12-2009

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Article

Journal of Applied Gerontology
Volume 28 Number 6
December 2009 743-767

10.1177/0733464809332785
http://jag.sagepub.com

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Individuals create cognitive maps based on relationships between cues in the environment. Older individuals are often impaired in wayfinding, especially in environments that lack distinctive features. This study examines how working memory ability in older women is related to wayfinding performance in the presence of salient (distinctive, prominent) or nonsalient cues. The degree of salient cue complexity is also examined, thus leading to the hypothesis that salient, complex cues are important in wayfinding and that working memory capacity is related to wayfinding performance. The virtual computer-generated arena is used to test this hypothesis in 20 healthy older women in three different environmental cue conditions varying in salience and complexity. Data analyses indicate that older women perform best in salient cue conditions. A greater working memory capacity is related to improved performance in the nonsalient cue condition. These findings offer preliminary evidence that cue salience is especially important in wayfinding.

Keywords: *wayfinding; cues; landmarks; working memory; aging*

Manuscript received: July 19, 2008; **final revision received:** December 2, 2009; **accepted:** January 6, 2009

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Working Memory, Cue Salience, and Wayfinding in Older Women

Wayfinding, the ability to find one's way in the world (Passini, Rainville, & Marchand, 1998), is essential for independent functioning. Individuals who cannot find their way are at risk for getting lost, which can cause great personal distress (Chiu et al., 2004; Rowe, 2003). Wayfinding ability typically declines with age; older people prefer familiar to novel places and are slower and less accurate at finding their way in new environments and more likely to get lost than younger people (Moffat, Zonderman, & Resnick, 2001; Newman & Kaszniak, 2000). In addition, certain diseases of aging, most specifically mild cognitive impairment and Alzheimer's disease, are associated with wayfinding problems even in the early stages of disease (Chiu et al., 2004; deIpolyi, Rankin, Mucke, Miller, & Gorno-Tempini, 2007; Rowe, 2003).

Ultimately, the fear of getting lost combined with reduced wayfinding abilities may lead to decreased exploration and social engagement. Thus, strategies to maintain or improve wayfinding abilities are important to preserve independence under conditions of normal and abnormal aging.

Wayfinding Strategies and Cognitive Maps

Wayfinding is required in large-scale spatial environments, that is, three-dimensional areas that cannot be viewed in total from any one vantage point (O'Keefe & Nadel, 1979). People use a multitude of strategies in wayfinding, depending on their motivations, a priori knowledge of the environment, and cognitive abilities (Allen, 1999a, 1999b; Kirasic, 2000). When environments are new, individuals often use simple landmark navigation whereby they travel from one landmark to another. Related to landmark navigation is route navigation, which involves the association of learned turns and directions based on a series of landmarks. For example, individuals may travel the exact same route every day through a particular part of town. They know to expect certain landmarks and paths to occur sequentially among the route. Although this is an effective method of navigation, individuals may have a problem if they are rerouted for some reason or if a landmark is missing (Golledge, 1999).

The most comprehensive method of understanding such large-scale spatial environments is achieved by generating and remembering a mental image of the environment, a process termed *place learning* (Allen, 1999b; Jacobs, Thomas, Laurance, & Nadel, 1998; Skelton, Bukach, Laurance, Thomas, & Jacobs, 2000). For example, most people use place learning to initially learn and then recall a memory of their place of employment. They can find their office or work station from different locations in the building without using a map. In almost any circumstance they can problem solve to find alternative ways to get to their destination. This enduring, adaptive memory structure of a specific large-scale environment is called a *cognitive map* (Tolman, 1948). In essence, cognitive maps allow individuals to know where they are in space and how to navigate from one place to another in the most efficient way. Cognitive maps are not reliant on any one landmark or route; instead, individuals have a sense of *knowing* where they are and can function with great flexibility (Bures, Fenton, Kaminsky, & Zinyuk, 1997; DiMattia & Kesner, 1988; Golledge, 1999; Maguire, Burgess, & O'Keefe, 1999; McNamara & Shelton, 2003; O'Keefe & Nadel, 1978). As Jacobson (1998) stated, "Cognitive mapping is used in spatial choice and decision making in wayfinding and navigation, migration, environmental preferences for modes of transport, shopping, recreation, housing, and in learning new environments and maps" (p. 289).

Environmental Influences on Encoding Cognitive Maps

Although cognitive maps are well accepted in the scientific world (Allen, 1999b; Foo, Warren, Duchon, & Tarr, 2005; Golledge, 1992, 1999; Kirasic, 2000; Montello, 2002; Newman & Kaszniak, 2000), their composition has many different explanations. In sighted people, visual cues such as landmarks (Golledge, 1999) are important for all aspects of environmental learning and navigation (Caduff & Timpf, 2007). Tom and Denis (2004), for example, showed that individuals learn and remember landmarks easier than street names when learning a new route, possibly due to the visual image that landmarks facilitate. When people recall a cognitive map, it is clear that they do not remember every detail of the environment but only a small portion of the information available (Golledge, 1999).

