CONTEXT PROCESSING AND AGING: OLDER ADULTS' ABILITY TO LEARN AND UTILIZE VISUAL CONTEXTS

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Context Processing and Aging: Older Adults' Ability to Learn and Use Visual Contexts

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

DOCTOR OF PHILOSOPHY

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ABSTRACT

The purpose of the present study was to examine how older adults utilize contextual information to guide attention in visual scenes. Studies that have examined context and attentional deployment have used the contextual cueing task. Contextual cueing reflects faster responses to repeated spatial configurations (consistent context-target covaration) than random spatial configurations (inconsistent covariation). Research has shown mixed results in older adults' ability to utilize context with this task. Young (18-23 years) and older (60-85 years) adults were tested in two contextual cuing experiments to assess age differences in how individuals utilize context in novel and real-world visual scenes. Experiment 1 investigated the development of contextual cueing effects using low-meaning visual contexts (letter arrays). In low-meaning arrays, young and older adults were able to use context effeciently with no age differences in the development of contextual cueing effects. Experiment 2 examined older adults' ability to utilize context when context was meaningful (real-world images). Younger and older adults saw real-world images in an upright (meaningful) or inverted (less meaningful) orientation. Older adults were able to use context similarly to younger adults, with no age differences in the development of contextual cueing. Contrary to predictions, context utilization was not impacted by the meaningfulness of the image. Contextual cueing effects occurred at the same time for upright and inverted images for young and older adults. Together, these studies demonstrated that older adults were able to utilize context. Meaningfulness did not provide an additional benefit for older adults, but this was true of young adults.

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CHAPTER 1: INTRODUCTION

Context is broadly defined as a set of circumstances that surrounds an event and helps to clarify the meaning of that event. Within the field of psychology, the specific definitions of context have varied by the areas in which it is studied. For instance, in memory, context has been defined as the environment in which a person has learned and recalled information (Godden & Baddeley, 1975). In language processing, an example of context is the sentential information (e.g., subject of the sentence) that disambiguates the meaning of a word, or the paragraph information that disambiguates the meaning of a sentence (Foss, 1982). In attention, context has been defined as the stimulus information that is used to predict upcoming target information or that helps determine the location of an object (Goldman-Eisler, 1958). Although the definitions of context have varied, consistent across these definitions is the cognitive benefits of context (Godden & Baddeley, 1975; Jefferies, Lambon-Ralph, & Baddeley, 2004).

People use context to remember, comprehend, and predict information. An important question within the field of cognitive aging is whether there are age-related changes in how individuals use context to guide cognitive processing. For example, memory studies have shown that, in general, older adults have poorer episodic memory than young adults (Craik, 1977; Zacks, Hasher, & Li, 2000), but older adults use contextual information to effectively improve memory (Craik, 1994; Craik, Byrd, & Swanson, 1987; Smith, Park, Earles, Shaw, & Whiting, 1998). Older adults also utilize contextual information within sentences to comprehend and predict words (Federmeier & Kutas, 2005; Federmeier, McLennan, De Ochoa, & Kutas, 2002).

Attention studies have shown disparate patterns in older adults' ability to use context. For example, in some studies there is an age-related decline in context utilization (Braver et al., 2001; Braver, Saptune, Rush, Racine, & Barch, 2005; Paxton, Barch, Storandt, & Braver, 2006;

Rush, Barch, & Braver, 2006), while in other studies there is relative age constancy in the contextual guidance of attention (Balota, Black, and Cheney, 1992; Burke, White, and Diaz, 1987; Langley, Saville, Gayzur, & Fuentes, 2008). What accounts for the disparity? The purpose of this dissertation was to determine the conditions under which older adults utilize contextual information to deploy attention in visual scenes. In the following sections, I review literature that has examined age differences in non-spatial contextual guidance of attention. Then, I review literature that has examined how younger and older adults learn and utilize context in visual scenes.

Aging and Context Processing

Context processing theory states that older adults have difficulty representing context due to age-related changes in the dorsolateral prefrontal cortex (DL-PFC) and the dopamine system (Braver & Barch, 2002; Braver et al., 2001). These neural changes lead to: (a) a reduced ability to detect associative patterns over time, and (b) a reduced ability to use these associations to bias stimulus-response patterns towards certain responses. Braver and colleagues (2001; 2005), using an AX-Continuous Performance Task (AX-CPT), found that older adults were able to learn but not use context. In other words, evidence suggested that older adults were able to detect associative patterns, but they did not use this knowledge to bias responses. In the AX-CPT, participants viewed a stream of letters. Associations between novel letter pairs (i.e., AX trials) were created with frequent pairings (70% of trials). The researchers hypothesized that young adults would be sensitive to this regularity (increased proportion of AX trials), and when presented with an “A,” they would prepare a detection response with the expectation that a target (“X”) would appear next. In contrast, older adults, who were predicted to be less sensitive to the regularity, would not prepare responses before seeing the target letter. The predictions of Braver et al. (2001) were mostly supported (Braver et al., 2005; Paxton et al., 2006; Rush et al., 2006). Young adults anticipated an upcoming letter, but older adults did not respond in an expectant fashion without additional exposure to the task (300 trials instead of 100 trials; Paxton et al., 2006). Questions presented after participants completed varying number of trials revealed that older adults were aware of the frequent pairing within the first 100 trials, which suggested that they were able to learn the context quickly but took longer to use this information in a predictive manner.

With the AX-CPT, regular letter pairings created the context to anticipate upcoming letters. In a similar vein, word associations in the semantic priming task create the context to anticipate future words. Participants view a prime word followed by a target word (e.g., “DOG” followed by “cat”). The semantic priming effect reflects faster responses to targets preceded by semantically related primes (“DOG”-“cat”) than to those preceded by unrelated primes (“CHAIR”-“cat”) or neutral stimuli (“xxxx”-“cat”). Similar to the AX-CPT, certain words can be paired more often than others to create an expectation that certain targets will follow certain primes. (If unrelated words are regularly paired, individuals respond to those pairs more quickly than infrequently-paired semantically related words based on the expectancy developed across trials; Posner & Snyder, 1975). On semantic priming tasks, young and older adults responded faster to expected words compared to unexpected words (expectancy effect; Balota et al., 1992; Burke et al., 1987; Langley et al., 2008). Contrary to the findings from Braver and colleagues (2001), in the semantic priming task, young and older adults learned the predictive nature of the prime and quickly (within 20 trials) used that context to bias responses (Langley et al., 2008). In my master’s thesis, I examined how context was learned. Participants (young and older adults) gave a self-report response (e.g., out of 100 trials, how many were unrelated?). I found that both groups were able to explicitly state that there were more unrelated trials. Thus, older adults were able to explicitly state the regularity of the word pairings (on most trials, the prime word was followed by a word from the other prime's semantic category) and use that regularity to bias their responses.

With the AX-CPT, older adults needed more exposure than young adults to utilize context (Paxton et al., 2006). In contrast, with a semantic priming task, older adults were able to use context as quickly as young adults (Langley et al., 2008). Why were older adults able to utilize context so quickly in the semantic priming task? One explanation could be that meaningful associations between words are established in long term memory. Even though the words are unrelated, participants can tap into long term memory resources to help guide attention, which may make the regularity easier to detect, leaving available resources for response selection. Thus, if context is meaningful, older adults may be more efficient at context utilization. Since the letter associations in the AX-CPT task were relatively novel, older adults may have needed more exposure to efficiently utilize context (Paxton et al., 2006).

Context in Novel Visual Scenes

The previous section reviewed how older adults use attentional processes to predict upcoming targets. Individuals can also use contextual information to guide attention spatially. In everyday life, people interact with complex visual environments. In order to efficiently navigate through these environments, what guides attentional deployment? Attention can be guided by bottom-up (stimulus-driven) features of items (e.g., color, shape, size, location) and by top-down (knowledge-based) factors (Treisman & Gelade, 1980). If a display item differs on a unique characteristic (e.g., a red car in a parking lot full of black cars), the unique item (the red car) "pops out". In this case, attentional deployment is highly efficient, and the target is located quickly, regardless of other visual elements (e.g., number of black cars). If goal relevant items share features with other items (e.g., a red car in a parking lot with red trucks and black cars), top-down processes play a prominent role in performance (i.e., the observer must know what s/he is searching for). In this case, attentional deployment is less efficient, and goal relevant items take longer to locate. Unlike feature-based guidance, top-down attentional guidance for targets defined by a conjunction of features can be affected by the number of visual elements in a visual scene (Treisman & Gelade, 1980).

With visual search tasks, older adults are typically slower than young adults and are less accurate at findings targets in an array (Madden & Whiting, 2004; McDowd & Shaw, 2000). Age differences are minimal when search is highly efficient, such as with feature search (Plude & Doussard-Roosevelt, 1989; Whiting, Madden, Pierce, & Allen, 2005), but are greater with more complex search displays, such as in conjunctive search when the target is a combination of features that are shared with other items (e.g., Hommel, Li, & Li, 2004; Humphrey & Kramer, 1997; Oken, Kishiyama, & Kaye, 1994; Plude, Enns, & Brodeur, 1994; Trick & Enns, 1998). In other words, older adults show more difficulty with top-down guidance of attention than with the bottom-up guidance of attention.

Scene context contributes to the guidance of attentional deployment (Chun, 2000; Chun & Jiang, 1998). Using novel spatial associations between letters, Chun and Jiang demonstrated that people use the spatial predictability of items to guide attention in visual scenes. In the contextual cueing task, participants identify the orientation of a target (e.g., a “T”) among distractors (e.g., “L’s”). The visual arrays are presented in new and repeated spatial configurations. In new configurations, the location and orientation of the target and distractors vary randomly, while with repeated configurations, the spatial location of target and distractors remains the same across trials. The orientation of the distractors remains the same, but the orientation of the target changes. The repeated trials are shown over many trials, intermixed with the new trials. In Chun and Jiang’s study, participants (young adults) learned the spatial associations between the targets and distractors of the repeated trials and used those associations to guide attention to the target. Participants responded to repeated configurations more quickly than new configurations, which was called the contextual cueing effect.

To examine if participants implicitly learned the visual context, they were asked if they noticed that the configurations repeated. Participants then completed a recognition task in which they were shown the repeated configurations (shown in the previous task) and new configurations (not previously seen in the task). Participants did not notice that the trials repeated and performed at chance levels on the recognition task (did not recognize the repeated configurations). Chun and Jiang (1998) concluded that participants incidentally learned the spatial configurations and used that contextual information from implicit memory to guide attentional deployment.

How do we interpret the results from the contextual cueing task? Chun (2000) stated that visual scenes are complex and contain copious amounts of information. There is predictable covariation (spatial association) between elements in a scene (Biederman, 1972; Chun & Jiang, 1998; Hollingworth & Henderson, 1998). According to Chun, knowledge of this covariation can reduce the complexity of the visual scene. This top-down knowledge of the scene has been argued by Chun and Jiang (1998) to be incidentally learned in an instance-based fashion (for review of instance theory see Logan, 1988). As the contexts repeat, participants encounter that information over and over (increased instances), which is subsequently stored in implicit memory. This contextual knowledge can then be used to deploy attention in visual scenes to locate a target quickly and efficiently (Chun, 2000).

