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The Roles for Prior Visual Experience and Age on the Extraction of Egocentric Distance

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Abstract

Objectives: In a well-lit room, observers can generate well-constrained estimates of the distance to an object on the floor even with just a fleeting glimpse. Performance under these conditions is typically characterized by some underestimation but improves when observers have previewed the room. Such evidence suggests that information extracted from longer durations may be stored to contribute to the perception of distance at limited time frames. Here, we examined the possibility that this stored information is used differentially across age. Specifically, we posited that older adults would rely more than younger adults on information gathered and stored at longer glimpses to judge the distance of briefly glimpsed objects.
Method: We collected distance judgments from younger and older adults after brief target glimpses. Half of the participants were provided 20-s previews of the testing room in advance; the other half received no preview.
Results: Performance benefits were observed for all individuals with prior visual experience, and these were moderately more pronounced for the older adults.
Discussion: The results suggest that observers store contextual information gained from longer viewing durations to aid in the perception of distance at brief glimpses, and that this memory becomes more important with age.

Keywords: Aging—Blind walking—Distance perception—Memory—Visual space

The perception of object distance is a dynamic process of information integration. Research involving very brief (< 150 ms) visual exposures to real scenes suggests that the visual representation of distance develops over time, with various sources of distance information extracted at different time points in viewing (Gajewski, Philbeck, Pothier, & Chichka, 2010; Gajewski, Philbeck, Wirtz, & Chichka, 2014). Gajewski, Philbeck, et al. (2014) have also demonstrated that sources of information available at longer durations can be stored to aid judgments of distance when viewing time is subsequently more limited, suggesting an effect of context familiarity on the fast extraction of distance information. Age-related differences in the effects of prior knowledge have been observed in recall tasks that required the encoding of visuospatial information from two-dimensional displays (Arbuckle, Cooney, Milne & Melchior, 1994; Hess & Slaughter, 1990); however, the possibility that older adults might make special use of prior knowledge in support of egocentric distance judgments remains an open question. A variety of real-world situations can limit the effective viewing duration available for localizing objects (e.g., high-workload conditions and highly dynamic environments). Because these limitations on effective viewing duration may cut short the accumulation of distance information and potentially cause systematic misperception of object locations, it is important to examine the role for prior visual experience and age on judgments of distance at both brief and extended viewing times.

Three critical findings motivate the current research. First, as indicated above, Gajewski et al. (2010) and Gajewski, Philbeck, et al. (2014) have determined that while some sources of distance information can be extracted quickly from the environment, others take longer to be extracted. On the one hand, a very brief (9–34 ms) glimpse can support highly sensitive judgments of distance, with slopes relating response distance to physical distance near one. Presumably, this good performance is possible because angular declination—an object's angular direction relative to an observer's line of sight (Ooi, Wu, & He, 2001)—is a source of information about distance to ground-level targets that is both reliable and quickly extracted. In fact, studies have shown that the viewing duration need only support target detection and directional localization for observers to capitalize on the target's angular declination (Gajewski, Philbeck, et al., 2014; Gajewski, Wallin, & Philbeck, 2015). On the other hand, Gajewski et al. (2010) have also demonstrated that performance improves when viewing time is extended (3–5 s). Because a similar time course of improvement has been shown for monocular versus binocular viewing (Cohen, Gajewski, Dameshghi, & Philbeck, 2011), this extended-viewing benefit cannot be explained just by binocular cues coming online. Instead, this benefit appears to be linked to the increasing effectiveness of information about the environment surrounding the target at these longer viewing durations. For instance, texture gradient cues are thought to contribute to an enhanced representation of the surface slant (Sedgwick, 1986; Wu, He, & Ooi, 2008). Details of the environment (e.g., edges of the floor and walls) may also provide cues for linear perspective and thereby aid the observer in deriving a sense of the overall scale of the space (Gajewski, Philbeck, et al., 2014; Gajewski, Wallin, & Philbeck, 2014). Such contextual cues would be expected to bolster performance on a distance judgment task.

