Older Adults Map Novel Environments but Do Not Place Learn: Findings From a Computerized Spatial Task

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ABSTRACT

The present study examined older adults’ memory for the layout of a novel environment. Young and older adults were trained to find a visible or an invisible target located in a fixed place in a computer-generated (CG) space. All adults relocated a visible target equally well; however, young adults consistently relocated an invisible target whereas older adults did not. With extensive exposure to the CG environment, all adults recalled and reconstructed the layout of that spatial environment equally well. More importantly, however, young adults placed the invisible target within the layout correctly, but the older adults placed the target incorrectly. It is striking that older adults appear to acquire and retain a cognitive map of a novel CG environment despite their continued difficulty in remembering a location within their map.

O’Keefe and Nadel (1978) suggested organisms acquire a cognitive map of an environment and then use the map to navigate through the environment or to relocate places within it. A cognitive map consists of representations of relations among environmental stimuli (cues) that may be used to guide novel search strategies (Nadel, 1991). This position, known as cognitive mapping theory, has received support from a number of investigations using a variety of non-human species as experimental subjects (for reviews, see, Brandeis, Brandys, & Yehuda, 1989; Burgess, Jeffrey, & O’Keefe, 1999; Nadel, 1991, 1994; Redish, 1999). O’Keefe and Nadel (1978) suggested organisms acquire a cognitive map of an environment and then use the map to navigate through the environment or to relocate places within it. A cognitive map consists of representations of relations among environmental stimuli (cues) that may be used to guide novel search strategies (Nadel, 1991). This position, known as cognitive mapping theory, has received support from a number of investigations using a variety of non-human species as experimental subjects (for reviews, see, Brandeis, Brandys, & Yehuda, 1989; Burgess, Jeffrey, & O’Keefe, 1999; Nadel, 1991, 1994; Redish, 1999).

Within the confines of cognitive mapping theory, both animal and human data suggest that older organisms form or retrieve a fine-grained cognitive map of a novel environment less well than younger organisms of the same species (for animal data see, Barnes, 1998; Gage, Dunnett, & Bjorklund, 1984; Gallagher, Burwell, & Burchinal, 1993; Rapp, Rosenberg, & Gallagher, 1987; for human data see, Barrash, 1994; Evans, Brennan, Skorpanich, & Held, 1984; Kirasic, 1991; Newman & Kaszniak, 2000; Walsh, Krauss, & Regnier, 1981; Wilkniss, Jones, Korol, Gold, & Manning, 1997). This finding is of interest because it suggests that an individual’s ability to navigate and learn about places on the basis of newly acquired cognitive maps declines as he/she ages.

The purpose of the present experiment was to examine memory for the layout of a novel environment, and places within it, in younger and older human adults using an experimental procedure strictly comparable to that used with other species (Jacobs, Laurance, & Thomas, 1997). This procedure, entitled the Computer-Generated (CG) Arena¹, is an adaptation of the Morris Water Maze (MWM; Morris, 1981). In the CG Arena, a

¹The software may be downloaded from: http://w3.arizona.edu/~arg/data.html. A revised version (New CG Arena) is available from the same site.

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computer monitor displays a representation of a circular arena housed within a large room. The walls of the room display icons (cues) representing objects such as doors or windows. Participants use a joystick to search this CG space for a small target located on the floor of the arena. When visible, the target (a blue square) moves from place to place. When invisible, the target remains in a fixed location. College-age adults quickly learn to relocate the visible target in the CG Arena, thus exhibiting cue learning, and to relocate the invisible target in the CG Arena, thus exhibiting place learning similar to that seen in young adult rats searching natural space (Jacobs et al., 1997; Jacobs, Thomas, Laurance, & Nadel, 1998; Morris, 1981).

We also developed a companion task to examine memory for place and layout within this procedure. Immediately upon completion of the CG Arena, participants complete an Arena Reconstitution Task (ART). In this task, the participants arrange cardboard icons, which represent the distal walls, the objects on those walls, and the target, to accurately reflect the layout of the CG environment and the location of the invisible target within the layout. We reasoned that successful ART performance requires the participant to (a) learn the layout of the environment, (b) learn the location of the invisible target within the environment, (c) recall that material accurately, and (d) represent both the environmental layout and target location in another medium (see also Skelton, Bukach, Laurance, Thomas, & Jacobs, 2000).