Context in Real-World Visual Scenes

Chun and Jiang (1998) argued that we learn spatial covariations implicitly. However, in real-world situations, there are many spatial covariations that can be explicitly stated. For instance, a coffee table is in front of a couch in a living room. Brockmole and Henderson (2006; Experiment 1) questioned if we implicitly learn context/spatial associations in real-world scenes. In their study, participants viewed photographs of real-world scenes (full color images) and identified a small, grey target (the letter “T” or letter “L” presented in 9 point font). In the repeated condition, the same scenes were shown multiple times (once per block), and the target appeared in the same location within a scene. In the new condition, new, unrepeated scenes were shown in each block, and the target appeared at random locations within the scene. Brockmole and Henderson found that participants demonstrated a contextual cueing effect (faster responses to repeated than new configurations), and the effect occurred faster (after about 4 repetitions) than with a typical contextual cueing paradigm (12 repetitions or more). When examining the difference in response times for repeated and new configurations, the effect was also greater in magnitude for this task than a typical contextual cueing task (participants were even faster to respond to targets in the repeated configurations than in the new configurations). The overall response times were greater in the Brockmole and Henderson study (3800 ms on average) compared to the Chun and Jiang study (1100 ms on average). However, in the Chun and Jiang study, participants showed a contextual cueing benefit of 60 – 80 ms, while in the Brockmole and Henderson study, participants showed a contextual cueing benefit of over 2 seconds. Overall, participants learned the visual context faster, and the contextual cueing effect was greater. Thus, the use of meaningful stimuli provided an additional context benefit.

Brockmole and Henderson (2006) examined how participants learned the context. Participants were shown the images from the search task (with the target removed) and new images. If an image was reported as old, participants placed a blue dot (the approximate size of the target letter) in the area where they previously saw the target. Participants reliably recognized repeated images (97% hit rate). The average distance between the actual location of the target and where the participant placed the dot was smaller for the repeated images (1.7 cm) than for images shown only once during the task (9.3 cm). Brockmole and Henderson concluded that not only did participants learn the images explicitly, but that participants learned the covariation between the elements in the image and the target explicitly.

In Experiment 1, Brockmole and Henderson (2006) demonstrated that meaningful context provided an additional benefit. To examine this, the authors manipulated meaningfulness by inverting the background images that were used in Experiment 1 (vertically rotated 180°) with new participants. Inverting pictures has been shown to affect how we cognitively process information (Klein, 1982; Rock, 1974). Thus, presenting pictures upside down would dampen (but not eliminate) the meaningfulness of the scene but would not eliminate the spatial relations between the items in the scenes (only rotate them). If meaningfulness impacts how context of real-world scenes is utilized, the influence of contextual information on the spatial deployment of attention would be dampened as compared to the upright images. This would, in turn, affect the time course and magnitude of the contextual cueing effect. Contextual cueing effects would take longer to develop and would be reduced in magnitude. As predicted, Brockmole and Henderson found that contextual cueing effects developed for inverted pictures, but it required about twice as many repetitions as upright pictures in Experiment 1. This finding suggests that the semantic meaning within the scenes impacted how efficiently participants utilized context.

Context in Visual Scenes and Aging

How do older adults utilize context in visual scenes? Howard, Dennis, Howard, Yankovich, and Vaidya (2004) examined if older adults were able to implicitly learn the spatial covariation using a contextual cueing task. Young and older adults identified the orientation of a target letter ("T") among distractors ("L's"; Experiment 1). Both groups showed a significant contextual cueing effect (faster to respond to targets in repeated configurations than new configurations). No significant age differences were found in the contextual cueing effect or in how quickly the two groups utilized context. Participants were then given a recognition task, and both young and older adults performed at chance levels. Howard and colleagues concluded that older adults implicitly learned the spatial covariations in the contextual cueing task. Although age differences in cueing effects were not statistically significant, my review of the data figures (mean reaction times plotted for repeated and new configurations across blocks of trials) noted that older adults had cueing effects that were slower to develop than those of young adults. Young adults appeared to show significant contextual cueing effects after approximately 10 repetitions, whereas older adults appeared to show contextual cueing effects after approximately 20 repetitions. Thus, it is possible that the Howard et al. study had insufficient power to detect age differences.

Noting the unexplored age disparity in the Howard et al. (2004) findings, Smyth and Shanks (2011) repeated the experiment but decreased the total numbers of trials (384 trials for Smyth and Shanks vs. 720 trials for Howard et al.). They argued if older adults did not show a contextual cueing effect with a decreased number of trials, this would be indirect evidence that it took older adults longer to utilize context. Young adults showed a consistent contextual cueing effect, but surprisingly, older adults did not (no significant differences in the responses between new and repeated contexts) at any time point. Together, the findings of Howard and colleagues (2004) and Smyth and Shanks (2011) suggest, but not conclusively so, that older adults are able to utilize context but only with greater exposure to the task.

With real-world scenes, Brockmole and Henderson (2006) demonstrated that semantic meaningfulness can be an additional resource to guide attentional deployment. As of yet, no studies have examined how older adults utilize the context in meaningful visual scenes to guide attention. It could be that with support from this contextual information, older adults would have additional cognitive resources to aid them in utilizing context quickly.

Spatial and Non-Spatial Contextual Guidance

There are similarities and differences between the spatial and non-spatial contextual tasks presented here. Both sets of tasks involve regularly pairing a target with surrounding information (e.g., cues or distractors) that participants must learn over several trials. However, the AX-CPT and the contextual cueing task (Brockmole & Henderson, 2006; Chun & Jiang, 1998) created novel associations (not established in memory) between the target and surrounding information, while the semantic priming task utilized pre-existing associations between word pairs.

How do these results of the spatial and non-spatial context tasks fit together? These studies demonstrate how context can guide attention. Overall, these studies have shown that when information is less meaningful (i.e., not in semantic memory), participants can learn to use context, but older adults may take longer than young adults to use that context (Braver et al., 2001; Paxton et al., 2005; Smyth & Shanks, 2011). When information is meaningful, participants (young and older) can use context quickly as compared to when information is less meaningful

(Brockmole & Henderson, 2006; Gayzur, 2008; Langley et al., 2008). However, this has not been examined with meaningful spatial context and older adults.

Present Study

The purpose of the present study was to examine if older adults are able to learn and utilize context when given additional resources, either through more exposure to the task or through increased meaningfulness. The first study examined how quickly older adults could learn and use context in novel visual arrays. Howard and colleagues (2004) found small non-significant age differences in context utilization. Consistent with this finding, Smyth and Shanks (2011) found an age-related reduction in contextual cueing effects when trial number was reduced. Experiment 1 of the present study directly measured how quickly older adults learned and used context in novel visual arrays. Because this task used novel associations between low-meaning stimuli (letters), and because there were no additional resources (e.g., long term memory) for older adults to rely on, I predicted that older adults would take longer to utilize context compared to young adults.

Chun and Jiang's (1998) study approximated the stable nature seen in static visual scenes, but Brockmole and Henderson (2006) demonstrated that more than spatial invariance is construed in real-world images. Their study showed that there are other contextual regularities, such as meaning in the placement of objects within a visual scene (e.g., a coffee table is placed in front of a sofa and not behind it), that are not accounted for in a typical contextual cueing task (Brockmole & Võ, 2010). Contextual regularities (e.g., semantic, social, and cultural meanings) are represented in long term memory. People can rely on their knowledge and memory of these exemplars of scenes to further reduce the complexity of the visual scene (Chun & Turk-Browne, 2008). This context information can guide attention in scenes to efficiently search for a goal-relevant target (Bar, 2004). People can use this context even if the association between the target and background is novel.

The second question my dissertation addressed was: When manipulating context meaningfulness in real-world visual scenes, does older adults' spatial attention benefit from context meaningfulness? Experiment 2 compared context learning and utilization for young and older adults using meaningful stimuli. Previous results, on non-spatial tasks, have shown that when meaningful information was used (e.g., word pairings), older adults were able to utilize context as effectively as young adults (Balota & Duchek, 1991;Balota et al., 1992; Burke et al., 1987; Chiarello et al., 1985; Craik, 1994; Craik et al., 1987; Gayzur, 2008; Langley et al., 2008; Smith et al., 1998). Based on these findings, I predicted that on the Brockmole and Henderson (2006) contextual cueing task, older adults would efficiently utilize contextual information in visual scenes when images were presented upright. When stimuli were less meaningful (inverted images), older adults would still use context but would take longer than young adults to do so.

CHAPTER 2: EXPERIMENT 1

This experiment investigated how quickly older adults learn to utilize contextual information for novel associations (associations not established in long term memory). Young and older adults completed a contextual cueing task (find a “T” among “L’s”), similar to that used by Howard et al. (2004; Experiment 1), in which participants made an orientation judgment about the target letter (“T”). Because the context was low in inherent meaningfulness, I predicted that older adults would show a contextual cueing effect, but that they would require more exposure than young adults before demonstrating a context benefit.

While previous findings suggested that older adults’ developed context benefits slower than young adults (Howard et al., 2004; Smyth & Shanks, 2011), the patterns were not strongly supported statistically. In one case (Howard et al., 2004), mean scores indicated that older adults were slower to develop contextual cueing effects than younger adults, but this pattern was not supported by an interaction between age, cueing condition, and block. In the second case (Smyth & Shanks, 2011), young adults developed significant cueing effects, but older adults did not. However, there were not enough trials to determine whether older adults would eventually develop cueing effects. In an attempt to more directly capture these inferred age differences in the contextual guidance of attention, I modified the contextual cueing task by reducing the number of repeated configurations. Howard and colleagues (2004) and Smyth and Shanks (2011) used twelve different configurations that were repeated in each block of trials, whereas I used eight repeated configurations. With fewer unique configurations to learn, the cognitive load of the task would be reduced, and both young and older adults might show contextual cueing effects after fewer repetitions. Howard and colleagues found that older adults demonstrated contextual cueing effects after approximately 20 repetitions. Smyth and Shanks (2011) found that older adults did not demonstrate context effects after 16 repetitions. Fewer configurations would also allow time for more repetitions of the displays. Whereas Howard and colleagues repeated twelve configurations 30 times and Smyth and Shanks repeated twelve configurations 16 times, in the present study, the eight configurations were repeated 40 times. The goal was to provide sufficient time for both age groups to develop cueing effects, with the expectation that young adults would be guided by context more quickly than older adults.

To assess the manner in which context was learned, Howard and colleagues (2004) and Chun and Jiang (1998) collected recognition data and calculated the proportion of trials that participants recognized a configuration as previously viewed. They found that "old" responses were around .50 in both repeated and new conditions, which indicated that participants were as likely to indicate that a new configuration had been presented earlier as a repeated configuration. Howard and colleagues found a similar pattern for both young and older adults. From this, they concluded that participants *implicitly* encoded the configuration information. This finding supported previous research that has shown relatively few age differences in implicit memory (Light & Singh, 1987). I predicted that the recognition scores would be similar for young and older adults, which would indicate that both young and older adults did not recognize the repeated configurations and that both groups implicitly learned and benefitted from the context. Paxton and colleagues (2006) found that older adults were able to quickly learn context (within 100 trials) but were not able to use that context without more exposure to the task. Consistent with the revised context processing theory (Paxton et al., 2006), I predicted that older adults would learn the context, but that they would not use the context to guide attention without sufficient exposure to the task.