Evidence suggests that salient (distinctive) cues are important for place learning necessary to develop a cognitive map, especially in aging. For example, older people do not recall previously learned environments as well as younger people when a number of cues are removed after learning trials (Newman & Kaszniak, 2000), a finding that shows an increased dependence on cues. In another study, Lipman (1991) used a slide presentation of an environmental route and required younger and older participants to remember critical cues; the older participants remembered fewer cues, and the cues they did recall were especially distinctive. These studies and others (Evans, Brennan, Skorpanich, & Held, 1984; Goodman, Brewster, & Gray, 2005) indicate that older adults have more difficulty learning new environments and may be more dependent on salient environmental cues than younger adults.

Caduff and Timpf (2007) also suggested that cues must be salient to be most effectively used for wayfinding and navigation. They further propose that overall salience is determined by three subsets of salience: perceptual, cognitive, and contextual. Perceptual salience refers to a cue's distinctive properties, that is, those properties that capture the observer's senses. Cognitive salience indicates that the observer has some experience or knowledge about the cue that makes it personally meaningful and, therefore, attended to. Contextual salience refers to the cognitive demands placed on individuals as they are navigating, that is, the type of wayfinding task and the amount of cognitive and physical resources demanded for that task.

Because aging changes sensory and place-learning mechanisms (Raz, Rodrigue, Head, Kennedy, & Acker, 2004), the quality of environmental cues may be especially important. Color, a specific aspect of visual cues, may be a critical cue property for place learning in aging. Older adults often have decreased visual acuity and contrast sensitivity (Faubert, 2002). Normally aging adults and those with dementia may benefit from the use of color in recognizing objects, perhaps due to these decreased visual abilities (Cernin, Keller, & Stoner, 2003; Wijk et al., 2002; Wurm, Legge, Isenberg, & Luebker, 1993). Color can improve the cue's degree of contrast with the environment and give additional sensory information about the cue. If used correctly, colorful cues can potentially help individuals at least in the early stages of landmark recognition and selection, which is one of the first steps in building a cognitive map.

The complexity of an environment is related directly to both perceptual and cognitive salience. We define complexity as the amount of information presented by the environmental cues. Visual cues, for example, which have properties such as geometric shape, color, texture, and size, and which can be numerous or few in any given environment (Wood & Dudchenko, 2003; Young, Choleris, & Kirkland, 2006), contribute to environmental complexity or simplicity. A complex environment might contain many cues with multiple colors, textures, and patterns. A simple environment might contain only black and white cues, with no patterns or textures. Kaplan and Kaplan (1982) stated that environments must have some degree of complexity or diversity to be engaging and invite exploration. Complex environments may capture the attention of the wayfinder and also create a sense of meaning as a result of increased exploration and familiarity. Because many environments inhabited by older people lack complexity (e.g., the long white hallways of many hospitals and senior residential facilities), this concept may be more significant than it at first appears in the development of cognitive maps among older adults.

Working Memory and Wayfinding

To understand salience one must consider the cognitive abilities of the user as well as the demands of the wayfinding task (Caduff & Timpf, 2007). Working memory, a basic cognitive function, is involved in attending to, selecting, and remembering relevant environmental information. This information, in turn, will be used by the hippocampus to generate a cognitive map (Kirasic, Allen, & Haggerty, 1992). Working memory is thought to have a limited storage capacity, meaning that there is a limit to the number of items (verbal or spatial) that individuals can hold in working memory at any one time (Baddely, 1992; Reuter-Lorenz et al., 2000).

Numerous studies have found a decrease in working memory capacity during aging (Jonides et al., 2000; Reuter-Lorenz et al., 2000; Salthouse, Mitchell, Skovronek, & Babcock, 1989). Decreased working memory capacity means that a smaller amount of environmental information is taken in and less information is eventually encoded. The result is a less detailed and informative cognitive map. In addition, with age there is a recognized decrease in the ability to inhibit competing distractions and to focus on relevant information; this may further confound a decline in working memory (Braver & West, 2008). Competing stimuli can be external (e.g., noise or crowds) or internal (e.g., anxiety or preoccupation with other concerns). Older individuals, especially those who are frail, may have more internal distractions due to decreased motor and sensory abilities and increased concerns with safety. It is realistic to expect that older adults will tend to ignore nonsalient cues or will not find them helpful for wayfinding. This decreased ability to focus on or retain nonsalient cues could lead to poor learning of new environments or decreased recognition of previously learned environments.

These findings suggest that demanding environments—ones with confusing information or a lack of salient cues—may be especially difficult for older individuals to learn due, in part, to a limitation in working memory capacity. Environments with many competing distractions may also be difficult for older individuals to learn due to a decreased ability to inhibit irrelevant information. Allen (1999b) suggested that the use of a cognitive map requires updating one's position based on landmarks and other environmental information and that an increased number of landmarks and the number of connections between them may place a greater demand on working memory.

Thus, working memory and cue salience appear to be closely interrelated in the process of learning environments. To encode a cognitive map, cues must be first attended to, then recognized, and finally selected. In aging, when working memory capacity declines along with a decreased ability to focus on relevant information, an increased reliance on salient cues may occur. In fact, evidence suggests that older animals rely more on salient environmental information than their younger counterparts and are less likely to recognize subtle environmental changes (Lamberty & Gower, 1991; Tanila, Sipila, Shapiro, & Eichenbaum, 1997). However, few studies have examined the impact of cues and working memory ability on wayfinding in older humans.

