 (23.29)	-21.42 (43.19)
Organized different	-0.64 (25.63)	-4.48 (38.76)
Unorganized same	-13.79 (22.66)	-15.98 (29.99)
Unorganized different	-20.00 (24.06)	-12.61 (31.33)

Note. ARC = adjusted ratio clustering.

category repetitions, maxR is the maximum possible number of category repetitions, and E(R) is the expected (chance) number of category repetitions (Roenker et al., 1971, p. 46). It adjusts for differences in the total number of items recalled, which is important considering that younger adults may recall more than older adults.

ARC analyses were performed for semantic-based and spatial-location clustering. Note that because landmarks were grouped by semantic categories in organized maps, spatial and semantic clustering could not be disentangled. To begin with, we performed a 2 (Age: Younger, Older) \times 2 (Organization: Unorganized, Organized) ANOVA associated with semantic clustering. We found a main effect of Organization, $F(1, 45) = 8.53, p < .001$. The ARC score was higher for organized maps ($M = .46$) compared to unorganized ones ($M = .14$). In addition, the interaction between Age and Organization was significant, $F(1, 45) = 4.45, p = .05$. Younger adults were more likely to cluster semantically when maps were organized compared with older adults, $t(46) = 2.53, d = .92$. For spatial clustering, we found main effects of Organization, $F(1, 45) = 26.32, p < .001$, and Age, $F(1, 43) = 13.39, p < .001$. Recall that with organized maps, the measure of spatial clustering was identical to the measure of semantic clustering. Therefore, the important comparison was between older and younger adults for unorganized maps. Younger adults were far more likely to cluster spatially ($M = .20$) compared with older adults ($M = -.13$), and confirmed by post hoc comparison, $t(45) = 2.91, p < .05$.

Distance

Distance estimation accuracy was calculated based on signed percent error, calculated by subtracting the actual distance between landmarks (actual) from participants' distance estimates (response), and dividing that score by the actual distance (actual). We then multiplied that value by 100, so Percent Error = [(Response - Actual)/Actual] \times 100. Negative values indicate underestimation, while positive values indicate overestimation. For each participant, we computed the mean percent error of same-category

and different-category landmark pairs within studied maps. A 2 (Age: Older, Younger) \times 2 (Organization: Organized, Unorganized) \times 2 (category: Same, Different) ANOVA found a main effect of Category, $F(1, 45) = 14.25, p < .001$. Participants more accurately estimated distances for ‘different category pairs’ ($M = -9.43$) as opposed to ‘same category pairs’ ($M = -24.56$). The interaction between Age, Organization, and Category was also significant, $F(1, 45) = 7.57, p < .05$. As Table 3 demonstrates, for unorganized maps, older and younger adults had a similar distance estimation bias, $t < 1$; however, for organized maps younger adults underestimated ‘same-category’ distances to a much greater extent than older adults, $t(46) = 2.54, d = .75$.

Discussion

Older adults were less influenced by semantic organization in maps than younger adults. Younger adults recalled more landmarks from semantically organized, compared with unorganized, maps. Semantic organization did not affect landmark recall in older adults. In addition, younger adults underestimated distances between landmarks from the same semantic category to a greater extent than those from different categories. Semantic organization did not affect distance estimation in older adults. While the findings in younger adults are consistent with preexisting literature (i.e., Hirtle & Mascolo, 1986), the findings in older adults are somewhat surprising. We expected that semantic organization of maps would affect some, if not all, aspects of older adults’ map memory. Research from the episodic verbal memory domain suggests that when semantic organization is apparent, older adults use a semantic-based strategy and improve memory. Semantic organization was apparent in the organized maps; however, landmark recall in older adults was unaffected by this map structure.

Older adults may not have been able to effectively use semantic organization in map learning, because of an age-related deficit in cognitive resources shown to be crucial for spatial learning. This resource deficit may have affected the ability to spontaneously engage in cognitive processes that directly related semantic labels to spatial representations. According to the environmental support

model (Craik, 1990) older adults may not spontaneously use processes that may assist memorization. In the context of Experiment 1, semantic information should assist spatial learning (cf. Hirtle & Mascolo, 1986), but only if participants have the available cognitive resources to concurrently encode, and note, the relationship among these elements. As map learning is likely dependent on working memory (Moffat, 2009), or fluid cognitive resources (Baltes et al., 2006), older adults may demonstrate deficits in concurrent encoding, in noting relations between spatial and nonspatial elements, and/or in using nonspatial elements to retrieve spatial information. These deficits may arise because such self-initiated processes are partially dependent on cognitive resources (Rabinowitz, Craik, & Ackerman, 1982).