Method

Participants

Thirty-four young adults (18-21 years) and 34 older adults (60-85 years) completed Experiment 1. Young adults were students at North Dakota State University who received course credit for participating, and older adults were from the Fargo-Moorhead community and received $10 per hour for participating. Older adults were recruited by means of the participants registry used by the Cognitive Aging Lab and at presentations given at senior apartments. A self-report health screening questionnaire (Christensen, Moye, Armson, & Kern, 1992) was used to screen for medical conditions that could impair cognitive functioning (e.g., heart disease, stroke, neurological diseases such as Parkinson's disease, and drug or alcohol abuse). All participants had English as their first language and a minimum of a high school education. Corrected near visual acuity was 20/40 or better as assessed with a Snellen eye chart (Precision Vision, La Salle, IL). All participants included in the data analysis scored 9 points or lower on the Geriatric Depression Scale (GDS; Yesavage & Brink, 1983), indicating minimal depressive symptomology, and 26 points or higher on the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), to demonstrate no significant cognitive impairment (including dementia). Participants that did not meet the inclusion criteria listed above were excluded from the data analyses. Ten older adults were excluded (nine older adults had health issues; one older adult had a high depression score). Their data were replaced with data from new participants. Data for the included participants can be seen in Table 1.

Materials

The visual search arrays were presented on a 17 inch color monitor controlled by a PC computer. Responses were made on a PST serial response box (Psychology Software Tools, Pittsburgh, PA). A chin rest maintained the participant's viewing distance at 40 cm. The experimental task was created using Presentation version 12.1 (Neurobehavioral Systems, Albany, CA). Twelve black letters (11 distractor "L's" and 1 target "T") were presented against a white background. The target letter ("T") was presented horizontally with the top of the letter directed to the left or right. Distractor "L's" were presented randomly rotated 0°, 90°, 180°, or 270°. Each letter subtended 1.1° of visual angle. Letters were randomly placed into cells of an invisible 6 × 8 (rows × columns) grid (48 total locations) and were jittered slightly (±2 pixels along each axis) within a cell to avoid possible colinearity. A set of eight arrays was randomly constructed for repeated configurations. Across trials, the target and distractors appeared in the same locations for these configurations. The distractors remained in the same orientation, but the target randomly changed orientation (left or right) from trial to trial. For new configurations, the distractor locations and orientations were randomly determined. Across configurations, the target letter was presented equally on the left and right side of the screen. The locations of the target were restrained so that the target appeared only in 24 non-central locations (12 left, 12 right; Figure 1) for both repeated and new configurations. Without constraining, the target could appear anywhere in the array in the new condition, but only a few select locations in the repeated condition, which would cause target likelihood effects and confound the contextual cueing effect (Chun & Jiang, 1998; Howard et al., 2004). Distractor locations, in both configuration conditions, were sampled from all possible locations in the array, including potential target locations.

Table 1

Demographic and Psychometric Data for Participants in Experiment 1 and 2

	Experiment 1				Experiment 2			
	Mean		SD		Mean		SD	
	YA	OA	YA	OA	YA	OA	YA	OA
Age (yrs)	18.7 *	72.7	1.1	6.6	19.3 *	69.4	1.6	6.8
Education (yrs)	12.6 *	14.9	1.0	2.7	15.1 *	12.9	1.1	2.6
WASI vocabulary (80 max)	55.1 *	64.2	5.6	7.6	53.6 *	64.4	6.2	8.1
Snellen acuity (20/___)	16.1 *	27.1	3.8	6.2	15.6 *	24.0	2.6	6.8
Color vision (11 max)	10.7	10.1	0.5	2.4	10.8	10.3	0.4	1.6
MMSE (30 max)	29.1	29.4	1.0	1.0	29.2	29.2	0.8	1.0
GDS (30 max)	1.9	2.0	1.1	0.7	1.1	1.6	1.6	2.1

Note. SD = standard deviation; YA = younger adult group; OA = older adult group; WASI = Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999). Maximum score on the vocabulary subscale is 80 points, with a higher score indicating better performance. Snellen acuity = denominator of the Snellen fraction for corrected near vision. A smaller number indicates better vision. Color vision was assessed with the Ishihara color plates. Maximum score was 11, with a higher score indicating better color vision. MMSE = Mini Mental State Examination. Maximum score is 30 points, with a higher score indicating better performance. GDS = Geriatric Depression Scale. Maximum score is 30, with a higher score indicating greater depression. An asterisk (*) indicates that mean scores differed between age groups according to an independent samples *t* test. Older adults were greater in age, had higher education, and had better vocabulary scores than younger adults. Younger adults had better visual acuity than older adults.

T	T	T			T	T	T
T	T	T			T	T	T
T	T	T			T	T	T
T	T	T			T	T	T

Figure 1. Possible target locations in Experiment 1. Targets could appear in the locations denoted with a “T.” Distractors could appear anywhere in the 6 × 8 grid.

Procedure

The testing session, including consent, screening, and computer task, lasted approximately 1.5 hours. For the computer task, participants completed a short practice block of 16 trials to orient them to the task. The configurations from the practice trials (all new trials) were not used in the experimental task. Both the practice and experimental trials began with a black fixation dot (.43° of visual angle) centered on the screen (see Figure 2 for the sequencing of a sample trial). After 500 ms, the dot was replaced by a search array (repeated or new). Participants were told to locate the “T” in the array and press a key to indicate the target orientation. If the top of the letter “T” was on the left, participants pressed the left button, and if the top of the “T” was on the right, participants pressed the right button. The trial ended (and the display was removed) when the participant responded. If a participant did not respond within 8,000 ms, the trial terminated (Howard et al., 2004). A 1,000 ms intertrial interval of a white screen was presented before the next trial began. Participants were instructed to respond as quickly as possible but not so quickly that they made mistakes.

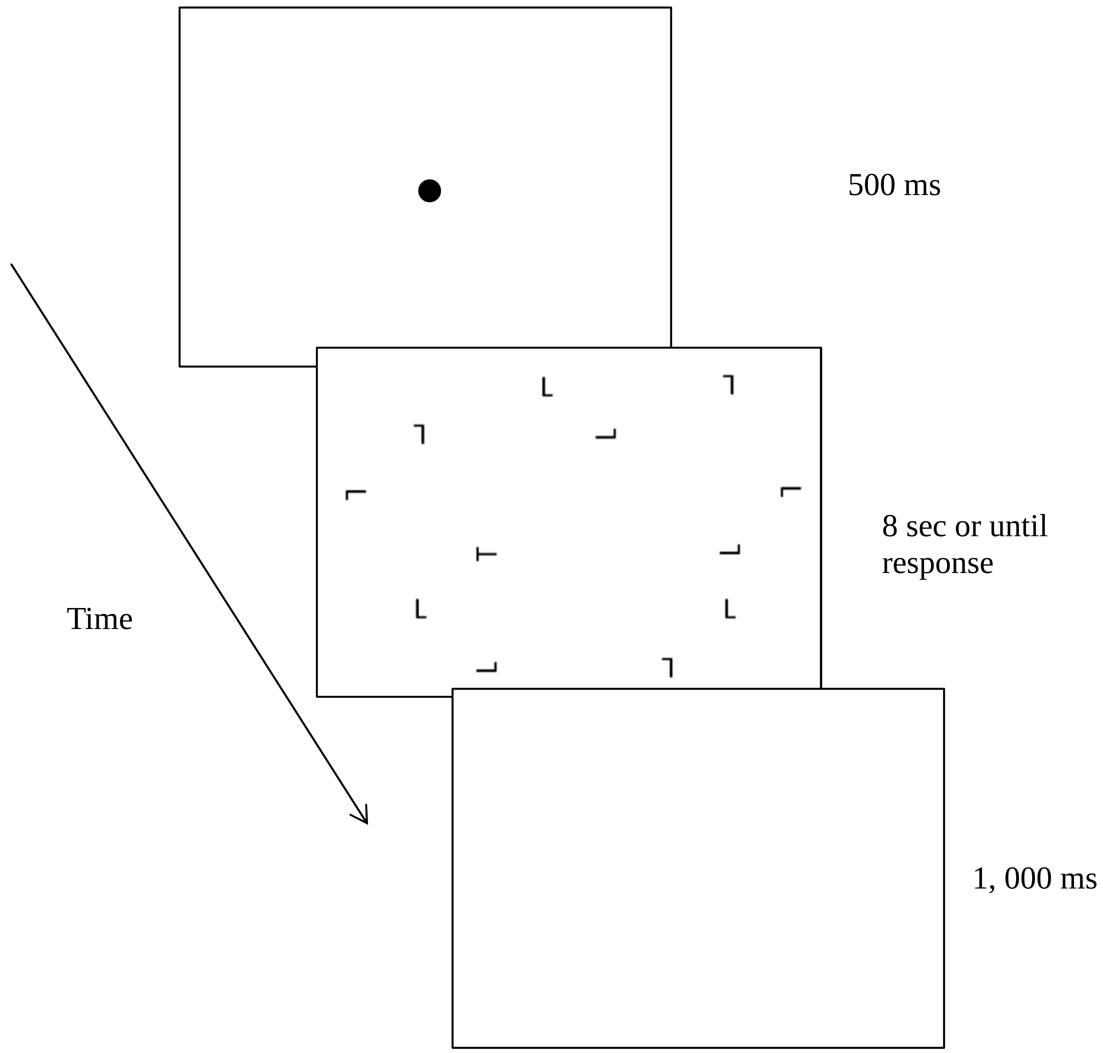

Figure 2. Sample trial sequence for Experiment 1. Stimuli are not sized to scale.

During the practice trials participants received accuracy feedback (the words “correct”, “incorrect”, or “no response detected” in the center of the computer screen) to ensure that they understood the task, but feedback was not given during the experimental trials. After the practice block (in which none of the arrays repeated), young and older adults completed 40 blocks of 16 trials (640 trials total). Each block consisted of eight repeated configurations and eight new configurations. The eight repeated configurations appeared once in each block but varied randomly in the order of presentation. The new configurations changed from block to block. Participants were encouraged to take short breaks between blocks.

After the final block of the search task, participants were given a recognition task and a target localization task. Both tasks consisted of 24 trials. The arrays presented on the trials consisted of the 8 repeated configurations (seen in the search task), 8 configurations from the new condition that were seen once, and 8 configurations that were not shown in the task and that were randomly generated for the memory task. All of the configurations were presented in a random order. For all trials, only L's were shown to participants. For the repeated and presented once trials, the T that had been presented during the experimental trials was replaced with an L. On each trial participants were asked if they saw "this display in the previous task." Participants made a "yes" or "no" response by moving the cursor (via the mouse) to the appropriate response. After the response to the configuration, participants completed a target recall task in which they placed a black dot on the location where they believed the T had been presented during the experimental trials. Participants were instructed to guess if they were unsure. No feedback was provided.

Results

Reaction Times for the Search Task

Trials with reaction times (RTs) that were 2.5 standard deviations from the condition mean for an individual were eliminated. Mean RTs for correct trials (after removing outliers) were calculated for each set of repeated and new configurations in each block, then averaged across blocks to yield a repeated and a new configuration RT for each five-block epoch (8 epochs with 80 trials in each epoch, 40 repeated trials and 40 new trials). Data were submitted to a 2 × 2 × 8 mixed analysis of variance (ANOVA), with age group (young and older adults) as a between-subjects variable, and configuration (repeated and new configurations) and epoch (1 through 8) as within-subjects variables. Since the epoch variable had more than two levels, I conducted Scheffe's post hoc tests to examine the nature of the significant effects. Scheffe's test not only examines the pairwise comparisons but also the complex comparisons (interactions). One older adult was excluded because his/her error rates were over 20%, and this person was replaced with data from a new participant. Data for the excluded participant was not represented in the demographic data or the analysis of the results. Data for all included individuals (same as the participants in the demographics table) are in Table 2.