Study Purpose

The purpose of this study was to increase understanding of how working memory ability and the salience of environmental cues are related to wayfinding performance. In light of the decrease in working memory capacity in aging, there may be a fine balance between the amount and type of information that is useful in place learning and the creation of cognitive maps versus that which is irrelevant or overwhelming. Thus, our study aims included the following: (a) to determine whether salient cues enhance wayfinding performance in older adults, (b) to determine the relative contribution of color and complexity to the concept of cue salience, and (c) to determine the contribution of working memory in place learning and cue salience. We hypothesized that (a) older women would show the best place learning when cues were salient and complex (colorful, varied), and (b) working memory capacity would be related to wayfinding performance, especially when cues were nonsalient.

Methods

Participants

This study was a part of a larger study in which place-learning performance was compared in healthy older and younger women (Davis, Therrien, & West, 2008). In both we included only women because some studies have

Table 1
Inclusion Criteria

Female
Living independently
Age 65 years or older
Intact vision (20/40 or better with correction)
Normal cognition (mini mental-status examination within normal limits for age and education, digit span forward test >5
No history of neurological or psychological problems
Not taking medications that could affect cognitive function
Not taking hormone replacement
No history of any musculoskeletal disorder or disabling condition that would inhibit use of a joystick
No self-reported problems with vertigo

shown that males and females have differing spatial abilities, with females often worse at place learning than males (Gron, Wunderlich, Spitzer, Tomczak, & Riepe, 2000; Veng, Granholm, & Rose, 2003). In addition, place learning is particularly important for aging women because many are widowed, live alone, and must rely on their own abilities to get around in the world (Federal Interagency Forum on Aging Related Statistics, 2008).

The sample included 20 women recruited from senior centers and independent living residences over a 7-month period. Criteria for inclusion are listed in Table 1. Only 20 women were selected based on an initial power analysis of a small sample of 6 older women. The women were in the age group of 65 to 90 years (mean = 79 + 6.35 years) and were well educated (mean = 15.2 + 0.54 years of education), Many of the women were single (n = 13, 65%) and widowed (69% of the single women). Subjects were most likely to live in a senior independent living setting, such as an apartment or condominium (n = 12, 60%). Subject characteristics are displayed in Table 2. All subjects volunteered to be in the study and signed an informed consent form.

Procedures

The study, including the informed consent form, was approved by the university's human subjects review committee. Individuals who responded to advertisements were screened over the phone for entry criteria and interest. After this initial screening, an appointment was set with the investigator at the place of recruitment (a senior center or apartment

Table 2
Subject Characteristics

Demographic Variables	*N* = 20
Age, years, *M* (*SEM*)	79 (6.35)
Education, year, *M*, (*SEM*)	15.2 (.54)
Single marital status *n* (%)	13 (65%)
Living status—lives alone *n* (%)	13 (65%)
Living setting	
House/apt/condo *n* (%)	8 (40%)
Senior apt/condo *n* (%)	12 (60%)
# of Medications, *M* (*SEM*)	3.9 (.68)
DSB, *M* (*SEM*)	5.05 (.29)
Corsi block, *M* (*SEM*)	5.25 (.25)
MMSE, *M* (*SEM*)	29.65 (.18)

Note: DSB = Digit span backwards; *M* = mean; *SEM* = standard error of measure; *MMSE* = mini mental-status examination.

complex) in a private room, and the study was explained to each potential participant. Those who wished to participate signed the consent form and were then asked to fill out a demographic survey. Next, the Snellen Eye Chart test, digit span test, corsi block test, and MMSE were administered. Then, a second appointment was scheduled within 1 week to complete the place learning portion of the study.

Instruments

The Computer-Generated Arena.[1] The Computer-Generated (C-G) Arena (Jacobs, Laurance, & Thomas, 1997) was used to measure place learning ability. This task is modeled after the gold standard Morris Water Maze task that is used to measure place learning in rodents, in which rodents are required to find a hidden platform in a pool of opaque water (Morris, 1983). Similarly, the CG Arena is a computerized virtual reality program that displays an arena enclosed by four walls. Subjects visually move about the arena by using a joystick so that their view changes as they rotate around the arena. The place-learning task required the subjects to find a hidden platform on the floor of the arena. To do this, subjects must use the constellation of cues that are presented visually on the walls of the arena. When subjects find the hidden platform and pass over it, the platform becomes visible and makes a loud clicking noise. The platform remains in the same location in relation to the environmental cues between trials. Thus, place learning occurs when subjects learn the location of the hidden platform by using only the cues.