Our laboratory recently used these procedures to examine the performance of younger and older humans in the CG Arena (Thomas, Laurance, Luczak, & Jacobs, 1999). That study showed (a) both young and older adults relocated a visible target equally well, and (b) with brief training young adults relocated an invisible target more quickly than older adults. We concluded that, “...young adults formulated efficient spatially-based strategies to search for a fixed but not proximally cued...[invisible] target in a computer-generated room. Older adults, in contrast, did not appear to formulate such search strategies and thus did not show accurate place learning” (p. 562). That study also showed that during the ART young adults more accurately reconstituted the layout of the arena, and the location of the invisible target within it, than the older adults. We interpreted this as an indication that the facility with which people acquire cognitive spatial maps of a novel environment declines as they age.

This interpretation is compatible with five suggested accounts of the place learning deficits consistently observed in aged organisms. First, aged organisms may fail to acquire an accurate spatial map (Rapp et al., 1987). Second, aged organisms may acquire only a coarse spatial map (Barnes, McNaughton, & O’Keefe, 1983). Third, aged organisms may acquire an accurate and refined map but inconsistently recall the appropriate map (Barnes et al., 1983; Barnes, Suster, Shen, & McNaughton, 1997; Rapp et al., 1987). Fourth, unlike young adults, aged organisms may use non-spatial strategies to relocate places in space (Barnes, Nadel, & Honig, 1980; Rapp & Gallagher, 1999). Finally, aged organisms may acquire an appropriate map more slowly than young adult organisms (Gallagher & Pelleymounter, 1988; Rapp et al., 1987).

The present study attempted to determine if, in older adults, increasing the number of acquisition trials affects (a) the quality of place performance in the CG Arena, and (b) the accuracy of the cognitive map as measured by ART. In addition, we took self-report measures designed to assess (c) level of task comprehension, and (d) confidence in ability to perform the task of finding the target and in mapping the environment.

**METHOD**

**Participants**

There were 8 individuals (3 males, 5 females), between 22 and 29 years of age ($M = 26.1$), who were assigned to the Young adult group while 8 individuals (2 males, 6 females), between 64 and 81 years of age ($M = 73.0$), were assigned to the Older adult group. Table 1 provides demographic information. All participants were recruited from a larger group of individuals who participated in previous studies designed to examine spatial cognition in young and older adults using a real-space analog of the MWM (for a description see, Newman & Kaszniak, 2000). All available participants were included in the present study.
Although no formal data were collected regarding exposure to computers and joysticks, all participants reported previous exposure to computers and computer games.

**CG Arena**

*Apparatus*
The CG Arena was used for this study. A personal computer and custom-designed software generated a display on a conventional flat screen PC monitor. The monitor displayed a multicolored view of a circular arena within one of three square rooms (a waiting room, a practice room, and an experimental room) from the perspective of a person standing on the floor of the room. The monitor did not display a representation of the participant. The ceiling of all the rooms was light gray, and the floor dark gray. The waiting room distinguished trials one from another and permitted the participants to practice moving in the CG space. For an illustration of the experimental room see Figure 1. Several characteristics within each of these CG Arena rooms were set by experimenter-defined variables outlined in Table 2. These variables did not vary in this experiment.

The walls of each square room were arbitrarily designated North, East, South, and West. A featureless, circular purple wall enclosed the central portion of each room floor, thus defining the arena. The arena was divided into four imaginary quadrants named Northeast (NE), Southeast (SE), Southwest (SW), and Northwest (NW). Lines demarcating each quadrant were not displayed on the monitor. Participants moved through the CG space using a joystick.