I found a main effect of age, $F(1, 66) = 80.37$, $p < .0001$, with older adults being slower to respond than young adults (1,983 ms vs. 1,382 ms, respectively). A configuration effect, $F(1, 66) = 371.54$, $p < .0001$, was due to faster responses to repeated configurations than new configurations (reflecting the contextual cueing effect; 1,503 ms vs. 1,862 ms, respectively). The effect of epoch, $F(7, 462) = 33.12$, $p < .0001$, indicated an overall decrease in RT as the number of epochs increased (a training effect; Chun & Jiang, 1998; Howard et al., 2004). In addition, there was a Configuration × Epoch interaction, $F(7, 462) = 11.25$, $p < .0001$, an Age Group × Configuration interaction, $F(1, 66) = 4.38$, $p = .040$, and an Age Group × Configuration × Epoch interaction, $F(7, 462) = 2.12$, $p = .040$.

To examine the Configuration × Epoch interaction, contextual cueing effects were examined at each epoch. Contextual cueing effects were present at each epoch, all *Fs* > 35.00, all *ps* < .0001. To examine the magnitude of the contextual cueing effect, contextual cueing difference scores (New RTs minus Repeated RTs) were calculated and submitted to a one-way ANOVA.

Table 2
Mean RTs (ms) and Error Rates (%) for each Epoch in Experiment 1

Mean RTs

	Young Adults			Older Adults		
	N *M (SD)*	R *M(SD)*	N-R *M(SE)*	N *M(SD)*	R *M(SD)*	N-R *M(SE)*
1	1,620 (230)	1,436 (286)	184 (35) *	2,212 (464)	2,018 (468)	194 (54) *
2	1,645 (221)	1,370 (279)	275 (38) *	2,181 (453)	1,875 (445)	307 (53) *
3	1,646 (199)	1,269 (214)	377 (36) *	2,184 (359)	1,837 (434)	347 (54) *
4	1,566 (203)	1,241 (226)	325 (39) *	2,228 (399)	1,821 (381)	407 (45) *
5	1,531 (212)	1,194 (220)	337 (32) *	2,201 (369)	1,774 (402)	427 (55) *
6	1,474 (157)	1,122 (215)	352 (29) *	2,159 (398)	1,687 (345)	473 (49) *
7	1,437 (189)	1,101 (226)	336 (27) *	2,196 (340)	1,666 (356)	530 (42) *
8	1,416 (226)	1,047 (202)	369 (33) *	2,091 (506)	1,599 (230)	492 (33) *

Error Rates

	Young Adults		Older Adults	
	N *M (SD)*	R *M(SD)*	N *M(SD)*	R*M(SD)*
1	1.4 (2.3)	1.5 (1.8)	5.6 (5.0)	4.7 (4.5)
2	1.4 (1.8)	1.5 (1.8)	6.0 (5.0)	4.4 (4.3)
3	1.8 (2.5)	1.5 (2.8)	5.6 (5.4)	4.0 (3.8)
4	1.8 (2.2)	1.3 (1.9)	6.5 (7.1)	3.5 (3.1)
5	1.3 (1.9)	1.0 (1.5)	4.6 (6.3)	3.6 (4.7)
6	1.0 (1.6)	1.3 (1.8)	3.8 (4.4)	2.9 (4.4)
7	1.5 (2.3)	1.3 (2.0)	3.5 (4.2)	2.6 (3.3)
8	1.5 (2.0)	1.7 (2.1)	4.6 (4.0)	3.2 (3.4)

Note. M = mean; SD = standard deviation; RT = reaction time; N = New Configuration RTs; R = Repeated Configuration RTs; N-R = New RT minus Repeated RT (mean difference score). M = Mean; SD = standard deviation. An asterisk (*) indicates that the difference score was significantly different from zero by a one-sample *t* test, $p < .05$.

According to Scheffe's test, difference scores were smallest at epoch 1, significantly bigger at epochs 2 through 6 (although not significantly different from one another), and largest at epochs 7 and 8, *ps* $< .05$. The pattern showed that the contextual cueing effect became larger as the number of blocks increased.

To explore the Age Group × Configuration interaction, I examined contextual cueing patterns for each age group (averaged across epoch). Young adults demonstrated contextual cueing effects, $F(1, 33) = 208.45$, $p < .0001$, (1,223 ms for repeated configurations vs. 1,542 ms for new configurations), as did older adults, $F(1, 33) = 176.73$, $p < .0001$ (1,784 ms for repeated vs. 2,181 ms for new), but the magnitude of the contextual cueing effect was greater for older adults than for young adults (397 ms vs. 319 ms, respectively).

Examining how quickly young and older adults learned to use context (Age Group × Configuration × Epoch interaction), I found that both young adults, $F(7, 231) = 5.32$, $p < .0001$, and older adults, $F(7, 231) = 7.29$, $p < .0001$, demonstrated a Configuration × Epoch interaction. Within each age group, contextual cueing effects were observed at all epochs, all *F*s > 12.5, all *p*s < .001, with increasing cueing effects with increasing epoch. Since both groups showed contextual learning, I used one-way ANOVAs to examine age differences in contextual cueing difference scores at each epoch. Age differences in the magnitude of the contextual cueing effect were observed at epochs 6-8 (Figure 3), with older adults showed greater contextual cueing effects compared to young adults, all *F*s > 4.5; all *p*s < .05.

RTs are an indirect measure of psychological effects. Motor output contributes to participants' overall RT. The motor contribution can be greater if the participant is slower to respond overall. This is part of the generalized slowing hypothesis in aging (Cerella, 1994). Older adults were found to be slower to respond than young adults.

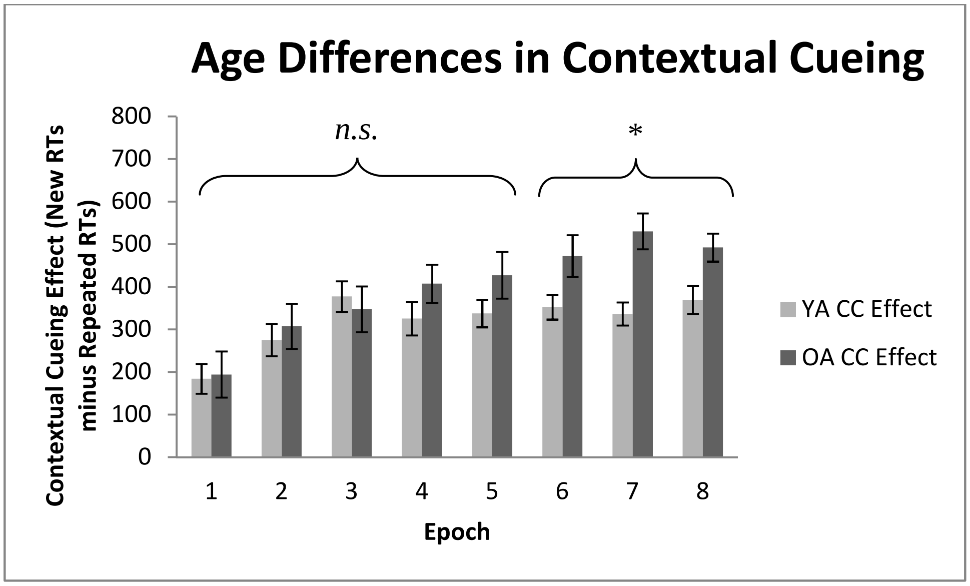

Figure 3. Adult age differences in the contextual cueing effect in Experiment 1. n.s. = age difference was not significant; YA = young adult group; OA = older adult group; CC = contextual cueing; epoch = 5 blocks of trials. The contextual cueing effect was calculated by subtracting Repeated RTs from New RTs. Age differences in the first five epochs were not significant, while age differences in epochs 6-8 were significant, with larger contextual cueing effects for older adults than younger adults. An asterisk (*) means a significant age difference as assessed by an ANOVA. Error bars represent the standard error of the mean (SEM).

Thus, to address the possibility that general slowing affected group differences in contextual cueing effects (Faust, Balota, Spieler, & Ferraro, 1999), I conducted a second set of analyses on RTs that were transformed to account for slowing (Langley et al., 2011; Madden, Pierce, & Allen, 1992; Madden, Whiting, Cabeza, & Huettel, 2004). Brinley plot analyses (Cerella, 1994) were used to determine the regression equation that best characterized the linear relationship between the sixteen condition means of older adults and young adults. I used the resulting equation (see Equation 1 below) to transform the data of young participants (i.e., I introduced slowing effects to their data). The assumption of this approach was that if age interactions remained significant using transformed data, then they were more likely representative of cognitive or perceptual effects, largely independent of general slowing.

$$\text{Older RT} = 1.08\ (\text{Young RT}) + 477,\ r^2 = .91 \qquad (1)$$

The transformed data were submitted to the same 2 × 2 × 8 mixed ANOVA described earlier. Results indicated that there was no longer a main effect of age, $F < 1$, as expected. The main effects of configuration, $F(1, 66) = 384.63$, $p < .0001$, and epoch, $F(7, 462) = 34.42$, $p < .0001$, remained significant. The Configuration × Epoch interaction also remained significant, $F(7, 462) = 11.28$, $p < .0001$, which demonstrated that the contextual cueing effect increased with increasing epochs. The Age Group × Configuration interaction was no longer significant, $F(1, 66) = 1.65$, $p = .20$. The magnitude of the contextual cueing effect was no longer significantly different between young and older adults. The three-way interaction of Age Group × Configuration × Epoch was also no longer significant, $F(7, 462) = 1.54$, $p = .15$ (Figure 4). The elimination of all previously significant age effects and age interactions suggests that after accounting for generalized slowing, older adults benefitted from repeated configurations to the same degree and at about the same rate as young adults.

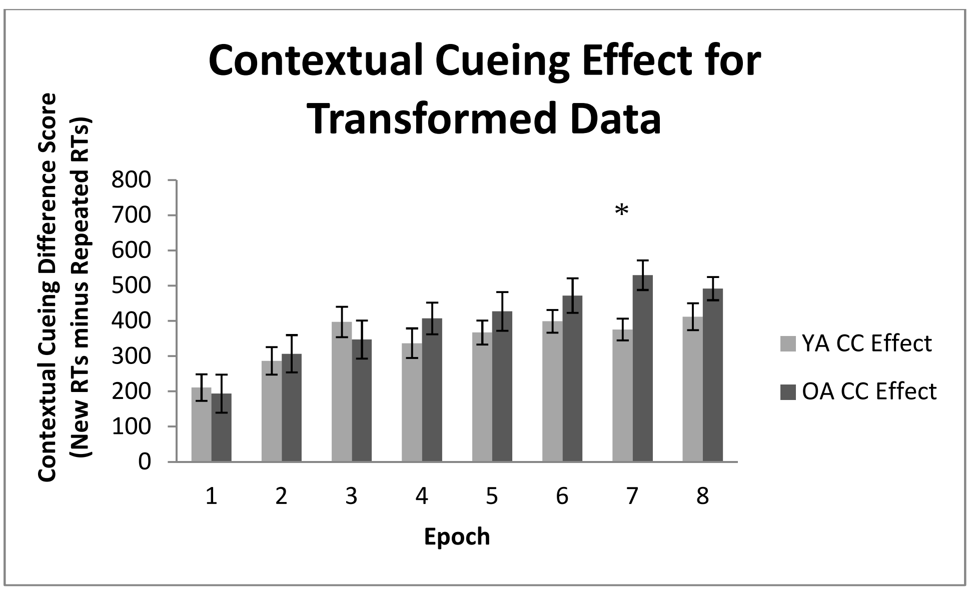

Figure 4. Generalized slowing and the contextual cueing effect in Experiment 1. YA = young adult group; OA = older adult group; CC = contextual cueing; epoch = 5 blocks of trials. The contextual cueing effect was calculated by subtracting Repeated RTs from New RTs. An asterisk (*) means a significant age differences as assessed by an ANOVA. Error bars represent ±1 SEM.