The second pivotal outcome that has led us to investigate the role for prior visual experience is evidence that sources of information collected at longer viewing durations can be stored in memory and lead to performance benefits on subsequent brief-glimpse distance judgment tasks (Gajewski et al., 2010; Gajewski, Philbeck, et al. 2014). Judgments of egocentric distance after a brief (113 ms) glimpse of a target in a real-world room environment have been found to be significantly less sensitive and more biased toward underestimation than judgments made after a longer (5 s) glimpse; when these fast glimpses are preceded by blocks of longer duration trials, however, brief-glimpse performance is similar to that under longer duration glimpses (Gajewski et al., 2010). Significant improvements in distance estimations have also been reported when observers receive a 15-s preview of the room environment prior to fast-viewing conditions (Gajewski, Philbeck, et al., 2014). Critically, because no target object was present during the preview of the room, information about the surrounding contextual space arguably drives this effect of prior visual experience.

The precise role for prior visual experience in judgments of distance is still early in its investigation, but Gajewski, Philbeck, et al. (2014) suggests that exposure to longer viewing durations prior to a brief glimpse allows an observer to build a representation of the physical space from sources of information only accessible at longer viewing durations. When viewing time is limited and the observer has no prior experience with the setting, the targets are effectively viewed in the context of a relatively impoverished environment; the representation of the ground surface slant might be imprecise or inaccurate, for example, if there is insufficient time for precise binocular cues or texture gradient cues to come online (Ooi et al., 2001; Wu et al., 2008). Similarly, visual cues specifying the overall size and shape of the environment might not be accessible without longer glimpses (see Gajewski, Philbeck, et al., 2014; Lappin, Shelton, & Rieser, 2006; Witt, Stefanucci, Riener, & Proffitt, 2007). However, if the observer has prior visual experience that allows these cues to reach their full potential, the observer can leverage a more elaborate, episodic representation of the setting to derive object distance when time is subsequently more limited.

Here we suggest that information about target direction derived from a brief glimpse can be integrated with stored information about the target's setting to derive a better representation of egocentric distance. The framework is more directly related to descriptive models from the scene perception literature (e.g., Hollingworth & Henderson, 2002; Irwin & Zelinsky, 2002) than it is to classic models of depth cue integration (e.g., Gibson, 1950, 1979; Landy, Maloney, Johnston, & Young, 1995; Sedgwick, 1986), although it is not necessarily inconsistent with cue integration models. Much of the scene perception research builds from the idea that vision is a dynamic, integrative process—that is, online scene representations contain details about currently foveated objects as well as other recently attended objects (Irwin & Zelinsky, 2002), with input from both visual short-term and visual long-term memory (Hollingworth, 2004). Critically, there is evidence that object representations are bound to locations within memory representations of the contextual surround (Hollingworth, 2006). Integration within our framework can be mechanistically conceptualized as relating the target's direction to a location within scene memory. Our dynamic framework also meshes well with Loomis and colleagues' proposal that locomotion toward a target is mediated by a *spatial image* or a spatialized working memory representation of an object's location that is maintained and updated as one traverses a space without any concurrent visual information (Loomis & Beall, 2004; Loomis & Philbeck, 2008). We extend this account by characterizing a specific role for memory representations of the contextual environment.

Finally, our research question was most directly motivated by a recent pattern of results from our laboratory that hinted at an age-related dependence on prior visual experience (Gajewski et al., 2015). In that study, we collected distance judgments via blind walking—that is, observers viewed a target and then indicated its location by attempting to walk to it without vision (see Philbeck, Woods, Arthur, & Todd, 2008). These judgments were not expected to differ between age groups because glimpse durations were individually set to be just above each observer's threshold for detection. Although older adults did require more viewing time than younger adults to detect the object, performance based on these near-threshold viewing times did not support the prediction that judgments would be similar across both age groups: younger adults were more accurate than older adults at judging distances, when the brief-glimpse and more extended viewing trials were administered in separate blocks. Critically, however, when brief and longer glimpses were intermixed, older adults were significantly more accurate than their younger counterparts. Such findings suggest that although detection is sufficient to support sensitive judgments of distance, some visual information extracted from longer glimpses and maintained in memory may play an increasingly important role for aging adults in the fast extraction of distance information. These conclusions are consistent with Bian and Andersen's (2013) findings that demonstrated distance estimations closer to the actual target distance for older adults compared with younger adults, after 5-s viewing durations of a target in a real-world, outdoor environment.