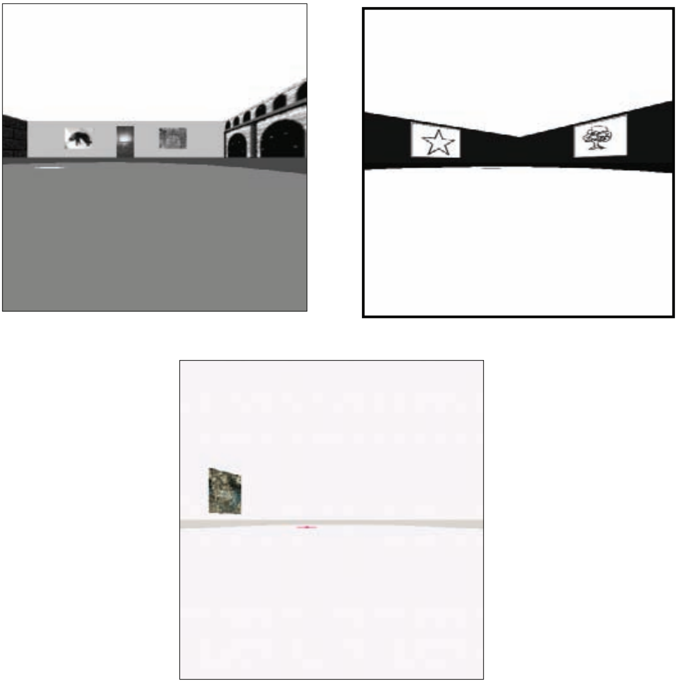
The C-G Arena has been tested for construct validity. Jacobs and colleagues (1997) showed that individuals can learn the location of the hidden target in the C-G Arena by using only constellations of cues distal to the arena; as cues are systematically removed, place learning occurs provided at least two cues are present. These findings are consistent with findings based on the theory of cognitive maps, which indicates that people learn cognitive maps based on the relationship between environmental cues (O'Keefe & Nadel, 1978). The C-G Arena place-learning test shows differences in individuals who have head injuries (Skelton et al., 2000) and in older individuals when compared to younger (Laurance et al., 2002). As predicted by the cognitive map theory, the hippocampal formation shows activation in fMRI when individuals perform place-learning tasks in the C-G Arena (Thomas, Hsu, Laurance, Nadel, & Jacobs, 2001).

Procedure for C-G Arena testing. Participants were taught how to use the joystick and given time to become familiar with the C-G Arena software until they felt comfortable. During the pretest session, all participants had to demonstrate proficiency with the joystick, as evidenced by successful movement to a visible target within 30 s.

Place learning is measured in the C-G Arena by computing (a) the time it takes the individual to find the hidden target and (b) the initial directional heading error taken while searching for the target. Time to find the hidden target was measured in seconds to a maximum of 180 s (the length of each trial). Directional heading error was calculated by measuring the angle formed between the initial direction the participant took and the actual direct path leading from the starting point to the target. The heading error could range from 0 degrees (meaning the subject had no error and headed directly toward the target) to 180 degrees (meaning the subject headed directly away from the target). It is expected that when individuals are learning the location of the target in relation to the environmental cues, the time to find the target and directional heading error would decrease over trials.

Cue conditions. To examine the effect of environmental cues, subjects were tested under three cue conditions with varying degrees of saliency and complexity (see Figure 1). These cue conditions were labeled nonsalient, simple salient, and complex salient.

Figure 1
Cue Conditions



Note: These pictures show one view of the complex salient (top left), simple salient (top right), and nonsalient (bottom) cue conditions. The participant used a joystick to move around and see a 360-degree view of the four walls, floor, ceiling, and cues. Cues in the complex salient cue condition were colored and textured, cues in the simple salient cue condition were bold black and white drawings, and cues in the nonsalient cue condition were two abstract gray and white designs.

The *nonsalient* cue condition had had white walls, floor, and ceiling and only two abstract grayscale cues. The lack of recognizable and meaningful cues as well as a lack of engaging colors and patterns gave this cue condition little perceptual or cognitive salience. The *simple salient* cue condition was a black and white room with four bold, black and white images: a star, a kite, a boat, and a tree. Though this cue condition had easily recognizable cues and cognitive salience (meaning), it lacked perceptual salience due to the absence of any engaging color or pattern. The *complex salient* cue condition was a colorful room with textured walls of brick and concrete and several life-like colorful cues such as a picture of a black cat lying on a rug, bricks, arches, and columns. Thus, both cognitive and perceptual salience were present in this cue condition due to the engaging colors and patterns and the meaningful (familiar) cues.

Subjects were instructed that the goal of the task was to locate the hidden target as fast as possible. The subjects completed 6 trials in each of the 3 cue conditions. Each trial lasted either until the platform was found or until 3 min had elapsed. If participants were not successful in finding the platform prior to the 3-min trial time limit, they were shown the platform location by the examiner. Subjects rested for 1 min between trials and 10 min between each cue condition. To avoid testing effects, we incorporated incomplete counterbalancing of the order of cue conditions during testing (Lander, 1998).