Experiment 2 examined whether a deficit in self-initiated processes could account for the age differences in map memory found in Experiment 1. We compared three groups of older adults, one of which was given instructions identical to Experiment 1, and two groups that were given one of two supportive instructions. The first support type encouraged participants to utilize semantic relationships; the second type encouraged spatial grouping. The instructions were designed to provide additional external support to older adults. That is, these instructions were designed to guide older adults in using cognitive processes that they may not spontaneously recruit. Our goal was to determine whether memory for maps could improve in older adults if they were given external support at encoding that would encourage recruitment of potentially useful cognitive processes. The external support manipulation used in Experiment 2 is consistent with the environmental support model (Craik, 1990), which posits that older adults typically demonstrate a deficit in initiating processes and that deficit is magnified in cognitively demanding tasks. We chose not to test younger adults in Experiment 2, because the data from Experiment 1 clearly demonstrated that younger adult map memory was influenced by nonspatial elements. Our goal in Experiment 2 was to determine whether nonspatial elements could also influence older adult map memory. We were interested in whether older adults could initiate processes to concurrently encode and use nonspatial elements if

Table 3
Means and SDs for Performance in Experiment 2

	<i>M (SD)</i>		
	Standard	Spatial	Semantic
Landmark recall			
Organized	.62 (.17)	.64 (.15)	.94 (.08)
Unorganized	.60 (.15)	.65 (.19)	.76 (.14)
Semantic cluster: ARC values			
Organized	.27 (.68)	.15 (.58)	.70 (.32)
Unorganized	.15 (.82)	.27 (.39)	-.01 (.45)
Spatial cluster: ARC values			
Organized	.27 (.68)	.15 (.58)	.70 (.32)
Unorganized	-.15 (.56)	.40 (.53)	.11 (.35)
Distance estimation: ARC values			
Organized same	-22.87 (32.95)	-29.25 (30.71)	-51.42 (20.28)
Organized different	3.09 (32.95)	-8.52 (33.85)	-0.82 (23.41)
Unorganized same	-13.46 (25.73)	-12.88 (30.31)	-10.58 (23.85)
Unorganized different	-8.99 (25.73)	-17.00 (33.54)	-15.81 (23.86)

Note. ARC = adjusted ratio clustering.

given external support. We predicted that when given encouragement to use semantic information, older adults would show better landmark memory and increased distance estimation biases. We predicted that spatial instructions would not affect landmark recall, but would affect recall output as measured by ARC scores.

Experiment 2

Participants

Ninety-nine older adults participated in this study. We used the same recruitment and screening procedures as Experiment 1. Older adults were divided into three groups: standard instructions, semantic instructions, and spatial instructions. Each group received specific instructions designed to facilitate targeted processing.

Design and Materials

The experiment used a 2 (Semantic Organization: *Organized*, *Unorganized*) \times 3 (Instructions: *Standard*, *Semantic*, *Spatial*) mixed factorial design, with Instructions serving as a between-participants variable and Semantic Organization as a within-participant variable. The order of the organization conditions (i.e., *Organized* and *Unorganized*) was counterbalanced across participants. Dependent measures included landmark recall accuracy, recall order, and distance estimation accuracy. We used the same materials as in Experiment 1.

Procedure

Instructions informed participants that they would study a series of maps on which their memory would be later tested. For the Standard Instructions Group, participants were instructed to “Pay attention to the general layout of the map as well as the locations of landmarks relative to other landmarks.” For the Semantic Instructions Group, participants were instructed to “Pay attention to the general layout of the map as well as the locations of landmarks relative to other landmarks. Notice the semantic relationship among landmarks. Using semantic relationships may benefit memory for information on the map.” For the Spatial Instructions, participants were instructed to pay attention to the layout and landmark locations. In addition, they were instructed to notice spatial relationships among landmarks. They were informed that using spatial relationships could benefit general map memory. Before the experiment began, participants practiced using the GUI slider used to measure distance estimation. After practice, participants studied two of the possible eight maps, one organized and one unorganized. To aid map study, participants listened to narratives describing the general map layout. The narratives were identical to those used in Experiment 1.

Following each map study phase, participants completed landmark free recall and distance estimation. After testing of the second map, participants completed the demographic questionnaire that assessed age, gender, education, handedness, and handedness of immediate family members. Results were unaffected by gender, therefore, reported results are collapsed across this variable.

Results

Landmark recall. A 3 (Instructions: *Standard*, *Spatial*, *Semantic*) \times 2 (Organization: *Unorganized*, *Organized*) ANOVA performed on average landmark free recall found main effects for both Instructions, $F(2, 96) = 35.08, p < .001$, and Organization, $F(2, 96) = 15.51, p < .001$. Landmark free recall was better when participants were given semantic instructions as compared with standard, $t(64) = 8.62, d = 2.16$, or spatial, $t(64) = 7.18, d = 1.79$, instructions. As Table 3 demonstrates, there was no difference in landmark recall between the spatial instructions group and the standard instructions group. In addition, recall was better when participants studied organized maps ($M = .73$) compared with unorganized maps ($M = .67$). Finally, Instructions and Organization interacted, $F(2, 96) = 14.15, p < .001$. While semantic instructions resulted in better recall for both map types than the other instructions, the benefit of semantic instructions was much greater for organized compared with unorganized maps, $t(32) = 6.25, d = 1.53$.