**Table 1. Demographic Variables.**

<table>
<thead>
<tr>
<th></th>
<th>Young adults</th>
<th>Older adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Sex</td>
<td>3 males, 5 females</td>
<td>2 males, 6 females</td>
</tr>
<tr>
<td>Handedness</td>
<td>7 right, 1 left</td>
<td>7 right, 1 left</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>22–29</td>
<td>64 – 81</td>
</tr>
<tr>
<td>M</td>
<td>26.13</td>
<td>73.00</td>
</tr>
<tr>
<td>SD</td>
<td>2.70</td>
<td>6.74</td>
</tr>
<tr>
<td>Education level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level (in years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>17.22</td>
<td>16.81</td>
</tr>
<tr>
<td>SD</td>
<td>2.24</td>
<td>1.17</td>
</tr>
</tbody>
</table>

**Target**
A square target was located on the floor of the practice and experimental rooms. When the experimental protocol called for the target to be part of the display, it was plain blue. When the protocol called for the target to be invisible, it was indistinguishable from the arena floor. When the participants moved across the place occupied by an invisible target, the target became blue and a brief CG tone sounded with each movement.

**Procedure**

*Instruction Phase*
Each participant received standardized verbal instructions about the structure of the arena, how to move within the CG space, and the object of the task (Jacobs et al., 1997). The experimenter explicitly stated,

You won’t be able to see the target at all until you are standing on it and the computer starts beeping. Once you find the target and hear the beeps, take a good look around the room and see where you are. This is important because the target will be in the exact same place every time. It is important to know the location of the target and the room. Remember the target will be in the exact same place each time.

An experimenter remained in the room throughout the procedure to answer questions about the task.
Demonstration Phase
Each participant received one demonstration trial in both the waiting and practice rooms. While the participant watched, the experimenter used the joystick to move around the waiting room, thereby demonstrating the full range of motion in the CG space. Then, the experimenter pressed the space bar to teleport into the practice room, and move directly to a visible blue target in the middle of the arena floor. Once on the target, the experimenter used the joystick to turn one complete revolution.

Practice Phase
Immediately following the demonstration phase, each participant completed two sets of trials in the practice room. The critical parameters for all the trials are shown in Table 3. The participant began in the center of the waiting room, facing the yellow wall. He/She was allowed to explore the waiting room for several minutes. Each participant was allowed as much time he/she needed to practice using the joystick to explore CG space.

Table 2. CG Arena Parameters.

<table>
<thead>
<tr>
<th>Room parameters</th>
<th>Waiting room</th>
<th>Practice room</th>
<th>Experimental room^a</th>
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</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td>3000×3000×475</td>
<td>3000×3000×475</td>
<td>3000×3000×475</td>
</tr>
<tr>
<td>Ceiling</td>
<td>Light gray</td>
<td>Light gray</td>
<td>Light gray</td>
</tr>
<tr>
<td>Floor</td>
<td>Dark gray</td>
<td>Dark gray</td>
<td>Dark gray</td>
</tr>
<tr>
<td>North wall</td>
<td>Blue</td>
<td>3 doors – gray wall</td>
<td>2 small windows, door – gray wall</td>
</tr>
<tr>
<td>East wall</td>
<td>Green</td>
<td>1 large window – textured wall</td>
<td>arched wall</td>
</tr>
<tr>
<td>South wall</td>
<td>Red</td>
<td>2 small windows – gray wall</td>
<td>3 small windows – gray wall</td>
</tr>
<tr>
<td>West wall</td>
<td>Yellow</td>
<td>Brick wall</td>
<td>Brick wall</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Arena parameters</th>
<th>Waiting room</th>
<th>Practice room</th>
<th>Experimental room</th>
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<tbody>
<tr>
<td>Wall color</td>
<td>Purple</td>
<td>Purple</td>
<td>Purple</td>
</tr>
<tr>
<td>Wall radius</td>
<td>460 units</td>
<td>460 units</td>
<td>460 units</td>
</tr>
<tr>
<td>Wall height</td>
<td>30 units</td>
<td>30 units</td>
<td>30 units</td>
</tr>
<tr>
<td>Target parameters</td>
<td>Absent</td>
<td>142×142</td>
<td>142×142</td>
</tr>
<tr>
<td>Participant parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant eye height</td>
<td>15 units</td>
<td>15 units</td>
<td>15 units</td>
</tr>
<tr>
<td>Move quantum</td>
<td>4 units</td>
<td>4 units</td>
<td>4 units</td>
</tr>
<tr>
<td>Turn quantum</td>
<td>1 unit</td>
<td>1 unit</td>
<td>1 unit</td>
</tr>
</tbody>
</table>

Note. ^aFor a bird’s-eye view of the experimental room, see Figure 1.
All measurements are in CG Arena units. If we, for the sake of convenience, take the length of a stride (4 units) to be the equivalent of 1 m, then in this experiment the room dimensions were 750×750×118.7 m, the arena wall was 7.5 m high and had a radius of 115 m, and the target measured 35.5×35.5 m.