Working memory. Verbal working memory and visual–spatial working memory were tested. The Digit Span Backwards (DSB) test (Weschler, 1987) was used to assess verbal working memory. To administer the DSB, an examiner read a series of numbers and the subject repeated the numbers back in reverse order. The examiner added a number with each successful series until the subject was unable to repeat a series of numbers two times. In performing the DSB test, individuals must first remember the numbers in order, hold these numbers in working memory, and then repeat them in reverse order. Test–retest reliability of the DSB test ranges from .66 to .89 and has been shown to be sensitive in identifying deficits in individuals with brain injury. (Lezak, 1995)

The Corsi Block-Tapping Test (CBT) was used as a measure of visual–spatial working memory. The CBT uses 10 blocks of varying height that are attached randomly to a board. The examiner taps 2–10 blocks in a planned sequence. The subject is required to repeat the sequence. Each time the subject is successful, a longer sequence (up to 10 blocks) is tested. The score is the number of blocks the subject is able to repeat without error. This test has been shown to be sensitive to brain injury, Alzheimer's disease, and other neurological disorders (Berch, Krikorian, & Huha, 1998; Corsi, 1972).

Analysis

The independent variables in the study included (a) *age*, (b) *cue condition*, (c) *trial*, (d) *DSB scores*, and (e) *CBT scores*. The dependent variables were the time it took to find the hidden target (*time to target*) and *directional heading error*. There were a total of 360 observations (3 cue conditions with 6 trials each for 20 subjects) for the dependent variables.

Linear mixed modeling (LMM) was used to determine the effects of the independent variables on the dependent variables. LMM provides for a functional analysis of learning over time (meaning that *trial* can be used as a continuous independent variable) and emphasizes individual differences, which is appropriate for this study. LMM can be thought of as linear regression modeling, with the additional flexibility of modeling between-subject variance via the inclusion of random subject effects (Krueger & Tian, 2004).

Separate LMMs were estimated for the dependent variables of *time to target* and *directional heading error*. Multivariate Type III analyses were used to estimate the effects of each term in the models, taking the effects of the other terms into account. In the LMMs, the intercepts and trial effects were allowed to vary between the subjects (to allow for between-subject variance in performance over time). Also, the variance of the errors associated with the measures on the dependent variable was allowed to vary from trial to trial, as greater variance was observed at some trials than others.

Main effects and two- and three-way interactions between the independent variables were estimated and tested for significance in each model. Selected terms were removed one at a time, starting with the higher-order interactions, until the most parsimonious model with all terms significant was achieved. Significance of fixed effects and the model as a whole was set at $p < .05$, and all analyses were performed by using procedures in SPSS Version 14.0 (SPSS, Chicago, IL).

Results

Age was not significant in any model and was dropped from the analyses for both cue salience and working memory.

Cue Salience

For both dependent variables, *time to find the target* and *heading error*, the best place learning occurred in the salient cue conditions and the worst in the nonsalient cue condition. For *time to target* (Table 3), trial-squared interacted marginally with cue condition, $F(2, 213) = 2.82$, $p = .062$, and trial-cubed had a significant interaction with cue condition, $F(2,213) = 4.25$, $p = .015$. Figure 2 displays the estimated trends based on the fitted mixed

Table 3
Type III Tests of Fixed Effects for Time to Target

Variable	Degrees of Freedom	F	Significance (p Values)
Intercept	1, 118	53.193	<.0001
Cue condition	2, 200	2.982	.053
Trial	1, 218	5.099	.025
Trial^2	1, 213	4.696	.031
Trial^3	1, 213	4.335	.039
DSB	1, 18	2.938	.104
Trial × Cue Condition	2, 216	1.614	.202
Trial^2 × Cue Condition	2, 213	2.817	.062
Trial^3 × Cue Condition	2,213	4.252	.015
DSB × Cue Condition	2, 261	7.936	<.0001

DSB = Digit Span Backwards. Trial was squared and cubed. As seen statistically here in the Trial 2 and Trial 3 × cue condition, there are differences in learning curves related to cue condition. Graphically (see Figure 2), there is a cubic trend in the simple salient cue condition.

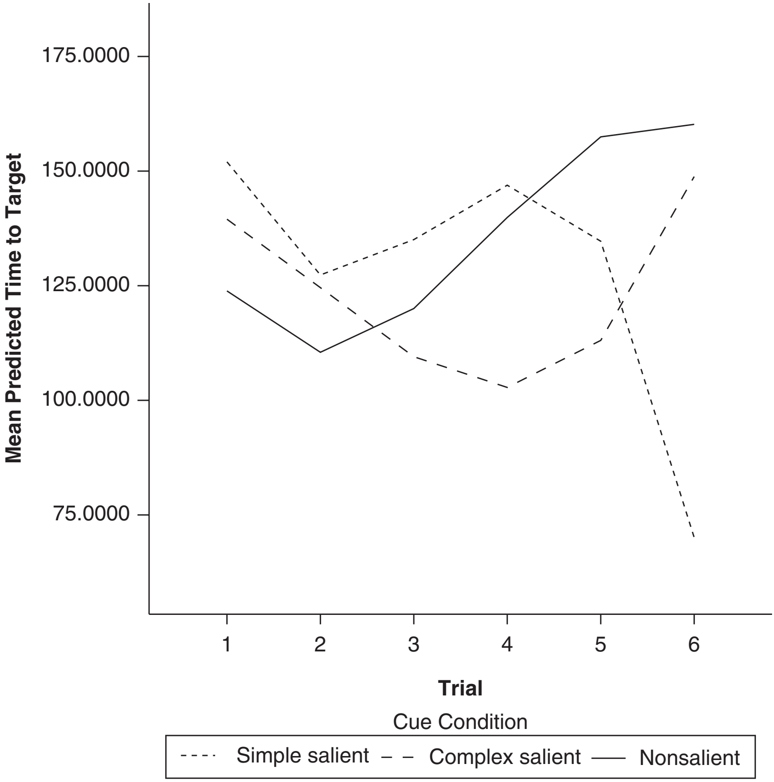
model. As expected, the *times to target* were highest (worst) in the nonsalient cue condition. Although the mean *time to target* was overall the fastest in the simple salient cue condition, the steepest (best) learning curve—as seen by the differences between Trials 1 and 6—was seen in the complex salient cue condition. Thus, the overall best learning over time was seen in the complex salient cue condition, although the fastest *time to target* overall (mean) was in the simple salient cue condition.