ARC analyses examined semantic-based and spatial-location clustering. Note that because landmarks were grouped by semantic categories in the organized condition, the spatial and semantic clustering could not be disentangled. A 3 (Instructions: *Standard*, *Spatial*, *Semantic*) \times 2 (Organization: *Unorganized*, *Organized*) ANOVA was performed on ARC scores to examine semantic clustering. We found a main effect of Organization, $F(1, 96) = 9.04, p < .005$. Semantic clustering was greater when participants studied semantically organized maps ($M = .39$) compared with unorganized maps ($M = .14$). In addition, the interaction between Organization and Instructions was significant, $F(2, 96) = 9.98, p < .001$. As Table 3 demonstrates, participants who received semantic instructions were far more likely to recall landmarks from organized maps in semantic clusters than other groups of participants, [standard-semantic: $t(64) = 9.67, d = 2.33$; spatial-semantic: $t(64) = 10.35, d = 2.49$]. Participants who received spatial and standard instructions demonstrated statistically identical, though numerically different, cluster patterns as a function of map organization, $t_s < 1$.

To examine spatial clustering we performed a univariate ANOVA, with Instructions as the variable of interest, on spatial clustering associated with unorganized maps. Organized maps were not included in this analysis as semantic and spatial clustering were redundant. The analysis yielded a main effect of Instructions, $F(2, 96) = 10.93, p < .001$. Pairwise comparisons revealed that participants were more likely to cluster spatially after receiving spatial instructions than after receiving semantic instructions, $t(64) = 2.53, d = .43$, and after receiving standard instructions, $t(64) = 4.06, d = .99$.

Distance Estimation

We performed a 2 (Organization: *Organized*, *Unorganized*) \times 2 (Category: *Same*, *Different*) \times 3 (Instructions: *Standard*, *Semantic*, *Spatial*) ANOVA on distance estimation averages. Replicating Experiment 1, we found a main effect of Category, $F(1, 96) = 39.30, p < .001$. As Table 3 demonstrates, participants were more likely to underestimate distances between semantically related landmarks ($M = -23.41$) compared with semantically unrelated landmarks ($M = -8.01$). The interaction between Organization

and Category was also significant, $F(1, 96) = 85.67, p < .001$. Semantic relationship between landmark pairs had no impact on distance estimation when maps were unorganized; however, when maps were organized, participants were far more likely to underestimate the distance between semantically related landmarks compared with semantically unrelated ones. Finally, the interaction between Category, Organization, and Instructions was significant, $F(2, 96) = 8.83, p < .001$. When maps were unorganized, distance estimation between landmarks did not vary as either a function of semantic relationship or instructions. However, when maps were organized, participants who received semantic instructions were far more likely to underestimate the distance between pairs from the same semantic category, than participants who received standard, $t(64) = 4.24, d = 1.05$, or spatial, $t(64) = 3.46, d = .87$.

General Discussion

The present study demonstrated that both older and younger adults were influenced by semantic elements in spatial map learning; however, older adults required explicit direction to encode semantic features, whereas younger adults did not. Our younger adult findings are consistent with previous research (e.g., Hirtle & Mascolo, 1986; Pezdek & Evans, 1979) and support the conclusion that semantic information is encoded concurrently with spatial information. Our older adult findings suggest that support, or direction, at the time of encoding is required in order for older adults to encode and effectively use semantic features. This finding is discordant with the prediction that semantic organization alone should improve free recall of landmarks. While verbal learning literature has consistently demonstrated that older adult memory performance is enhanced when presented with semantically related lists, the present results demonstrate that the advantage of semantic organization may not directly transfer to conditions where semantic information is presented in the context of spatial arrays. In addition, Experiment 1 demonstrated that older adults were less likely to semantically organize recall than younger adults, and older adults were *less* biased in their distance estimates compared with younger adults, counter to our initial predictions. In Experiment 2, older adults did demonstrate increased semantic organization in recall output and were more biased in their distance estimation judgments when they received semantic instructions compared with standard instructions that did not explicitly direct them to attend to semantic elements.