Table 3. CG Arena Trial Parameters.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Demonstration</th>
<th>Practice</th>
<th>Acquisition</th>
<th>Elimination</th>
<th>Probe</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trials</td>
<td>1</td>
<td>2</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Target condition</td>
<td>Visible</td>
<td>Visible</td>
<td>Invisible</td>
<td>Invisible</td>
<td>Not present</td>
<td>Visible</td>
</tr>
<tr>
<td>Target location</td>
<td>Center</td>
<td>Center</td>
<td>NW quad</td>
<td>NW quad</td>
<td>Not present</td>
<td>Center</td>
</tr>
<tr>
<td>Time limit</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
</tbody>
</table>

Note. ^aThe participant teleported into the experimental room at start position facing, and within 2 units of the arena wall. On the acquisition trials, the participant teleported into the experimental room at a pseudo-random start position facing, and within 2 units of arena wall. This pseudo-random sequence was utilized to ensure an equal distribution of start locations across the acquisition trials.
Upon striking the space bar, the participant teleported to the start position in the CG practice room. The task was to find and stand on a visible blue target located in the same place as in the demonstration phase. After reaching the target, the participant was required to stand in one place and rotate at least one full revolution. This portion of the task was designed to demonstrate that the participants understood the instructions, comprehended the computer display, could move within CG space, could locate a visible target in the CG Arena, and were exposed at least twice to all the cues in the CG environment.

This phase allowed all participants to become familiar with the use of a joystick and with task parameters. Successful visible target relocation suggests that any differences between subjects in locating an invisible target is not easily attributed to difficulties with using computer displays, joysticks, or both.

**Practice ART**
Immediately following the practice phase, the participants completed an ART. Each participant sat at a table on which flat icons representing each of the following were placed: (a) the four distal walls of the practice room, (b) the objects on those walls, and (c) the target. A 11 × 17 in. sheet of paper was placed on the desk with the outline of a purple circle drawn in the middle representing the arena wall. The participants were instructed to arrange the icons to reconstitute the spatial relations observed among the walls of the practice room, the objects on the walls, and the target location.

Four performance measures were taken: wall placement, object placement, object accuracy, and target placement. For wall placement, there were three possible scores: 0, 2 or 4. A score of 0 reflected a completely inaccurate configuration; a score of 2 was awarded when two walls were in the correct relation to each other, and two walls were switched; a score of 4 was awarded when each wall was placed in the correct relation to every other wall. For object placement, 1 point was awarded for each object that was placed on the correct wall for a maximum score of 6. For example, three windows placed on a gray wall would be 3 points, or a large window placed on a square textured wall would be 1 point. For object accuracy, 1 point would be awarded to each object placed in the correct spatial location and on the correct wall for a maximum score of 6. For example, if an individual placed a large window in the center of the square textured wall, 1 point would be awarded. For target placement, two points would be awarded if the target was placed in the correct quadrant (NW), 1 point if the target was placed in either of the adjacent quadrants (NE or SW), and no points if the target was placed elsewhere (SE, Center).

**Acquisition Phase**
Immediately following the practice ART, each participant received a series of acquisition trials in the experimental room. Again, the participant began in the center of the CG waiting room. After striking the space bar, the participant was teleported to the start position in the CG experimental room. Once in that arena, the participant searched for an invisible target that was, unbeknownst to the participants, located in the NW quadrant on the arena floor. Each acquisition trial lasted a maximum of 180 s; however, on the first 3 trials, if the participant did not find the target within 180 s, the experimenter guided the participant to the target. On each trial after that, if the participant did not find the invisible target within 180 s, he/she was automatically transported back into the waiting room.

**Elimination Phase**
Immediately following the acquisition phase, the participants entered the elimination phase. This phase consisted of four pairs of elimination trials during which two randomly determined distal walls were removed and replaced with white walls. Each elimination trial was immediately followed by a trial identical to those occurring during the acquisition phase.