Likewise, for the dependent variable of *heading error* (Table 4), there was a significant effect of cue condition, $F(2, 336) = 4.27$, $p = .003$. The least *heading error* overall (meaning the best performance) was in the simple salient cue condition, and the most error was in the nonsalient cue condition. There was also a significant main effect of trial, $F(1,218) = 3.818$, $p = .052$, with an improvement in *heading error* over trials in all cue conditions. Trial did not interact significantly with cue condition when considering directional *heading error* (Figure 3). Thus, for both *time* and *heading error*, the worst performance was in the nonsalient cue condition and the overall best performance was in the salient cue conditions.

Working Memory

The CBT was not a significant predictor of performance for either *time to find the target* or *heading error* and was dropped from the analysis. However, the DSB had an interactive effect for both dependent variables.

Figure 2
Mean Predicted Values for Time to Target



This graph shows the predicted values holding DSB at the mean (5.0). There was a significant effect of cue condition, $F(2, 200) = 2.982$, $p = .053$. Note the cubic trend for the simple salient cue condition. Although learning started out better in the first four trials in the simple salient cue condition, by the final trials subjects were predicted to perform better in the complex salient cue condition. Statistically, the complex salient cue condition had a steeper learning curve.

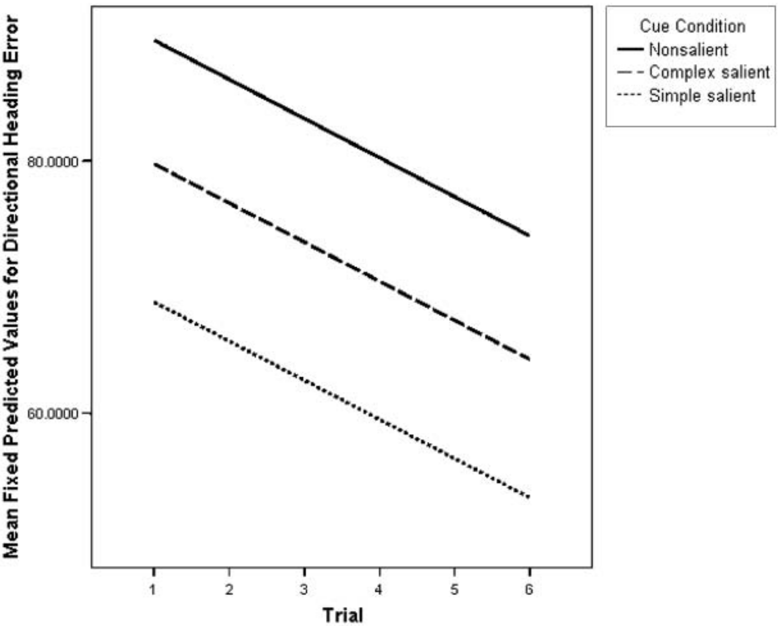
DSB interacted with cue condition for *time to target*, $F(2, 261) = 7.936$, $p < .0001$; higher scores (indicating better working memory) were associated with a decreased *time to target* in the nonsalient cue condition (Figure 4). There was no significant interaction of DSB with either of the salient cue conditions. For *heading error*, DSB interacted with *trial*, $F(1, 218) = 6.532$,

Table 4
Type III Tests of Fixed Effects for Heading Error

Variable	Degrees of Freedom (Numerator/Denominator)	*F*	Significance (*p* Values)
Intercept	1, 163	3.332	.070
Cue condition	2, 342	5.823	.003
Trial	1, 218	3.818	.052
DSB	1, 163	3.053	.082
DSB × Trial	1, 218	6.532	.011