Although prior work from our laboratory has supported the idea that prior visual experience is useful when viewing time is limited in a real-world distance estimation task (Gajewski et al., 2010; Gajewski, Philbeck, et al. 2014), the Gajewski et al. (2015) study was not designed to test the idea that prior visual experience might be more important for older adults. We suspect the importance of prior visual experience in older adults is related to a decreased ability (or willingness) to relate target direction to a coarse representation of the setting. Performance in this case could be more heuristically based (e.g., higher targets are further away) and therefore more subject to error. This hypothesis relates to several aspects of cognitive aging reported in the literature, such as the beneficial role for prior knowledge with increasing age (Hess, 2005; Hess & Slaughter, 1990), age-related decline in cognitive flexibility (Chasseigne, Mullet, & Stewart, 1997), and age-specific performance deficits linked to task uncertainty (Kray, Li, & Lindenberger, 2002). Here, we directly test the idea that is more critically important for older adults to have a structured representation of the environmental context in place when judging distance.

In the present study, we manipulated visual experience by providing half of the participants with a 20-s preview of the room. Because our prior research suggests visual information about a room can be stored to aid distance judgments when viewing time is limited, we expected a general performance benefit for all participants exposed to the preview before brief-glimpse trials. To test a differential age effect, we ran two groups of participants, a younger group of college-aged students and a group of older adults aged 65 years and older, using the blind walking response type. If older observers are indeed more reliant on a stored representation when judging the distance of a briefly glimpsed target, a performance benefit (e.g., an increase in response sensitivity and decrease in bias) is expected to be larger for the older observers as compared to the younger observers when exposed to a preview. Alternatively, if prior visual experience is similarly important to both age groups, we expect no differential age effect of the preview. In addition, all brief glimpses were followed by extended viewing trials that provided individual baseline measures.

Method

Participants

Fifty-two students (aged 18–24 years) from The George Washington University participated in exchange for course credit. Fifty-two older adults (aged 65–90 years), recruited from the Washington, DC metropolitan area, participated in exchange for US$10 per hour. All participants were naive to the experiment and had no previous experience with the testing environment.

Prior to testing, the visual acuity of participants was screened using the Optec Vision Tester. Although older adults had diminished acuity relative to younger adults ($p < .001$), all participants scored at 20/70 or better. The Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975) was administered as a screening method for general cognitive impairment. All participants scored 24/30 or above, indicating good cognitive function. Digit and Spatial Spans (Wechsler Memory Scale III; Wechsler, 1997) and the Digit Symbol Coding task (Wechsler Adult Intelligence Scale IV; Wechsler, 2008) were included as measures of short-term memory for verbal and spatial material and perceptual processing speed, respectively. Older adults scored significantly lower on Spatial Span and Digit Symbol Coding tasks (ps < .001), but Digit Span scores did not differ across age, $p = .08$. These data are summarized in Table 1, and analyses are included within the Results section.

Stimuli and Apparatus

Targets were yellow rectangular sheets of foam placed on the floor at distances ranging from 2.5 m–5.0m in 0.25 m increments. Angular target size was held constant and physical size changed with distance so that each target subtended approximately 0.67° × 4.94° of visual angle. Although relative angular size does not affect performance when targets are on the floor (Gajewski, Philbeck, et al., 2014), we held angular size constant in an effort to maintain control of stimulus information and remain consistent with previous work manipulating age (see Gajewski et al., 2015).

Table 1. Means and Standard Deviations of Participants' Demographic Information and Test Scores

	Younger Preview[a]		Younger No-Preview[b]		Older Preview[c]		Older No-Preview[d]	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age (years)	19	1.9	19	1.5	70	4.7	72	7.0
Acuity	20/20	1.5	20/19	1.3	20/28	1.3	20/30	1.4
Digit span	20	4.3	19	4.0	19	4.1	17	4.8
Spatial span	19	2.6	18	3.1	15	3.3	14	3.8
Digit symbol coding	86	13.3	91	18.1	63	14.2	61	12.0
MMSE	30	0.7	29	0.8	28	1.7	28	1.6

[a]n = 26 (19 female, 7 male).
[b]n = 26 (18 female, 8 male).
[c]n = 26 (15 female, 11 male).
[d]n = 26 (17 female, 9 male).

The experiment took place in a large empty room (5 m × 11 m), extending 9.3 m from the observer's viewpoint.