**Probe Trial**
Immediately following the Elimination phase, each participant received a single probe trial. The probe trial was identical to the acquisition trials except, unknown to the participants, the target was removed from the arena.

**Final Trial**
The last trial, the 20th, was identical to a practice trial with a visible target located in the middle of the arena floor.

**Experimental ART**
Immediately following the final trial, each participant completed a second ART as described above. A failure to reconstitute the map indicates a failure of cognitive mapping. A failure to place the target accurately indicates a failure of place knowledge within the map. Accurately reconstituting the map and accurately placing the target combined with poor arena performance indicates a failure to translate map and place knowledge into efficient behavioral strategies.

**Spatial Questionnaires**
Immediately following the ART, each participant completed a Functional Spatial Ability questionnaire, (an instrument designed to evaluate self-reported spatial orientation in people with Alzheimer’s disease; Liu, Gauthier, & Gauthier, 1996).
Metacognition Questionnaires

Before and after each practice and experimental ART, the participants completed a brief questionnaire composed of 7-point scales asking them to rate their confidence in (1) their knowledge of the arrangement among the walls in the arena, and (2) their ability to place the objects and target in correct spatial relations. Before entering the experimental arena and upon completion of the CG task, all participants also completed a brief questionnaire asking them to rate on a scale of 1–7, their confidence in (1) the understanding of the task and (2) accomplishing the goal of finding the invisible target. Results from these questionnaires are important in helping to determine whether or not participants understood the task.

Data Collection

Medical history collected from each participant included current medications, hyper/hypotension, systemic illnesses, vision/perceptual difficulties, loss of consciousness, and soft signs of dementia. The dependent variables gathered from the computer task included: (a) the time required to find the target, (b) the path taken in the arena, (c) the distance traveled from the start point to the target, and (d) the time spent in each of the arena quadrants. Other measures included: (a) responses to questionnaires, and (b) wall placement, object placement, object accuracy, and target placement taken from the ART. The Type I error rate was set at .05 for all statistical decisions.

RESULTS

Demographics

Analyses conducted on medical history and a variety of other demographic variables (e.g., education level, handedness, sex) detected no significant between-group differences in the measures taken at the time when these individuals participated in the present study.

The Young adults in the current study obtained an average score of 34.5 ($SD = 2.1$), and Older adults obtained an average score of 34.5 ($SD = 1.9$) on the Functional Spatial Abilities Questionnaire (FSAQ; Liu et al., 1996). Differences between the two groups are not statistically significant ($F < 1$) and fall within the normal range. None of the participants met the criterion for clinical depression (score greater than 12) as measured by the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). The Young adults obtained an average score of 3.37 ($SD = 4.00$), and Older adults obtained an average score of 2.45 ($SD = 3.38$).

CG Arena

Figure 2 illustrates the mean time the participants in each group required to find the target across all

![Fig. 2. Mean latency and SE (±1) to find the target in seconds across CG Arena trials. Each data point represents two trials collapsed.](image-url)
CG trials. Each individual in the Young adult and Older adult groups found the visible target quickly and consistently when the target was visible (the two Practice trials). A split-plot ANOVA conducted on the mean time participants in each group required to find the target on these trials detected no significant group effect, $F(1, 14) < 1$, trials effect, $F(1, 14) < 1$, or group × trials interaction, $F(1, 14) = 1.26$.

During the first three invisible acquisition trials, none of the 8 participants in the Young adult group and 3 of the 8 participants in the Older adult group required help to locate the invisible target. The Young adults appeared to learn the location of the invisible target quickly and relocated the target easily, whereas the Older adults appeared to learn slowly and to have difficulty relocating the target. A split-plot repeated measures ANOVA confirmed this impression. The analysis detected a significant group effect, $F(1, 14) = 56.75$, and a significant group × trials interaction, $F(11, 154) = 2.10$, but no significant trials effect, $F(11, 154) = 1.22$. Separate repeated measures ANOVAs conducted on time to relocate the target detected a significant trials effect for the Young adult group, $F(11, 77) = 3.31$, but not for the Older adult group, $F(11, 77) = 1.23$, hence replicating the pattern of results reported by Thomas et al. (1999).