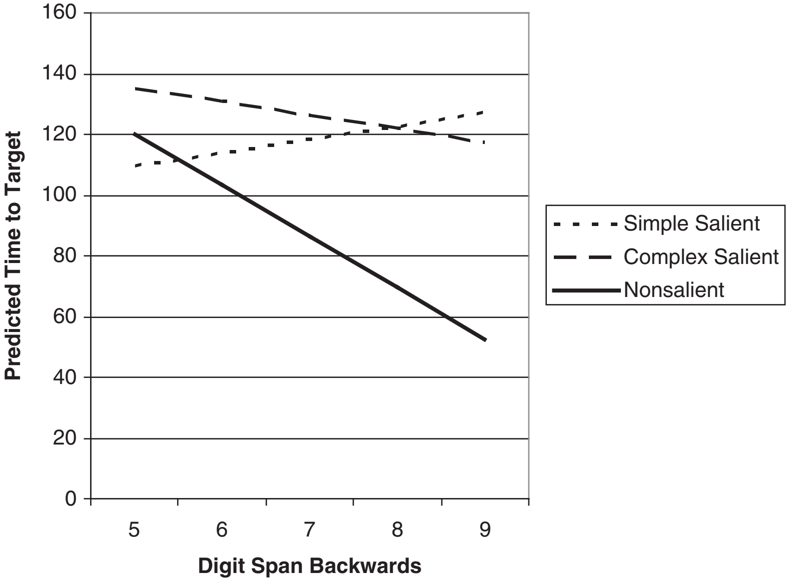
DSB = digit span backwards. Note that DSB interacted with trial, suggesting that those with better working memory had a steeper learning curve.

Figure 3
Mean Predicted Values for Directional Heading Error



This graph shows the significant interaction between *directional heading error* and *trial* holding values of *DSB fixed*, $F(1, 218) = 3.818$, $p = .052$, indicating learning over time. The effect of cue condition, $F(2, 342) = 5.823$, p = .003, is seen with the nonsalient cue condition showing the highest (worst) *heading error* and the simple salient showing the least *directional heading error* across trials.

Figure 4
Interaction of Digit Span Backwards and Cue Condition for Time to Target



This figure shows the interaction of DSB with cue condition: $F(2, 261) = 7.936$, $p < .0001$; trial was held fixed at Trial 3 for this graph). The nonsalient cue condition shows the greatest effect of DSB, with a much faster time to find the target predicted for those with higher (indicating better working memory) scores. The relationship between DSB and cue condition for the simple and complex salient cue conditions was not significant.

$p = .011$; higher scores were related to steeper (better) learning curves in all cue conditions. Thus, verbal working memory as measured by the DSB scale affected place learning for both *time to target* and *heading error*. Better working memory related to improved *time to target* in the nonsalient cue condition and less *heading error* overall.

Discussion

This study examined the effect of varying degrees of cue salience on place learning and the relationship between working memory and cue salience in older women. The most important finding from this study was that place learning in the virtual environments was affected by the types of cues present and the working memory ability of the older women. The subjects relied on perceptually and cognitively salient cues to learn new environments; place learning and wayfinding ability were poor in the simulated nonsalient cue condition. Better working memory capacity was positively related to place learning.

Although few investigators have examined the effects of cues on place learning, there is some support for the importance of saliency in helping older adults learn and remember locations. For example, previous studies have shown that older individuals have more difficulty learning novel environments and have an increased reliance on landmarks (Evans et al., 1984; Lipman, 1991). The poor performance of our subjects in the nonsalient cue condition supports the need for more salient cues as an intervention to modify environmental information and improve wayfinding ability (Passini et al., 1998).

Many environments that older people are exposed to, such as senior aggregate living residences and health care facilities, often have nonsalient characteristics (e.g., long white hallways and equally spaced doors) and are especially difficult for wayfinding (Passini, Pigot, Rainville, & Tetreault, 2000; Webber & Charlton, 2001). This lack of salience can have profound consequences. For example, there is evidence that nursing home residents with intact cognition often do not recognize common areas within their own residence and show an overwhelming preference for their own rooms (Weber, Brown, & Weldon, 1978), perhaps because they are fearful of getting lost. Likewise, Passini and colleagues (2000) showed that nursing home residents with dementia are often unable to find their way from one place to another within their facility. This lack of environmental knowledge can lead to a lack of social engagement. In fact, nursing home residents have been shown to spend approximately 85% of their time on their own without any social interaction (Voelkl, Winkelhake, Jeffries, & Yoshioka, 2003). Thus, a better understanding of how individuals use salient cues to perceive, learn, remember, and navigate environments is needed for those with and without cognitive deficits.

The data also show a difference in learning ability based on the complexity of the salient cues. Initially, subjects performed faster overall, and the overall means for *time to target* and *directional heading error* were less in the simple salient cue condition. Yet when looking at the graph of performance and the effect of trial on *time to target*, the quadratic learning curve noted in the simple salient cue condition showed worsening performance in the last two trials.

Graphically and statistically, the complex salient cue condition had the most dramatic and consistent downward (improved) learning curve, and subjects performed better with respect to time by the fifth trial. Given that this was on the first day of exposure to the C-G Arena, the steeper curve over all trials indicates better, sustained learning over trials. Whether this learning curve would be sustained during repeated exposures over several days is unknown. Because this study only looked at initial learning—which is typically highly variable—further research looking at learning over days would be beneficial.

Caduff and Timpf's (2007) salience model suggests an explanation for the difference in learning curves between the simple and complex salient cue conditions. In one sense, black and white, high-contrast drawings may be bold and memorable and thus have cognitive salience because they have meaning. However, in a room with only black and white drawings as cues, the ability to distinguish among and remember the cues may not be possible without considerable effort. Also, the lack of visual interest in the simple salient cue condition may have discouraged engagement and exploration of the C-G Arena. In contrast, the complex salient cue condition, with its colorful, textured cues and surroundings, may have been sufficiently engaging to encourage exploration. Exploration in the initial trials may have actually increased the time spent in the cue condition. However, this increased exploration could have improved the subjects' environmental knowledge, which would have resulted in superior learning over time with respect to finding the hidden target.