A liquid crystal smart window (LC-Tec, Borlänge) was used to control viewing durations (see Pothier, Philbeck, Chichka, & Gajewski, 2009). Within 2 ms, the window can transition between semiopaque and clear state. Although some light can pass through the window in its semiopaque state, the window has a dense milky appearance that prevents identification of objects on the other side, even if the room is well-lit; in the clear state, the observer can see the target on the ground as well as the floors and walls of the room (see Figure 1). Following each glimpse, a mechanical shutter made visible a colored checkerboard-masking image, which was projected onto a screen positioned to the left of the observer. A beamsplitter angled at 45° allowed this image to be reflected into the smart window and appear straight ahead of the observer. This setup caused the apparatus to obscure a portion of the ground surface on the left (about 1.8 m) and on the right (about 0.8 m). The field of view, as measured from the midline, was approximately 65° × 60° (horizontal × vertical). To prevent head movement and maintain observer's eye height, a chin rest was positioned in front of the window. The apparatus was situated on a rolling stand so that it could be cleared out of the way for walking trials.

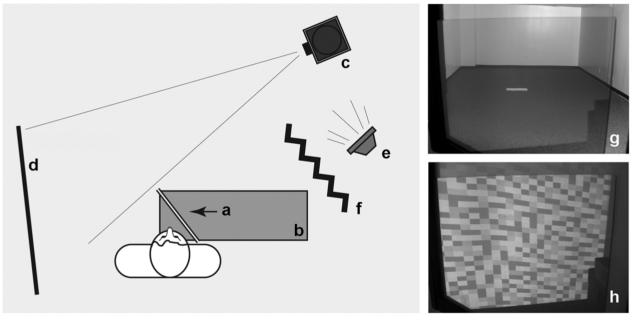

Figure 1. An overhead schematic of the apparatus used to present a brief glimpse of the real-world room to the observer is depicted on left. The observer views the room through a shutter window and beamsplitter (a) that are jointly mounted to a movable stage (b). The mask projector (c) projects the masking image onto the projection screen (d). The floodlight (e) illuminates the target and stimulus environment. The baffle (f) prevents the spillage of light into the staging area. A view through the shutter window when the window is in its clear state is depicted on the top right (g). A view when the shutter window is light scattering (semiopaque) and the colored mask image is reflected in the beamsplitter is depicted on the bottom right (h).

Design and Procedure

Participants were randomly assigned to one of two visual experience conditions (Preview or No-Preview). Half of the participants from each age group were assigned to the Preview condition that provided a single 20-s preview of the empty laboratory room from the same viewing location used in "glimpse" trials immediately prior to testing. Remaining participants were assigned to the No-Preview condition. Participants in the No-Preview group were kept blindfolded until experimental trials began. All participants were exposed to two trial types that differed by viewing durations: Fast ("glimpse") trials and slow trials. These trials were blocked, with fast trials preceding slow trials. This blocking ensured that information gathered at longer viewing durations was not used to improve performance at fast-glimpse durations.

Prior to entering the darkened room, participants donned a blindfold to control visual exposure and hearing protectors to minimize potential contribution of auditory cues during task. Once inside the room, the experimenter oriented participants to the apparatus, highlighting relevant areas of the window (i.e., directing gaze to the general region where ground-level targets appear) with a flashlight. Once all instructions were delivered, lights were turned on and the experiment began. Participants assigned to the Preview condition were then provided a 20-s preview of the room. The preview occurred outside of the window apparatus; the experimenter, with a large piece of cardboard, manually controlled the preview's viewing duration. During this preview, participants were instructed to view the room with their head held steady. Participants assigned to the No-Preview condition did not receive this additional viewing time and immediately began experimental trials.

One brief-glimpse trial was run to acquaint observers with the procedure and to ensure their gaze direction allowed them to see the target. These initial trial durations were longer than those employed in the experimental trials but were sufficiently brief to prohibit execution of eye movements (100 ms and 186 ms for younger and older adults, respectively). A distance judgment was not requested for initial trials. The Fast viewing durations for the current study were selected to be the fastest values that would reliably support target detection for all observers within each age group (40 ms and 88 ms for younger and older adults, respectively). All viewing durations were selected on the basis of performance in the detection threshold task reported by Gajewski et al. (2015). Specifically, the Fast viewing durations here were 1.5 *SD*s above the means for each respective group in that prior study.