A split-plot repeated measures ANOVA conducted on the elimination trials detected a significant group effect, $F(1, 14) = 39.21$, no significant trials effect, $F(3, 42) = 1.47$, and no significant trial × group interaction, $F(3, 42) = 2.70$. Separate within-subject repeated measures ANOVAs detected no significant effects across elimination trials for the Young adults, $F(3, 21) = 1.24$, and no significant effects across elimination trials for the Older adults, $F(3, 21) = 2.51$. An analysis of group comparing the last acquisition trial, where all the cues were present, to the first elimination trial detected significant group effects $F(1, 14) = 12.41$. Separate within-subject repeated measure ANOVAs detected no significant effects across the two trials for either the Young adults [$F(1, 7) < 1$] or Older adults [$F(1, 7) < 1$]. Thus, it appears that eliminating the distal cues on any two walls did not affect place performance for the Young or the Older adults. Their mean time required to find the target for the four elimination trials remained stable across trials, thus replicating results reported by Jacobs et al. (1998) in humans and Suzuki, Augerinos, and Black (1980) in rats. Young adults continued to perform optimally, whereas Older adults continued to have difficulty locating the target.

Figure 3 illustrates the time each group spent searching the four quadrants during the probe trial. It appears that the participants in the Young adult group searched the target quadrant (NW) more persistently than they did the other three quadrants. A repeated-measures split-plot ANOVA conducted on the time spent in each quadrant detected a significant group × quadrant effect, $F(3, 42) = 4.23$. Separate within-subject repeated measures ANOVAs conducted on the data obtained from each group detected a significant quadrant effect, $F(3, 21) = 13.55$ for the Young adults but not for the Older adults, $F(3, 21) < 1$. It appears that the Older adults distributed their search equally over the four quadrants. The ANOVAs detected no significant quadrant effect in the Older adult group.

**Metacognition Arena Questionnaires**

Independent Wilcoxon tests detected significant differences on the self-report responses between the two groups on both arena pre-task confidence questions: (1) How well do you think you understand this task? ($W = 43$), and (2) How confident are you that you can accomplish the task of finding the invisible target? ($W = 36$). Older adults report less confidence in their understanding of the task at the beginning of the study.

In contrast, on the arena post-task confidence questions, there was no detectable difference on the question: (1) How well do you think you understood this task? ($W = 55$); whereas there was a significant difference on the question: (2) How confident are you that you accomplished the task of finding the invisible target? ($W = 42.5$). Thus, although Older adults reported less confidence in their understanding of the task at the beginning the experimental phase, Young and Older adults reported being more, and equally confident in their understanding of the arena task at the end of testing. Older adults reported less confidence in accurately completing the arena.
task, as compared to Young adults both pre- and post-task completion.

**Arena Reconstitution Task (ART)**

*Practice ART*

Two independent raters scored the ART. Inter-rater agreement was perfect. Figure 4 illustrates the mean scores for each group on three measures: wall placement, object placement, and object accuracy. These three measures reflect the participants’ explicit knowledge of the spatial configuration (two measures of layout and one of location) of the practice room. It appears that on the practice ART, the Young adults placed the walls and the objects more accurately than the Older adults. Wilcoxon tests confirmed this impression detecting significant differences

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**Fig. 3.** The mean time in seconds SE (±1) spent in each quadrant during the probe trial.

**Fig. 4.** Distribution of practice ART scores. Maximum scores: 4 for wall placement, 6 for object placement, and 6 for object accuracy.
between the performance of the two groups on measures of wall placement ($W = 40$), object placement ($W = 44$), and object accuracy ($W = 46$). Because the visible target moved from trial to trial during the Practice trials, no target placement score was obtained from the practice ART.

**Experimental ART**

Two independent raters scored the experimental ART. Inter-rater correlations on each measure yielded: object placement ($K = 1$), object accuracy ($K = 1$), wall placement ($K = .49$), and target placement ($K = .70$) in the experimental task. The relations between the ratings on each of the latter two measures were correlated at the .05 level. The raters disagreed on 5 of the 128 scores rated. For those 5 items, the statistical analyses used an average of the two raters’ scores.

Figure 5 illustrates the mean scores for each group on four measures for the experimental ART. The scores on wall placement, object placement, and object accuracy measures are comparable and high, suggesting that the Young and Older adults accurately reconstituted the layout of the experimental room after extensive experience with it. Wilcoxon tests detected no significant differences between the performance of the two groups on wall placement ($W = 56$), object placement ($W = 60$), or object accuracy ($W = 52$).