Block Analysis for the Search Task

I predicted that older adults would develop contextual cueing effects later than young adults. However, both groups showed significant contextual cueing effects in epoch 1. To determine if older adults developed contextual cueing effects later than younger adults, I conducted a block analysis limited to the first epoch of data (first five blocks). Data were submitted to a 2 × 2 × 5 mixed ANOVA, with age group (young and older adults) as a between-subjects variable, and configuration (repeated and new configurations) and block (1 through 5) as within-subjects variables. Since the block variable had more than two levels, I conducted a Scheffe's post hoc test to examine the nature of the significant effects.

I found a main effect of age, $F(1, 66) = 44.93$, $p < .0001$, with older adults being slower to respond than younger adults (2,169 ms vs. 1,604 ms, respectively). The configuration effect was significant, $F(1, 66) = 40.11$, $p < .0001$. Participants were faster to respond to repeated configurations than new configurations (1,789 ms vs. 1,985 ms, respectively). No other main effects or interactions were significant, *p*s > .35.

Age differences in the development of contextual cueing would have been observed with an Age Group × Configuration × Block interaction, but it was not significant, $F(4, 264) = 0.32$, $p = .87$. Although the interaction was not significant, I submitted mean RTs to a 2 × 5 repeated measures ANOVA for each age group, with configuration (new and repeated configurations) and block (1 through 5) as the variables. Configuration effects were significant for both young adults, $F(1, 33) = 28.44$, p < .0001, and older adults, $F(1, 33) = 16.89$, $p = .0002$. Both groups were faster to respond to repeated than new configurations. The Configuration × Block interaction was not significant for young adults, $F(4, 132) = 0.40$, $p = .81$, or older adults, $F(4, 132) = 0.83$, $p = .51$. Finally, I examined age differences in the difference scores (New RTs minus Repeated RTs) at each block. Age differences in the contextual cueing difference scores were not observed at any block, all *Fs*< 1.1, all *ps* > .30 (Figure 5).

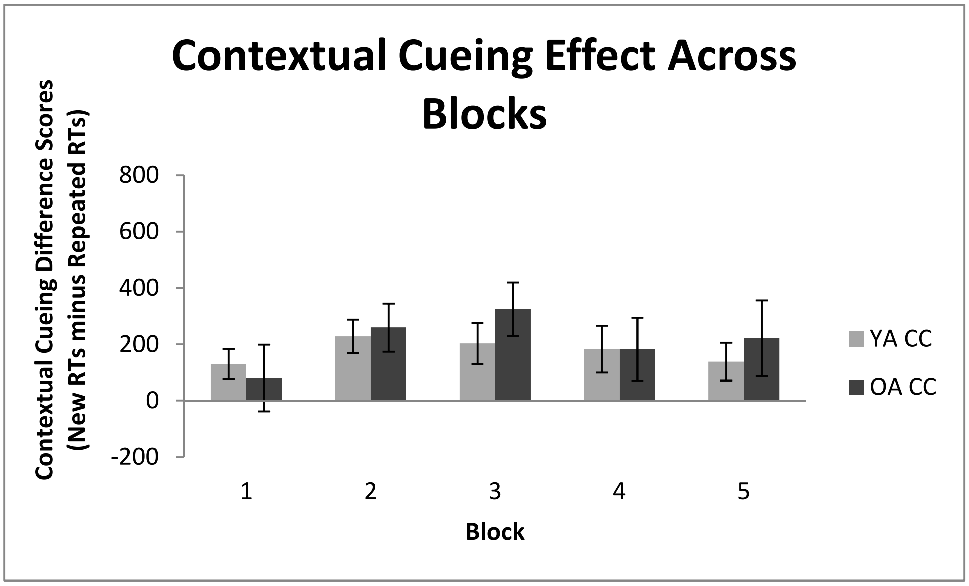

Figure 5. Block analysis of contextual cueing effect in Experiment 1. YA = young adult group; OA = older adult group; CC = contextual cueing; The contextual cueing effect was calculated by subtracting Repeated RTs from New RTs. Error bars represent ±1 SEM.

Error Analysis for the Search Task

Overall search errors were less than 5% for each group. Two types of responses were counted as errors on this task: misses (did not make a response within 8,000 ms) or incorrect responses (pressed the wrong button). Misses accounted for 43% of the errors, while incorrect responses accounted for 57% of the errors. Young adults' errors were mostly incorrect responses (88% of errors), whereas older adults' error were more evenly divided between misses (53%) and incorrect responses (47%). I submitted mean percent errors (for misses and incorrect responses) to a 2 × 2 × 8 mixed ANOVA, with age group (young and older adults) as the between subjects variable, and configuration (new and repeated configurations) and epoch (1 through 8) as the within subjects variables. Mean percent errors reflect inaccuracy rates.

I found a main effect of age, $F(1, 66) = 26.24$, $p < .0001$, with older adults making more errors than young adults (4.3% vs. 1.4%, respectively). Configuration effects were also significant, $F(1, 66) = 13.64$, $p = .001$. Error rates were greater for new configurations than repeated configurations (3.2% vs. 2.5%, respectively). A main effect of epoch, $F(7, 462) = 3.41$, $p = .002$, indicated that error rates declined as epoch number increased. However, a follow-up Scheffe's test showed no significant differences in the error rates when accounting for multiple comparisons across epochs, $ps > .05$. An Age Group × Epoch interaction, $F(7, 462) = 2.19$, $p = .034$, and an Age Group × Configuration interaction, $F(1, 66) = 10.76$, $p = .002$, were significant. No other interactions were significant, $ps > .35$.

To examine the Age Group × Epoch interaction, I examined epoch effects for each age group. Epoch effects were not significant for young adults, $F(7, 231) = 0.74$, $p = .64$, but were significant for older adults, $F(7, 231) = 3.30$, $p = .002$. Error rates for older adults declined as epoch number increased, but after accounting for multiple comparisons with Scheffe's test, no differences in error rates were observed across epochs for older adults. Thus, the interaction demonstrated that older adults benefitted more from task exposure than young adults, but when accounting for multiple comparisons, older adults' error rates did not decline significantly.

The Age Group × Configuration interaction was explored by examining configuration effects for each age group. Young adults did not demonstrate configuration effects, $F(1, 33) = 0.33$, $p = .57$. No differences were observed in the errors between new and repeated configurations (1.5% vs. 1.4%, respectively). Older adults did show configurations effects, $F(1, 33) = 13.98$, $p = .0007$. Older adults showed greater errors for new configurations than repeated configurations (5.0% vs. 3.6%, respectively).

Memory Task

Recognition Task

I submitted the proportion of old responses to a 2 × 3 mixed ANOVA, with age group (young and older adults) as the between subjects variable and trial type (repeated, presented once, and new) as the within subjects variable. Data for the recognition task are presented in Table 3.

Table 3
Mean Responses for the Recognition and Target Localization Tasks for Experiment 1

Recognition Task	Young Adults *M (SD)*	Older Adults *M (SD)*
New	0.44 (0.31)	0.45 (0.34)
Repeated	0.42 (0.29)	0.45 (0.36)
Presented Once	0.47 (0.28)	0.47 (0.33)

Localization Task	Young Adults *M (SD)*	Older Adults *M (SD)*
New	N/A	N/A
Repeated	11.7 (2.1)	10.8 (2.6)
Presented Once	11.2 (2.4)	11.5 (2.0)

Note. Responses for the recognition task are the proportion of old responses (the proportion of times the participant responded "yes, this display was presented during the search task"). Responses for the localization task are the distance between where the target letter appeared in the array and where the participant placed a black dot (in cm). Greater distance means less accurate localization. M = mean; SD = standard deviation; N/A = not applicable. New trials were randomly generated configurations that were not shown during the search task. Repeated trials were the repeated configurations that were shown in the search task. "Presented once" trials were shown one time during the search task.

The effect of age, $F(1, 66) = 0.04$, $p = .83$, was not significant. Young and older adults demonstrated similar proportion of old responses (0.44 vs. 0.46, respectively). Configuration effects, $F(2, 132) = 0.98$, $p = .38$, were also not significant. No differences in responses were observed for repeated, presented once, and new configurations (0.43, 0.47, and 0.44, respectively). I did not observe an Age Group × Configuration interaction, $F(2, 132) = 0.21$, $p = .81$. Young adults, $F(2, 66) = 1.19$, $p = .31$, and older adults, $F(2, 66) = 0.18$, $p = .83$, demonstrated similar responses to repeated, presented once, and new configurations, which were all around chance levels.

Target Localization Task

The distance between where the black dot was placed and where the target was located (in cm) was submitted to a 2 × 2 mixed ANOVA, with Age Group (young and older) as the between subjects variable and Configuration (repeated and presented once) as the within subjects variable. Data are presented in Table 3. No effects were significant. Young and older adults placed the target similarly far from the target (11.2 cm vs. 11.4 cm, respectively), $F(1, 66) = 0.15$, $p = .70$. Targets for repeated and presented once configurations were also placed similarly (11.5 cm vs. 11.1 cm, respectively), $F(1, 66) = 0.55$, $p = .46$.

Discussion

The results of Experiment 1 indicated that both young and older adults implicitly learned and benefitted from context. Older adults showed greater contextual cueing effects than young adults. These effects did not withstand correction for general slowing, which suggests that the age differences in contextual effects were influenced by processing speed. I predicted that older adults would develop contextual cueing effects later than young adults, but I did not observe those age differences. Older adults developed contextual cueing effects as quickly as young adults and benefitted from context similarly to young adults. Results from the memory task demonstrated that both groups were unable to reliably recognize the arrays or to locate the target in the arrays, which demonstrates that both groups implicitly learned and used context to effectively guide visual search in the scenes.

Older adults' search performance rapidly benefitted from context. I predicted that if the memory load of the task was decreased by reducing the number of configurations that were repeated, the contextual cueing effect would develop faster than in Howard et al. (2004) and Smyth and Shanks (2011). I did, in fact, find that both young and older adults developed contextual cueing effects quickly, with both groups showing contextual cueing effects within the first five repetitions of the displays. Smyth and Shanks found that older adults did not demonstrate a pattern that resembled contextual cueing effects after 16 repetitions. What about Howard et al.? In the present study, participants (young and old) were given relatively less information to learn with more time to learn and use it. This change may explain the speeded development of contextual cueing effects for older adults.