After the initial brief-glimpse trial and participant's confirmation of object detection, the walking trials began. Viewing duration was decreased to the age-appropriate Fast duration and the shutter window opened to provide the participant with a glimpse of the room. The experimenter then asked whether the participant saw the target. In the infrequent event that participants failed to detect the object (about 6% of the trials), the trial was rerun at the same viewing duration at the end of the block. If the participant reported seeing the yellow foam target on the floor, the lights were turned off, the apparatus was pushed away, and the object was removed. The participant then indicated the target location by blind walking—that is, attempting to walk to the remembered target location without vision (Philbeck et al., 2008). An experimenter measured the walked distance with a tape measure and then guided the participant back to the starting location, still without vision. No error feedback was provided. Lights were then turned back on and participants prepared for the next trial.

After 11 Fast trials were completed, a second block of 11 longer duration (Slow) trials began. If the participant was assigned to the Preview group, she/he was provided with another 20 s preview of the room prior to the start of Slow trials. If she/he was assigned to the No-Preview group, the Slow trials began immediately following Fast block completion. All Slow trials were run outside of the shutter window apparatus. The participant stood facing the room with a large piece of cardboard held in front of him/her by the experimenter to occlude the room. The experimenter manually controlled the duration of the trial (approximately 5 s) by lowering and raising the cardboard. The participant was instructed to look at the object without moving his/her head. Excluding the duration and the use of the apparatus, the Slow trials were procedurally the same as the Fast trials.

Data Analysis

Performance was analyzed in terms of sensitivity (slopes relating response distance to target distance), bias (percent mean signed errors), and precision (given by the standard error of the estimate for each participant's best-fitting regression line). All analyses were conducted in separate repeated measures Analyses of Variance (ANOVAs). Because differences in some pretest measures were associated with age, correlation and regression analyses were performed to evaluate the predictive value of these assessment measures on performance.

Results

In a preliminary analysis, we screened out participants whose data were exceptionally noisy, which we took to indicate a lack of engagement or a misunderstanding of the task parameters. Toward this end, we calculated r^2 values for responses as a function of target distance for each participant and condition. This yielded a measure of the goodness of fit for the linear functions that best fit the data for each participant. The resulting r^2 values averaged 0.647 and 0.652 for younger and older adults, respectively, showing that linear functions provided good fits to the data for the majority of participants. Four participants, two in each age group, had r^2 values that fell conspicuously below those of the rest of their respective group (0.07 or less) and more than 2 *SD*s outside the mean r^2 values for their group. Accordingly, these participants were excluded from the data analyses presented below in order to provide a more robust estimate of the sample population. With only one minor exception, outlined below, their removal did not qualitatively alter the results.

Three metrics were considered in our primary repeated measures ANOVAs: response sensitivity, bias, and precision. For each of these, because the Slow durations served as controls for the Fast durations for each individual, and we were primarily interested in the between-group differences in performance, interactions with viewing duration were most diagnostic. Observers were generally expected to do better when viewing time was more extended (Gajewski et al., 2010). This would be indicated by a main effect of viewing duration. If older adults improve more when the viewing duration is increased, whether a preview was provided or not, an Age × Viewing Duration interaction would be observed. Critically, the preview was expected to reduce the difference between viewing durations. That is, if the preview is beneficial, performance with brief viewing durations should be more like performance when viewing time is extended. If the preview were generally beneficial (i.e., facilitates Fast performance in both age groups), a Preview × Viewing Duration would be observed. Finally, the primary question of the present study was whether the preview is more beneficial for older adults than younger adults. If so, an Age × Preview × Viewing Duration interaction would be observed.

Sensitivity

Response sensitivity corresponds to the slope of the observer's walked responses in each condition as a function of the actual target distance and is a metric that reflects how well the observer can discriminate the differences between target distances. There was a main effect of viewing duration on response sensitivity, F (1, 96) = 97.722, p < .001, η_p^2 = .504, with increased sensitivity for the longer viewing condition (see Table 2). The effect of viewing duration depended on age, F (1, 96) = 10.067, p = .002, η_p^2 = .095, with older adults benefiting more from extending viewing, t (49) = 8.047, p < .001, than younger adults, t (49) = 5.365, p < .001. That is, older adults' ability to discriminate distances improved more than younger adults across the slow- and fast-viewing durations (see Figure 2). Response sensitivity was generally greater with the preview, though this effect did not reach the level of statistical significance, F (1, 96) = 3.73, p = .056, η_p^2 = .037. However, there was a significant three-way interaction, F (1, 96) = 6.316, p = .014, η_p^2 = .062. (The three-way interaction did not reach the level of significance prior to exclusion of outliers, F(1, 100) = 23.567, p = .062.) The preview substantially diminished the difference across viewing durations but only for the older adults (older: t(47) = 2.235, p = .03; younger: t(48) = −1.113, p = .27; see Table 3). In other words, in terms of response sensitivity, older observers benefited more in fast-viewing conditions when they had prior visual experience with the room environment. There were no other effects or interactions on this metric (all ps > .263).