It also appears that, although Young adults accurately placed a representation of the target in the correct quadrant, Older adults did not. All 8 Young adults received a perfect score on target placement (score of 2); six of the 8 Older adults received scores of 1; the remaining 2 Older adults received scores of 0. A Wilcoxon test detected a significant difference between aggregate target score received by the two groups ($W = 36$).

**Metacognition Experimental ART Questionnaires**

Wilcoxon tests detected no significant differences between the two groups on the ART pre-task confidence questions: (1) How confident are you that you know the way the walls were arranged in the arena? ($W = 52.5$), and (2) How confident are you that you will be able to place the objects on the walls and the target in their correct places? ($W = 58.5$). In contrast, there was a significant difference on both ART post-task confidence questions: (1) How confident are you that you

Fig. 5. Distribution of experimental ART scores. Maximum scores: 4 for wall placement, 6 for object accuracy and object placement, and 2 for target placement.
knew the way the walls were arranged in the arena? (W = 49), and (2) How confident are you that you placed the objects on the walls and the target in their correct places? (W = 49.5). Thus, although both Young and Older adults reported confidence in their ability to accurately complete the ART pre-task, the Older adults were less confident than the Young adults, in the quality of their performance.

**Real Space versus CG Space**

Correlational analyses were conducted on each participant's performance in the CG Arena compared to his/her performance in a real-space analog of the MWM (Newman & Kaszniak, 2000). Comparable measures of performance were taken from each study for behavior on learning, acquisition, and cue-elimination trials. Each analysis indicated positive correlations between .58 and .76. It could be argued that this suggests similar patterns existed between performances on the two tasks on learning, acquisition, and cue-elimination trials. These, of course, are merely preliminary analyses. However, high positive correlations suggest that place learning in the CG Arena may accurately reflect place learning in the actual world. Although there are other analyses that can be conducted between the two tasks, they are ongoing and will be left for future studies.

**DISCUSSION**

The present data demonstrate that (a) participants in the Young adult group and Older adult group located and relocated a visible target in CG space, but (b) although the Young adults learned to relocate an invisible target efficiently in the space, Older adults did not. Furthermore, the data demonstrate that during the probe trial (c) Young adults searched the target quadrant more persistently than any other quadrant, but (d) the Older adults searched the four quadrants equally. The data patterns from the acquisition trials and probe trial taken together indicate that in the absence of proximal cues, Young adults learned, remembered, and navigated to the location of the invisible target, but Older adults did not. These data fail to replicate data patterns reported by Rapp et al. (1987) and Gallagher and Pelley (1988) using rats as experimental subjects. It appears that even with extensive exposure, our older participants did not learn the location of an invisible target in the CG Arena.

The most interesting finding in this study is that Older adults accurately mapped an environment, but did not remember a particular place in that environment. Thus, the data from the present study appear incompatible with earlier suggestions that Older adults (a) do not acquire a map, (b) acquire a coarse map, or (c) do not consistently recall the correct map of a given space. The ART data showed that both Younger and Older adults accurately reproduced the layout of the CG Arena. Moreover, the accuracy of the layout map produced by the Older adults was statistically indistinguishable from that produced by the Young adults. Thus, both Younger and Older adults appeared to acquire and retrieve an accurate layout map and to reproduce that layout in a two-dimensional representation of the CG environment.

These data are, however, compatible with the suggestion that older adults acquire a spatial map more slowly than young adults. Immediately following three trials, the Young adults accurately reconstructed the layout of the experimental room whereas the Older adults did not. In contrast, immediately following 18 trials (12 acquisition, 4 elimination, 1 probe, and 1 final trial), both the Young adults and the Older adults accurately reconstructed the layout of the experimental room. Thus, the Older adults appeared to acquire an accurate layout map of the CG Arena comparable to that acquired by the Young adults, but required more trials to do so. Nevertheless, the Older adults recalled and reproduced an appropriate map on demand. This result is compatible with the Thomas et al. (1999) findings. In that study, the Older adults' layout of the CG environment was significantly less accurate than the Younger adults after six acquisition trials. Although the data are silent regarding the hypothesis that older adults use non-spatial strategies to locate a place in space, it is plausible that an accurate layout map of the CG Arena was available to each of them.
In contrast to the layout data, target placement data suggest that the Older adults (a) did not acquire, (b) did not retain, or (c) did not reproduce the location of the target in another medium. The Young adults placed the target accurately when reconstituting the CG Arena, but the Older adults did not. Remarkably, no participant in the Older adult group placed the target in its appropriate location during the ART. In contrast, all the participants in the Young adult group placed the target in its appropriate location during the ART. The present study was not designed to sort among hypotheses that might account for this unexpected finding.