I also predicted that older adults would develop contextual cueing effects later than young adults. Surprisingly, I found that young and older adults developed contextual cueing effects at a similar rate. Why were context benefits observed so quickly for older adults? Unlike previous studies, I decreased the number of displays that repeated (8 repeated displays vs. 12 repeated displays) and increased the number of times each display repeated (each display was shown 40 times over the course of the experiment). I predicted that a decrease in the memory load would shift the distribution so that we would be able to measure age differences in the development of contextual cueing. However, decreasing the load may have also decreased age differences. A study that manipulates load (e.g., including a condition with 10 repeated displays that repeated 36 times) is needed to test the hypothesis that context memory load impacts age differences in spatial guidance by visual context.

Older adults demonstrated contextual cueing effects, which suggested that older adults were able to learn and utilize context to guide attention in visual search. I predicted that older adults would be able to utilize context but would be delayed in their ability to do so. Paxton et al. (2006) found that older adults were able to learn context quickly (within 100 trials) but were not able to use that context as quickly as younger adults (older adults needed more exposure). The present study demonstrates that older adults were able to quickly use context, even when the inherent meaning of the context was low, to guide attention when memory demands were relatively low. Contrary to the predictions from the context processing theory (Braver & Barch, 2002), older adults were sensitive to context, even when that context was implicitly encoded, and they can use context to guide attention.

CHAPTER 3: EXPERIMENT 2

Experiment 2 examined how older adults' attention is guided by contextual information in real-world visual scenes. Using the Brockmole and Henderson (2006) contextual cueing task, participants identified a small letter ("T" or "L") placed in a photograph of a visual scene that was presented upright or inverted. Brockmole and Henderson found that when images were inverted, young adults were slower to utilize context, and the magnitude of the contextual cueing effect was smaller compared to when images were presented upright, which suggested that semantic meaningfulness impacted how attention was deployed.

Research has demonstrated that older adults use semantic categorical information to predict the identity of an upcoming target word (Balota et al., 1992; Burke et al., 1987; Chiarello, Church, & Hoyer, 1985). When information is less meaningful (e.g., novel letter pairings), older adults do not benefit from context to the same extent as young adults, unless given more exposure to the task (Paxton et al., 2006). Based on these findings, I predicted that when context was meaningful (upright images), older adults would benefit from the meaningful contexts and demonstrate contextual cueing effects, similar in magnitude to young adults. I also predicted that older adults would develop contextual cueing effects as quickly as young adults for upright images. When context was less meaningful (inverted images), I predicted that older adults would benefit from context, but they would demonstrate smaller contextual cueing effect that occurred later compared to young adults.

Method

Participants

Thirty-six young adults (18-23 years) and 36 older adults (60-85 years), who did not participate in Experiment 1, completed Experiment 2. The same inclusion criteria used for

Experiment 1 were used in this experiment. Two older adults were excluded for health-related issues (heart attack and brain surgery). One older adult and two young adults were excluded for high GDS scores. One young adult was excluded for poor color vision. The data for these participants were replaced with data from new participants. Demographic data from the included participants is presented in Table 1.

Materials

Arrays and stimuli were presented on a 17 inch color monitor controlled by a PC computer. Responses were made on a PST serial response box (Psychology Software Tools, Pittsburgh, PA). A chin rest maintained the participant's viewing distance at 40 cm. The experimental task was created using Presentation version 12.1 (Neurobehavioral Systems, Albany, CA). Full color scenes from Corel Image Feature database were used, which was the same database Brockmole and Henderson (2006) used. Images were presented in 1024 × 683 pixel resolution with a black border around the image. A small, bolded grey (128R, 128G, 128B) target (either a "T" or an "L") was presented in 14 point Arial font in an upright position.

Four trial types were created. Upright repeated trials consisted of eight real-world images that were shown repeatedly across blocks. Upright new trials consisted of new images that were not repeated across blocks (96 new images). Inverted repeated trials consisted of eight different images (not seen in the upright condition) that were shown repeatedly across blocks that were presented upside down (180° inversion). Inverted new trials used unrepeated images (96 additional images not seen in any other condition) that were presented upside down. Different pictures were used in the upright and inverted conditions in order to reduce learning effects transferring from one condition to another. In the repeated conditions (upright or inverted), the target appeared in the same location on each presentation, but the identity of the target ("T" or

“L”) changed randomly from block to block. Thus, the image was predictive of the target location but not the target identity.

Brockmole and Henderson (2006) randomly placed the target in the image. However, this could lead to wide variation in contrast differences between the target and the background. To maintain similar levels of localization difficulty across images (the contrast is not so high that the target “pops out” and not so low that the target is unlikely to be detected within the 20 second time limit), I placed targets within the images at locations that would result in the appropriate level of target-background contrast. (Localization difficulty was determined through pilot testing with a small sample of young and older adults). The target location within an image did not change across presentations or conditions. However, images were randomly chosen to be upright/inverted and repeated/new for each participant.

Procedure

The testing session, including consent, screening, and computer task, lasted approximately 2 hours. On the computer task, half the participants completed the upright blocks first, and half the participants completed the inverted blocks first. Before completing the blocks for each picture orientation, participants completed a short practice block of 16 trials to orient them to the task. Images in the practice block were not used in the experimental or memory trials. For both practice and experimental trials, the sequencing of events was the same. See Figure 6 for a sample task sequence. Trials began with a blue fixation dot (0.43° of visual angle) centered on a grey screen. After 500 ms, the fixation screen was replaced by a photograph of a scene. Participants were told to locate the target letter in the scene and to press a button to identify the target (“T” or “L”). The trial ended and the display was removed as soon as the participant responded. If a participant did not respond within 20 seconds, the trial terminated. A black screen was presented for 1,000 ms between the completion of a trial and the start of a new one. Participants were instructed to respond as quickly as possible but not so quickly that they made mistakes. During the practice trials participants received accuracy feedback (the words “correct”, “incorrect”, or “no response detected” in the center of the computer screen) to ensure that the participants understood the task, but feedback was not given during the test blocks. After the practice blocks, young and older adults completed 18 experimental blocks of 16 trials per block (288 trials total). There were 9 blocks of upright images and 9 blocks of inverted images (order of picture orientation was counterbalanced).

After the final search block, participants began the recognition task. Participants saw eight upright and eight inverted repeated configurations (previously seen in the search task), eight upright and eight inverted scenes that were only shown once during the search task, and eight upright and eight inverted images that were never shown in the experiment (48 images total). The target was removed from the images, and the images were presented randomly. Since images were randomly chosen for the different conditions in the search task for participants, the images for the recognition task were randomly chosen based on what the participants saw or did not see in the search task. On each trial, participants determined if they saw the image in the search task and used the mouse to click on a “yes” or “no” box presented at the top of the screen. After a recognition response, participants made a target localization response. Participants were asked to place a small blue dot on the location they remembered the target appeared using a computer mouse. Participants were instructed to guess if they were unsure. No accuracy feedback was provided.

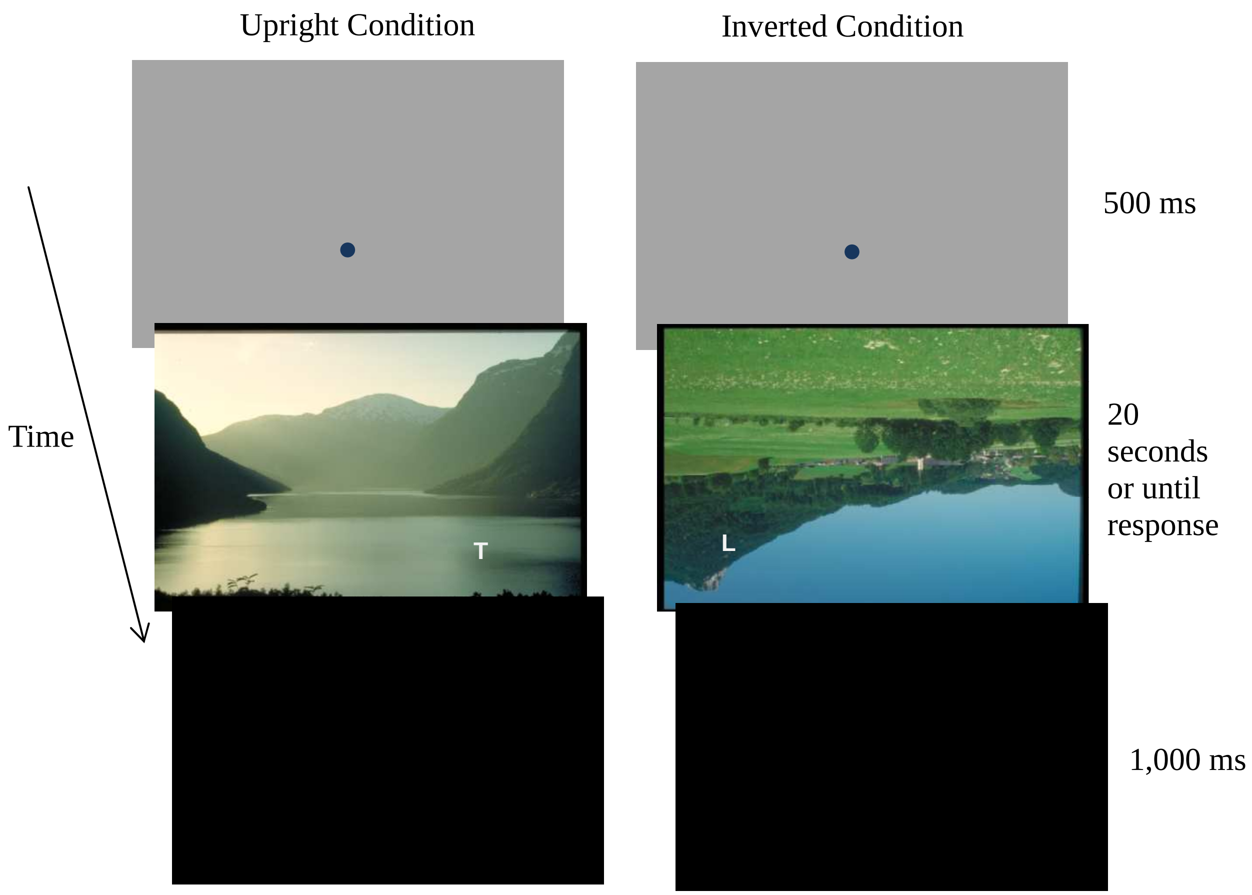

Figure 6. Sample sequence of an upright trial and an inverted trial in Experiment 2. The target letters are highlighted in white but were presented in mid-gray (128 pixel value) in the experiment. Stimuli are not sized to scale.

Results

Reaction Times for the Search Task

Trials with RTs 2.5 standard deviations from the condition mean for an individual were eliminated as outliers. Mean RTs for correct trials (after removing outliers) were calculated for each block, then averaged across blocks to yield a repeated and a new configuration RT for each three-block epoch (three epochs per meaningfulness condition). Data were submitted to a 2 × 2 × 2 × 3 mixed ANOVA, with age group (young and older adults) as a between-subjects variable and meaningfulness (upright image and inverted image), configuration (repeated and new configurations), and epoch (1 through 3) as within-subjects variables. Since the epoch variable had more than two levels, I conducted Scheffe's post hoc tests to examine the nature of the significant effects. Six older adults had error rates that were over 30%, and they were excluded from the analysis. Their data were replaced with data from new participants. Participant characteristics presented in Table 1 (and in the method section) do not reflect the exclude participants. Reaction time and error data for the included participants are presented in Table 4 (upright images) and Table 5 (inverted images).