Table 2. Marginal Means and Standard Errors for Sensitivity (Given by the Slope Relating Response Distance to Target Distance), Bias (Given by the Percent Means Signed Error Across Distances), and Precision (Given by the Standard Errors of the Estimates)

	Sensitivity	Bias	Precision
Viewing Duration			
Fast	0.85 (0.04)	−24.4 (2.2)	0.50 (0.03)
Slow	1.15 (0.03)	−5.5 (1.6)	0.38 (0.02)
Visual Experience			
No-Preview	0.95 (0.03)	−17.8 (2.3)	0.40 (0.02)
Preview	1.06 (0.04)	−12.1 (1.8)	0.48 (0.03)
Age			
Younger adults	1.00 (0.03)	−11.9 (1.6)	0.45 (0.02)
Older adults	1.00 (0.04)	−18.0 (2.5)	0.42 (0.02)
Age × Viewing Duration			
Younger, Fast	0.90 (0.04)	−16.4 (2.5)	0.54 (0.04)
Younger, Slow	1.10 (0.04)	−7.6 (1.7)	0.37 (0.03)
Older, Fast	0.81 (0.05)	−32.5 (3.2)	0.46 (0.03)
Older, Slow	1.20 (0.04)	−3.3 (2.6)	0.39 (0.02)
Visual Experience × Viewing Duration			
No-Preview, Fast	0.78 (0.05)	−29.5 (3.3)	0.43 (0.03)
No-Preview, Slow	1.11 (0.05)	−6.1 (2.5)	0.37 (0.02)
Preview, Fast	0.93 (0.05)	−19.4 (2.7)	0.56 (0.04)
Preview, Slow	1.19 (0.04)	−4.9 (1.9)	0.40 (0.03)
Age × Visual Experience			
Younger, No-Preview	0.92 (0.04)	−15.0 (2.1)	0.38 (0.02)
Younger, Preview	1.07 (0.05)	−9.0 (2.2)	0.52 (0.04)
Older, No-Preview	0.97 (0.06)	−20.5 (4.2)	0.42 (0.03)
Older, Preview	1.04 (0.05)	−15.4 (2.8)	0.43 (0.03)

Bias

Our measure of bias reflects the overall tendency for observers to judge targets as being closer or farther away than their actual position in distance and is reported here as a percentage of the mean signed error (PMSE). Based on prior research (Gajewski et al., 2015), we expected the preview effect to be most prominent on this bias metric. There was a main effect of viewing duration on mean bias, F(1, 96) = 122.276, p < .001, η_p^2 = .560, indicating greater underestimation at fast viewing durations (see Table 2). The effect of viewing duration depended on age, F(1, 96) = 35.580,

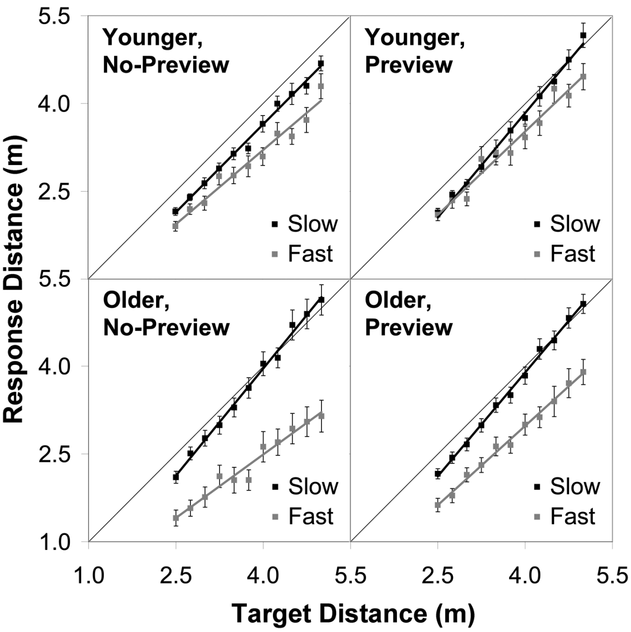

Figure 2. Mean response distance depicted as a function of target distance. Viewing duration was either Fast (40 ms for younger, 88 ms for older) or Slow (5 s). Performance for each of the four groups, differing by age (Younger vs. Older) and condition (No-Preview vs. Preview), are depicted.