Previous verbal learning research has demonstrated how older adults can effectively use semantic organization (Fernandes & Grady, 2008) and how semantic organization can distort memory (Tun et al., 1998; Thomas & Sommers, 2005). In the present research, we found that semantic relationships were less likely to influence spatial memory in older compared with younger adults (Experiment 1), and that semantic relationships influenced older adult spatial memory when instructions to attend to those relationships were given (Experiment 2). One reason for this finding is that the map learning task may be more cognitively demanding than standard list-learning. Several research findings have supported this conclusion and have demonstrated that older adults generally have more difficulty using maps than younger adults (for review see Moffat, 2009). For example, Wilkniss, Jones, Korol, Gold, and Manning (1997) found that older adults had more difficulty re-

drawing maps and effectively navigating compared with younger adults. Meneghetti, Fiore, Borella, and De Beni (2011) demonstrated similar age-deficits in map-drawing and also established a relationship between map learning and other spatial abilities. Furthermore, older adults have been shown to have access to fewer cognitive resources compared with younger adults (Park, 1999; Salthouse, 1996; Salthouse & Babcock, 1991; Schaie, 1994), and spatial abilities have been shown to decline with age (Dollinger, 1995; Salthouse, Babcock, Skovronek, Mitchell, & Palmon, 1990). The cognitive demands of map learning coupled with the established age deficit in available cognitive resources and spatial abilities, may have affected older adults' ability to use semantic organization at retrieval.

Retrieval models (e.g., Raaijmaker & Shiffrin, 1981; Wingfield & Byrnes, 1981) suggest that in free-recall tasks retrieval begins with a memory search for an appropriate retrieval cue, such as a category name. The search for a category name is thought to be an effortful process; however, once a name is generated, recall of category members is facilitated by free association (Ashcraft, Kellas, & Keller, 1976; Shuell, 1969; Wingfield & Byrnes, 1981). Thus, individuals who have cognitive resource deficits or are under cognitive load may have difficulty initially generating useful category names. In support of this hypothesis, research has demonstrated that depressed patients, who scored low on measures of executive function (similar to older adults), remembered fewer items and were less likely to cluster items categorically during free recall when categorized lists were presented in random order as opposed to a blocked presentation (Taconnat et al., 2010). In addition, older adults were more susceptible to memory interference from a divided attention task at retrieval when to-be-remembered items could have benefitted from semantic organization (Fernandes & Grady, 2008).

Experiment 1 results are consistent with the conclusion that appropriate retrieval cue extraction may be impaired in older adults in this cognitively demanding task. If older adults did not properly encode and/or did not automatically generate organizing retrieval cues, then landmark recall and landmark clustering would be unaffected by map organization. Furthermore, research has demonstrated that older adults' have more difficulty devising and implementing useful strategies (Erber, 1976; Thomas & Bulevich, 2005). However, when given specific and detailed instructions, improvements in older adults' memory and decision-making have been found (Thomas & Bulevich, 2006; Thomas & Millar, 2012). Results from Experiment 2 demonstrate that instructions can also impact older adults' memory for maps. That is, when older adults were explicitly encouraged to use semantic relationships, landmark recall improved, landmark output was more likely to be semantically clustered, and distance estimation biases resulting from semantic relationships emerged. When given support, older adults in Experiment 2 performed similarly to younger adults in Experiment 1. Thus, the present study suggests that with some direction older adults may be able to recruit processes that allow them to encode and use nonspatial elements when learning spatial information. This supports Craik's (1983, 1991) assertion that older adults require environmental support to better use available cognitive resources, particularly with more cognitively demanding tasks. The map-learning tasks used in the present study may require more cognitive resources than standard episodic verbal learning tasks. As such, older adults may require "environmental support" to

effectively encode and/or retrieve different spatial and nonspatial map elements.

Finally, the present results suggest that older adults are also less likely than younger adults to spatially organize map learning. With unorganized maps, younger adults recalled landmarks by spatial groups; older adults did not. As with semantic instructions, spatial instructions did affect landmark output in older adults. That is, after receiving spatial instructions, older adults were more likely to spatially group unorganized maps. As a whole, this study suggests that older adults do not spontaneously recruit strategies that could be beneficial in gathering both spatial and nonspatial information from maps, although they will with explicit direction. On the flip side, the weaker influence of semantic information in map memory resulted in more accurate distance estimates in older compared with younger adults. Thus, prior experiences and preestablished semantic relationships may aid the organization of new information, but also can distort the encoding and/or retrieval of that information. While the limited influence of nonspatial features on map memory does have advantages, without environmental support, older adults will acquire less information, and have less detailed memories of spatial layouts. Not only is this theoretically interesting, but practically, this means that older adults are less able to develop map representations that integrate cues demonstrated to be important in comprehending spatial instructions or directions, and in navigating their environments. Fortunately, our results demonstrate that older adults are able to learn information from maps. However, as with many cognitively demanding tasks, older adults require external, or environmental support to aid in map acquisition.

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