Table 4
Mean RTs (ms) and Error Rates (%) as a function of Age Group, Meaningfulness Condition, and Epoch in Experiment 2 for Upright Image

Mean RTs

	Young Adults			Older Adults		
Epoch	N *M (SD)*	R *M(SD)*	N-R *M(SE)*	N *M(SD)*	R *M(SD)*	N-R *M(SE)*
1	2,257 (663)	1,925 (531)	332 (128) *	4,837 (1,789)	4,429 (1,642)	408 (219) †
2	2,291 (541)	1,405 (337)	886 (93) *	4,536 (1,469)	3,806 (1,828)	729 (283) *
3	2,139 (615)	1,246 (192)	893 (98) *	4,368 (1,571)	2,989 (1,433)	1,378 (195) *

Error Rates

	Young Adults		Older Adults	
Epoch	N *M (SD)*	R *M(SD)*	N *M(SD)*	R*M(SD)*
1	3.1 (4.3)	3.8 (5.9)	14.0 (10.6)	12.4 (10.6)
2	3.7(5.2)	2.8 (5.0)	11.7 (10.2)	8.6 (9.2)
3	3.2 (6.5)	2.3 (3.8)	13.8 (9.3)	6.3 (8.5)

Note. M = mean; SD = standard deviation; RT = reaction time; N = New RTs; R = Repeated RTs; N-R = New RT minus Repeated RT (mean difference score). An asterisk (*) indicates that the difference score was significantly different from zero by a one-sample *t* test, $p < .05$. A dagger (†) indicates that the difference score was marginally different from zero by a one-sample *t* test, $.05 < p < .10$. An epoch consisted of three blocks.

Table 5
Mean RTs (ms) and Error Rates (%) as a function of Age Group, Meaningfulness Condition, and Epoch in Experiment 2 for Inverted Images

Mean RTs

	Young Adults			Older Adults		
Epoch	N *M (SD)*	R *M(SD)*	N-R *M(SE)*	N *M(SD)*	R *M(SD)*	N-R *M(SE)*
1	2,485(679)	2,255 (694)	230 (148)	4,367 (1,620)	4,047 (1, 478)	320 (212)
2	2,317 (431)	1,722 (548)	595 (99) *	4,713 (1,592)	3,857 (1,665)	856 (211) *
3	2,301 (588)	1,397 (367)	904 (100) *	4,397 (1,769)	3,422 (1,822)	975 (257) *

Error Rates

	Young Adults		Older Adults	
Epoch	N *M (SD)*	R *M(SD)*	N *M(SD)*	R*M(SD)*
1	3.2 (4.3)	3.0 (4.3)	13.5 (9.4)	14.8 (10.9)
2	2.5 (3.5)	1.3 (3.1)	14.8 (9.3)	10.0 (9.4)
3	3.4 (4.1)	1.3 (2.2)	13.7 (10.9)	8.9 (9.1)

Note. M = mean; SD = standard deviation; RT = reaction time; N = New RTs; R = Repeated RTs; N-R = New RT minus Repeated RT (mean difference score). An asterisk (*) indicates that the difference score was significantly different from zero by a one-sample *t* test, $p < .05$. A dagger (†) indicates that the difference score was marginally different from zero by a one-sample *t* test, $.05 < p < .10$. An epoch consisted of three blocks.

I observed main effects of age, $F(1, 70) = 96.59$, $p < .0001$, with older adults being slower to respond than young adults (4,147 ms vs. 1,973 ms, respectively). Significant configuration effects, $F(1, 70) = 144.73$, $p < .0001$, reflected faster RTs to repeated configurations than new configurations (2,696 ms vs. 3,425 ms, respectively). The main effect of epoch, $F(7, 140) = 40.18$, $p < .0001$ was also significant. Scheffe's test demonstrated that the responses in Epoch 1 were significantly slower than the responses in Epoch 2, which in turn were significantly slower than the responses in Epoch 3 (3,316 ms, 3,078 ms, and 2,787 ms, respectively), *p*s < .05. A main effect of meaningfulness was not significant (3,018 ms for upright images vs. 3,103 ms for inverted images), $F(1, 70) = 1.02$, $p = .32$. There was a Configuration × Epoch interaction, $F(2, 140) = 20.68$, $p < .0001$, and an Age Group × Meaningfulness × Epoch interaction, $F(2, 140) = 4.91$, $p = .009$. No other interactions were significant, *p*s > .05.

To examine the Configuration × Epoch interaction, I assessed contextual cueing effects (faster responses to repeated configurations than new configurations) at each epoch. Contextual cueing effects were significant at each epoch, all *F*s > 16.5, all *p*s < .0001. I then calculated contextual cueing difference scores (New RTs minus Repeated RTs) and submitted them to a one-way ANOVA, followed by Scheffe's post hoc test. Contextual cueing effects were smallest at Epoch 1, larger at Epoch 2, and largest at Epoch 3 (342 ms, 792 ms, and 1,055 ms, respectively), *p*s < .05. Therefore, the contextual cueing effect increased as the epochs increased.

I examined the Age Group × Meaningfulness × Epoch interaction by examining the RT patterns within each group. Young adults did not demonstrate a Meaningfulness × Epoch interaction, $F(2, 140) = 0.73$, $p = .48$. They showed a decrease in RT as epoch increased whether images were upright, $F(2, 70) = 14.33$, $p < .0001$, or inverted, $F(2, 70) = 20.41$, $p < .0001$. Older adults demonstrated a Meaningfulness × Epoch interaction, $F(2, 140) = 4.17$, $p = .02$. For upright images, older adults' responses decreased as epoch increased, $F(2, 70) = 17.55$, $p < .0001$. Epoch effects were demonstrated for inverted images, $F(2, 70) = 3.20$, $p = .047$. However, follow-up Scheffe's test showed no significant differences in response times between the epochs, *p*s > .05. Therefore, older adults' overall RTs benefitted from increased exposure to upright images but not inverted images.

I predicted a Meaningfulness × Configuration interaction (greater contextual cueing effects for upright images than inverted images). I did not observe this interaction, $F(1, 70) = 1.02$, $p = .32$. Further, I predicted that the Meaningfulness × Configuration interaction would be modified by age (an Age Group × Meaningfulness × Configuration interaction). I predicted that contextual cueing effects for upright images would be similar for young and older adults, but that older adults would demonstrate smaller contextual cueing effects for inverted images compared to young adults. I did not observe this interaction, $F(1, 70) = 0$, $p = .96$. I calculated the contextual cueing effect difference scores and examined age differences for each meaningfulness condition. I did not observe age differences for upright images, $F(1, 70) = 0.29$, $p = .590$, or inverted images, $F(1, 70) = 0.31$, $p = .579$. Thus, young and older adults showed similar contextual cueing effects that did not vary significantly by meaningfulness.

I predicted a Meaningfulness × Configuration × Epoch interaction, which would demonstrate that development of the contextual cueing effect would be faster for upright images than inverted images. Again, I did not observe this interaction, $F(2, 140) = 0.13$, $p = .877$. This effect would be modified by age (Age Group × Meaningfulness × Configuration × Epoch). I predicted that age differences in the development of contextual cueing would be reduced for upright images, but age differences in the development of contextual cueing would be greater for inverted images. I did not observe this interaction, $F(2, 140) = 1.67$, $p = .191$ (Figure 7).

To examine if generalized slowing affected age patterns in the contextual cueing effect (in this case, masking an age-related reduction in the cueing effect), I conducted a similar set of analyses as described in Experiment 1. Brinley plot analyses were used to determine the regression equation that best characterized the linear relationship between the condition means of older adults with those of younger adults. I used the resulting equation (see Equation 2 below) to transform the data of young participants (introduced slowing to the young adults' data).

$$\text{Older RT} = 1.1\ (\text{Young RT}) + 1{,}969,\ r^2 = .75 \qquad (2)$$

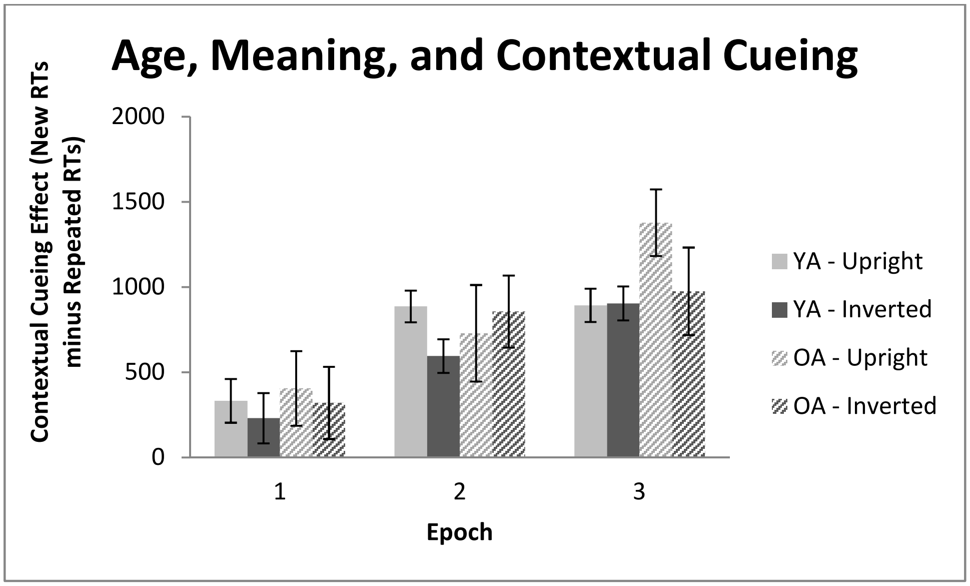

Figure 7. Meaningfulness and the contextual cueing effect. YA = young adult group; OA = older adult group; epoch = 3 blocks of trials. The contextual cueing effect was calculated by subtracting Repeated RTs from New RTs. Error bars represent ±1 SEM.

The transformed data were submitted to the same 2 × 2 × 2 × 3 mixed ANOVA described earlier. Results indicated that there was no longer a main effect of age, $F < 1$, as expected. The main effects of configuration, $F(1, 70) = 141.52$, $p < .0001$, and epoch, $F(2, 140) = 43.48$, $p < .0001$, remained significant. The Configuration × Epoch interaction also remained significant, $F(2, 140) = 21.56$, $p < .0001$, which demonstrated that the contextual cueing effect increased as epoch increased. The Age Group × Meaningfulness × Epoch interaction was still significant, $F(2, 140) = 4.98$, $p = .008$. The pattern of effects for this interaction remained the same. No other interactions were significant that were not significant before the transform, *p*s > .05. Thus, after accounting for generalized slowing, RT patterns remained relatively unchanged.