Although our interpretation of the ART data suggests intriguing alternatives to the traditional hypotheses described earlier, the data are not definitive. Whereas it is possible that older adults construct spatial maps accurately but do not use those maps to navigate, there are other possibilities that might account for our findings.

First, the CG Arena is a relatively simple environment compared to natural real-space environments. Hence, it remains possible that older adults have difficulties mapping complex environments. Differences in the quality of maps between older and younger adults might emerge under complex conditions. Nevertheless, the Older adults appeared to map this ‘simple’ spatial environment, yet did not locate or learn the location of a place in that mapped environment. Taken together, these results suggest that, although the successful relocation of a place in space may require the use of a cognitive map, the presence of a cognitive map does not necessarily imply that an individual (a) can relocate a place in the map or (b) will use that map to relocate a place in the environment. That is to say, mapping and learning to relocate a place within a spatial environment may be potentially dissociable processes.

Second, it remains possible that Older adults did not map the CG space. Instead, they may have used simple associations (S–R or S–S), acquired while they moved through the CG space, to guide an accurate reconstitution of the layout of the CG Arena during the ART (Mackintosh, 1975). For example, an individual might simply have associated one distal cue with the next in a rigid linear sequence. When asked to reconstitute the arena, the person located and placed an appropriate cue, then located and placed the appropriate ‘next cue’ beside it. We consider this possibility unlikely because it requires rather dramatic generalization from the CG Arena to icons representing those distal cues. Nevertheless, using such a strategy, a person could reconstruct the environment during ART, but be unable to (a) navigate through the environment easily, or (b) place the target correctly during ART. Such an account predicts an inflexible, easily disrupted, strategy to reconstitute the layout of the CG Arena during the ART. We suspect that the importance of spatial maps to solve adaptive problems for mammals of all ages makes this theoretically uncomfortable possibility unlikely, but it remains necessary to rule it out.

Lastly, it remains possible older adults cannot navigate effectively in computer space, or that they did not understand the procedures. Although each of these volunteers reported experience with computers, it remains possible that the computer experience of these individuals differed from that of the younger population (e.g., very much less gaming experience). Thus, the differences in ‘spatial’ performance that we observed may reflect differential experience with CG space rather than cognitive differences in spatial mapping. On the other hand, perhaps the differences in spatial performance we have observed reflects an executive (frontal-lobe) problem (e.g., inefficiency in the selection and use of task-appropriate problem-solving strategies; Duncan, Emslie, & Williams, 1996; Hayes, Gifford, & Ruckstuhl, 1996). Results from the visible trials, however, offer some evidence against these possibilities. Older adults both move successfully through a CG environment and locate visible places in space. Further, analysis of the metacognition questionnaires showed that upon completion of the task, Older adults report an understanding of both the CG task and the ART task that is equal to the report of understanding of the Young adults, despite not

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2 We would like to thank Mary Peterson, University of Arizona, for alerting us to the possibility of association learning affecting ART performance in older adults.

3 We would like to thank an anonymous reviewer for directing our attention to this interpretation.
finding the invisible target and not being able to accurately place it within the map.

In summary, the Older adults who participated in the present study appeared (a) unable to relo-cate an invisible target in CG space, but simultaneously appeared to (b) learn and remember the environmental layout of the CG space. Although they do so more slowly than Young adults, the quality of their cognitive maps appears surprisingly accurate. Data obtained from the CG Arena and the ART taken together lead us to suggest that these Older adults form and retrieve accurate cognitive maps but have difficulty locating places within those maps. Although alternatives to these interpretations remain viable, the results presented in this study suggest a rich research pro-gram for those interested in the study of spatial cognition.

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