Table 3. Means and Standard Errors for Sensitivity (Given by the Slope Relating Response Distance to Target Distance), Bias (Given by the Percent Means Signed Error Across Distances), and Precision (Given by the Standard Errors of the Estimates).

	Sensitivity	Bias	Precision
Younger adults			
No-Preview, Fast	0.85 (0.06)	−20.3 (3.3)	0.43 (0.03)
No-Preview, Slow	1.00 (0.06)	−9.7 (2.3)	0.33 (0.02)
Preview, Fast	0.95 (0.07)	−12.5 (3.7)	0.63 (0.06)
Preview, Slow	1.19 (0.06)	−5.6 (2.4)	0.41 (0.04)
Older adults			
No-Preview, Fast	0.72 (0.07)	−38.4 (5.0)	0.42 (0.05)
No-Preview, Slow	1.22 (0.07)	−2.6 (4.3)	0.41 (0.03)
Preview, Fast	0.90 (0.08)	−26.6 (3.5)	0.49 (0.05)
Preview, Slow	1.18 (0.04)	−4.1 (3.0)	0.37 (0.02)

$p < .001$, $\eta_p^2 = .270$; underestimation in the Fast condition (relative to that in the Slow condition) was greater for the older adults, $t(49) = 10.339$, $p < .001$, than the younger adults, $t(49) = 4.066$, $p < .001$. There was a Preview × Viewing Duration interaction, $F(1, 96) = 6.289$, $p = .014$, $\eta_p^2 = .061$; underestimation in the Fast condition (relative to that in the Slow condition) was greater for the No-Preview condition, $t(48) = 7.35$, $p < .001$, than the Preview condition, $t(51) = 5.97$, $p < .001$. This preview-dependent viewing duration effect of bias is in agreement with the benefit of prior visual experience in previous work (Gajewski, Philbeck, et al., 2014). There were no other significant main effects or interactions in the bias data (all *p*s > .163). Because the three-way interaction was not significant, the results from this analysis do not support the hypothesis that prior visual experience is especially critical for older adults.

Precision

Precision is a metric quantifying the amount of variance in the observer's judgments of distance across trials and is estimated here by the standard error of the estimate (SEE). There was a main effect of viewing duration on precision, $F(1, 96) = 26.722$, $p < .001$, $\eta_p^2 = .218$, with more precise judgments (i.e., lower SEEs) at extended viewing durations compared with judgments at fast durations (see Table 3). There was also a main effect of preview on precision, $F(1, 96) = 5.500$, $p = .021$, $\eta_p^2 = .054$, with less precise judgments (i.e., higher SEEs) on average for participants exposed to a preview. There was a significant Preview × Viewing Duration interaction, $F(1, 96) = 5.662$, $p = .019$, $\eta_p^2 = .056$. Oddly, SEEs were greater in the Fast condition (relative to the Slow condition) only for the Preview group, (Preview: $t(50) = 5.269$, $p < .001$; No-Preview: $t(48) = -1.885$, $p = .066$). This outcome suggests that previews lead to *less* precise judgments of distance. There was also an Age × Viewing Duration interaction, $F(1, 96) = 4.573$, $p = .035$, $\eta_p^2 = .045$, with significantly greater differences across viewing durations (higher SEEs in the fast viewing) for the younger adults, $t(49) = -5.22$, $p < .001$, compared with the older adults, $t(49) = -2.07$, $p = .043$. These findings were somewhat surprising because previews of the room typically do not have a negative impact on precision; that is, past work has shown that previews either lead to no reliable differences in response precision (Gajewski, Philbeck, et al., 2014) or enhanced response precision (Arthur, Philbeck, & Chichka, 2007), at least for manually pointing estimations of nonvisual, whole-body rotations. More research is required to resolve this issue, but for the present purposes, it should be noted that precision patterns are the same across age groups. There were no other significant main effects or interactions in the precision data (all *p*s > .056).