Furthermore, cognitive salience may be easier to achieve with realistic colored pictures and objects than with simple line drawings because color and texture are more life like, and color has been shown to enhance object recognition in aging (Wijk, Sivik, Steen, & Berg, 2001). By using more meaningful cues, the complex salient cue condition may have provided more information from which to generate a detailed cognitive map, which would have resulted in better learning after a longer exposure.

Surprisingly, spatial working memory, as measured by the CBT, was not a significant factor for either *time to target* or *heading error*. Indeed, there was no correlation between the CBT and DSB in our sample. However, the CBT is a test of small-scale space and may not be related to search strategies in large-scale spatial tests such as the C-G Arena.

As hypothesized, verbal working memory, as measured by the DSB, was significantly related to place learning in the models for both *directional heading error* and *time to target*. However, DSB scores were significantly related to *time to target* only in the nonsalient cue condition. Although this condition had fewer cues, it may have required more working memory and greater attention due to the cues' abstract nature and lack of distinctiveness. In fact, during testing several women complained of not being able to remember the cues in this condition. Simple environments that lack salient cues are more difficult for individuals to learn, especially when they have a decreased working memory capacity.

Because working memory capacity declines with aging (Georgiou-Karistianis et al., 2006), in normal aging working memory may be important in initial place learning because individuals must both suppress distractions and attend to relevant information to a greater degree upon initial exposure. In addition, some kind of mental rehearsal of cue locations may occur in initial learning. Because individuals with cognitive impairments may not remember their locations from one day to another, working memory may play a continued role in environmental knowledge. We are currently examining the continued effects of working memory in individuals during repeated exposures over days to different types of environmental cue conditions.

Of interest in this study is the use of virtual reality in testing place learning. Virtual reality tasks similar to the CG Arena are being developed and used extensively to assess place learning (Astur, Ortiz, & Sutherland, 1998; Cubukcu, 2004; Foreman et al., 2000; Foreman, Wilson, Duffy, & Parnell, 2005; Gamberini & Bussolon, 2001; Gillner & Mallot, 1998; Kallai, Makany, Karadi, & Jacobs, 2005; Livingstone & Skelton, 2007; Moffat & Resnick, 2002; Moffat et al., 2001; Newman et al., 2007; Richardson, Montello, & Hegarty, 1999). The benefit of using VR is that it provides an experimental environment in which maximum control of extraneous variables can be maintained, which is often not possible in real-world environments that contain distractions such as people, noises, and other stimuli. Furthermore, there is documented evidence for the congruence of VR testing as a measure of hippocampal-based place learning, using fMRI (Hartley, Maguire, Spiers, & Burgess, 2003; Janzen, Wagensveld, & van Turennout, 2007; Jordan, Schadow, Wuestenberg, Heinze, & Jäncke, 2004; Parslow et al., 2004; Stern et al., 1996; Thomas et al., 2001) and evidence for transfer of knowledge in some VR tasks to the real world (Foreman et al., 2000, 2005). Thus, although it is recognized that VR environments are not the same as the real world, there is substantial evidence that they are useful in measuring cognitive mapping in humans.

Several issues should be considered in future studies. One design limitation was that the measurements of place-learning performance for each subject were taken consecutively on a single day. Thus, this study examined place-learning performance on initial exposure to a new environment versus learning over days or weeks. This resulted in the typical wide variability in performance common to the early phase of learning. It is unknown how older adults would respond to place-learning tasks during repeated exposures over days. More information about changes in place-learning ability over the life span is needed. In addition, differences related to gender should be explored. In addition, we recognize the small sample of this pilot study size limits the generalizabiliy of our results and must be replicated in larger studies.

This study has several implications for future work. The meaning of cue salience is not clearly understood. Our contextually and perceptually salient (i.e., the complex salient) cue condition had colorful, textured, and familiar cues. The role of each of these properties has not been established—that is, whether color is the dominant cue property of importance or if texture and familiarity more strongly influence learning. The number of cues is also an issue. On one hand, an increased number of cues can lead to engagement and allow each individual to have more cues to select from when learning. On the other hand, too many cues, especially for an older adult with decreased working memory capacity, may provide an overwhelming amount of irrelevant information and lead to confusion. Finally, the use of cues to aid those with cognitive impairments should be examined once cue salience is better understood.

In summary, this study showed a positive effect of cue salience on the place-learning performance of older women. Older women who had better working memory capacity fared better on place-learning tasks, especially when faced with environments that contained fewer salient cues. Many environments that older people reside in, such as assisted living residences, have notably nonsalient characteristics that can be compared to the nonsalient cue condition in this study. The results of this study, which showed that learning in the nonsalient environment was the poorest, can be used to build on research that informs practice and understanding related to human cognition and environmental factors. The ultimate goal should be to improve environments so that individuals truly know where they are and can feel secure in their surroundings.

Note

1. The C-G Arena is available for free from the University of Arizona Anxiety Research Group at http://web.arizona.edu/~arg/data.html

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