Performance as a Function of Pretest Measures

Pearson correlations were run on the slope, PMSE, and SEE differences between fast and slow conditions for all participants. Slope differences were significantly correlated with visual acuity, $r = .215$, $p = .032$, and spatial span, $r = -.223$, $p = .025$. Subsequent regressions were run including these factors as predictors along with our measures of interest. As in our primary analyses, the effect of preview on slope differences depended on age, both *p*s < .016. Mean bias differences were significantly correlated with Spatial Span Scores, $r = -.212$, $p = .034$, and Digit Symbol Coding scores, $r = -.243$, $p = .015$. Similarly, inclusion of these predictors along with our measures of interest showed an effect of preview on the bias difference (both *p*s < .05) that was not dependent on age (both *p*s > .10). It should be noted, though, that performance in our task and the pretest measures were not significantly related when age was included as a partial correlate, *p*s > .14. Thus, while age predicts primary task performance even when pretest measures are statistically controlled for, the pretest measures do not predict primary task performance when statistically controlling for age. SEE differences were not significantly correlated with any pretest measures, all *p*s > .380.

Discussion

In this study, we investigated the role for prior visual experience on judgments of egocentric distance. We argued based on prior research that having access to a stored spatial representation of the environment enhances the computation of distance at limited viewing durations across ages (Gajewski et al., 2010; Gajewski, Philbeck, et al., 2014). The results of the present study were in alignment with the expectation that prior visual experience provided by a preview of the room enhances performance generally. In particular, regardless of age group, underestimation was less substantial with brief viewing durations when the room was seen in advance. In addition, the design of the present study was unique in its use of extended viewing trials as baselines. It was not clear from prior work whether having seen the environment in advance would have the same impact on performance as viewing the environment along with the target during a single, extended-viewing episode. Here, we find that performance with the preview, though better than without, generally did not eliminate the advantage associated with extended-viewing time. Thus, though the preview is not as beneficial as having *online* access to contextual information, our findings suggest that having a memory representation of the context does aid the observer on distance judgments when viewing time is limited.

Of particular interest here was whether older observers would rely more heavily on stored contextual information when viewing time was subsequently more limited. Although there was an increased benefit of prior visual experience for older adults at fast-glimpse durations, this benefit did not manifest equally across the sensitivity, bias, and precision measures. In previous work, prior visual experience given by a visual preview of the room (Gajewski, Philbeck, et al., 2014) or suggested by viewing duration, block-order effects (Gajewski et al., 2010) primarily reduced the bias toward underestimation typically observed with brief-glimpse durations. The overall pattern of results suggest prior visual experience is at least somewhat more important for older observers, but the age-associated memory reliance is not as robust as predicted.

Although our paradigm differs from previous work demonstrating age-related declines in cognitive functioning related to spatial navigation (see Moffat, 2009, for review), it depended on a measure that could be linked to path integration differences. By including longer viewing durations, we could compare young and older adults on their ability to maintain and update their spatial location during their walked response. Because older and younger adults did not differ in walked distance estimations at these longer viewing durations, age-related differences in path integration were unlikely to account for performance differences under brief glimpses in our study.

The take home message from the current work is twofold. On the one hand, we do provide some evidence that information stored from prior episodes is important for older adult performance. This outcome connects to prior work outside the domain of distance perception implicating a special role for knowledge structures in the organization of incoming visual information for older adults (Hess, 2005; Hess & Slaughter, 1990). On the other hand, the present work also highlights a task environment where older adults are not substantially impaired. Even without a preview of the room, older adult performance with 88-ms glimpses is remarkably well constrained (slopes relating response distance to target distance near 1). Gajewski et al. (2015) argued that detection of the target affords the observer access to its visual direction, and this coupled with the ability to assume it is on the ground is enough to support use of the most primary distance cue, angular declination. Under these conditions, in which a salient target is placed at floor level on a horizontal ground plane, an observer has some sense of target distance as long as the object is detected. These conditions did not tax the memory of the older adults—in fact, working memory and acuity deficits did not account for age-related differences in distance estimations. Thus, the greatest factors in time-pressured distal localization, regardless of age, are factors that increase the likelihood of detection, such as the use of bright colors to increase target saliency.

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