Between Subjects Analysis of Meaningfulness

A potentially important difference in design between the present experiment and the Brockmole and Henderson (2006) study is that I manipulated meaningfulness (picture orientation) using a within-subjects approach, whereas Brockmole and Henderson manipulated this variable in a between-subjects fashion. This design difference might account for the more prominent impact meaningfulness had on contextual cueing in the Brockmole and Henderson study. To address this possibility, I compared responses for the participants that completed upright images first (first 9 blocks of trials) with participants that completed inverted images first (first 9 blocks). I submitted the RTs for those first 9 blocks to the same 2 × 2 × 2 × 3 mixed ANOVA used previously, with age group (young or older) and meaningfulness (upright or inverted) as the between subjects variables and configuration (repeated or new) and epoch (1 through 3) as the within subjects variables. I found a main effect of age group, $F(1, 68) = 87.15$, $p < .0001$, with older adults responding slower than young adults (4,256 ms vs. 2,024 ms, respectively). Configuration effects, $F(1, 68) = 90.07$, $p < .0001$, indicated that participants were faster to respond to repeated configurations than new configurations (2,714 ms vs. 3,565 ms, respectively). Epoch effects were also significant, $F(2, 136) = 24.57$, $p < .0001$. Scheffe's test demonstrated that participants were slower to respond at epoch 1, faster at epoch 2, and fastest at epoch 3 (3,480 ms, 3,151 ms, 2,787 ms, respectively). I found a Configuration × Epoch interaction, $F(2, 136) = 7.21$, $p = .001$. No other main effects or interactions were significant, all *Fs* < 3, all *ps* > .05.

To examine the Configuration × Epoch interaction, I examined configuration effects at each epoch. Configuration effects were significant at all epochs, all *Fs* > 14, all *ps* < .001. I calculated contextual cueing difference scores (New RTs minus Repeated RTs) and submitted them to a one-way ANOVA examining the effect of epoch. Follow-up Scheffe's analyses showed that context cueing effects were smaller at epoch 1 than epoch 3. Thus, context effects increased as epoch increased. As in the original analysis, while I found that participants demonstrated contextual cueing effects quickly, I did not find that meaningfulness provided an additional contextual benefit.

Block Analysis for the Search Task

The epoch analysis demonstrated significant contextual cueing effects within the first epoch. To explore the development of contextual cueing within those initial three blocks, I calculated mean RTs for correct trials for each set of repeated and new configurations in the first three blocks Data were submitted to a 2 × 2 × 2 × 3 mixed ANOVA, with age group (young and older adults) as a between-subjects variable and meaningfulness (upright image and inverted image), configuration (new and repeated configurations), and block (1 through 3) as within-subjects variables.

I found a main effect of age, $F(1, 70) = 85.74$, $p < .0001$,with older adults being slower to respond than younger adults (4,743 ms vs. 2,594 ms, respectively). The configuration effect, $F(1, 70) = 19.15$, $p < .0001$, indicated faster responses to repeated configurations than new configurations (3,472 ms vs. 3,865 ms, respectively). I found a Configuration × Block interaction, $F(2, 140) = 5.33$, $p = .006$. No other main effects or interactions associated with the block variable were significant, *p*s > .10.

The Configuration × Block interaction was assessed with one-way ANOVAs of configuration effects at each block. At block 1, configuration effects were not significant, $F(1, 71) = 0.52$, $p = .473$. At blocks 2 and 3, configuration effects were significant, both *Fs* > 6.5, both *ps* < .05. To further examine the interaction, I calculated difference scores

(New RTs minus Repeated RTs) for each block. Scheffe's test showed that difference scores were smaller at blocks 1 and 2 than at block 3. Thus, contextual cueing effects developed consistently across conditions after two repetitions of the images (by Block 3) (Figure 8).

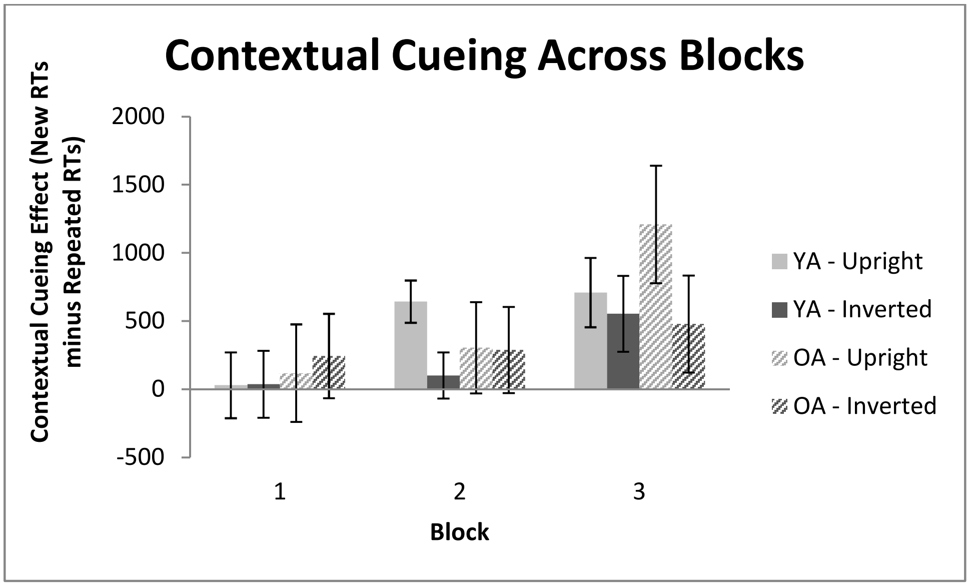

Figure 8. Block analysis of the contextual cueing effect in Experiment 2. YA = young adult group; OA = older adult group. The contextual cueing effect was calculated by subtracting Repeated RTs from New RTs. Error bars represent ±1 SEM.

Error Analysis for the Search Task

Search errors could be characterized as misses (did not make a response in 20 seconds) or incorrect responses (pressed the wrong button). I calculated percent errors (either an incorrect button press or a miss). Overall, 23% of the error trials were incorrect responses, while 77% of the trials were misses. Although error rates were relatively low for young adults, they were fairly evenly split between incorrect responses (56% of errors) and misses (44% of errors). Older adults showed more miss errors (85% of errors) than incorrect responses (15% of errors). To examine error rates for the groups, I submitted the percent errors to a 2 × 2 × 2 × 3 (Age Group × Meaningfulness × Configuration × Epoch) mixed ANOVA, with age group (young and older adults) as a between-subjects variable and meaningfulness (upright or inverted image), configuration (repeated or new configurations), and epoch (1 through 3) as within-subjects variables. The percent error reflects inaccuracy.

I found main effects of age, $F(1, 70) = 58.66$, $p < .0001$, with older adults having greater errors than young adults (11.8% vs. 2.8%, respectively). Configuration effects, $F(1, 70) = 21.16$, $p < .0001$, showed greater errors for new trials than repeated trials (8.4% vs. 6.3%, respectively). An epoch effect, $F(2, 140) = 8.45$, $p = .0003$, was also significant. A follow-up Scheffe's test showed fewer errors on epochs 2 and 3 (6.9% and 6.7%, respectively) than in epoch 1 (8.5% errors), *ps* < .05. In addition to the main effects, I observed the following interactions: Configuration × Epoch, $F(2, 140) = 13.91$, $p < .0001$, Age Group × Epoch, $F(2, 140) = 3.08$, $p = .049$, and Age Group × Configuration, $F(1, 70) = 8.57$, $p = .005$. These two-way interactions were further modified by an Age Group × Configuration × Epoch interaction, $F(2, 140) = 4.00$, $p = .020$.

I examined the higher order three-way interaction by conducting Configuration × Epoch ANOVAs within each age group. The two-way interaction was significant for both older adults, $F(2, 70) = 10.46$, $p = .0001$, and young adults, $F(2, 70) = 3.54$, $p = .034$. The decrease in error rates across epochs was largely limited to repeated trials (with little change in errors for new trials). The decrease in repeated trial errors was exaggerated for older adults compared to young adults (possibly due to floor effects for young adults) (Figure 9).

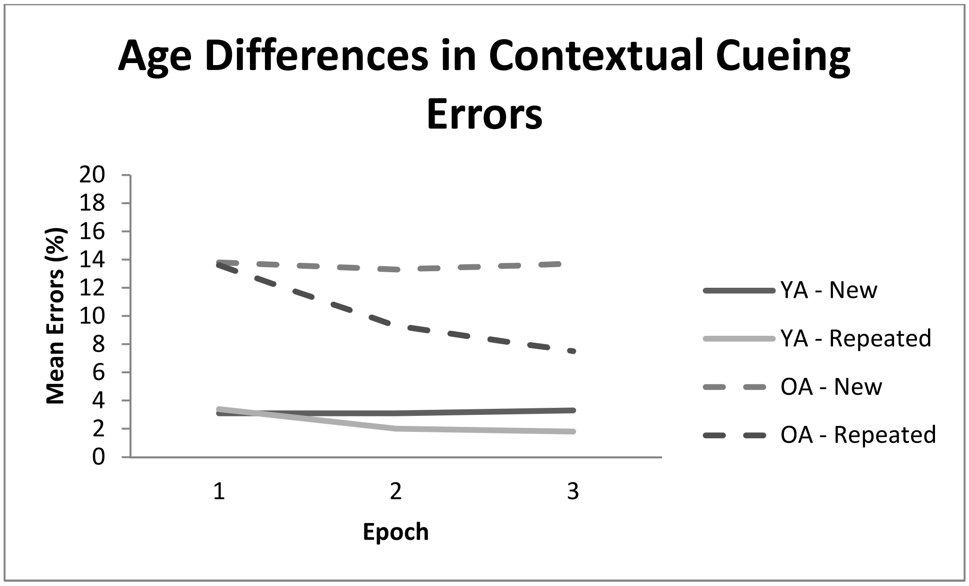

Figure 9. Age differences in contextual cueing errors. YA = young adult group; OA = older adult group. Epoch = three blocks of trial.

Memory Task

Recognition Task

For the recognition task, I calculated the proportion of old responses and submitted those scores to a 2 × 2 × 3 mixed ANOVA with age group (young and older adults) as the between subjects variable, and meaningfulness (upright and inverted images) and configuration (repeated, presented once, and new) as the within subjects variables. Data for the recognition task are presented in Table 6 (upright images) and Table 7 (inverted images).

There was a main effect of age, $F(1, 70) = 4.45$, $p = .039$. Older adults had a higher proportion of old responses than young adults (.53 vs. .46, respectively). Configuration effects were also significant, $F(2, 140) = 270.37$, $p < .0001$. Scheffe's post hoc analyses revealed that repeated trials showed a higher proportion of old responses than presented once trials, which, in turn, had a higher proportion of old responses than new trials (.78, .43, and .26, respectively), *p*s < .05. I observed a Meaningfulness × Configuration interaction, $F(2, 140) = 10.52$, $p < .0001$, and an Age Group × Configuration interaction, $F(2, 140) = 5.24$, $p = .006$.

Table 6
Mean Responses for the Recognition and Localization Task for Experiment 2 for Upright Images

Recognition Task

	Young Adults	Older Adults
	M (SD)	*M (SD)*
New	0.13 (0.14)	0.31 (0.29)
Repeated	0.83 (0.19)	0.76 (0.24)
Presented Once	0.44 (0.22)	0.46 (0.25)

Localization Task

	Young Adults	Older Adults
	M (SD)	*M (SD)*
New	N/A	N/A
Repeated	14.0 (2.7)	13.6 (2.7)
Presented Once	11.0 (1.9)	12.4 (2.7)

Note. Responses for the recognition task are the proportion of old responses (the proportion of times the participant responded “yes” to recognizing images). Responses for the localization task are the distance between where the target letter appeared in the array and where the participant placed a black dot (cm). M = mean; SD = standard deviation; N/A = not applicable. New trials were randomly generated configurations that were not shown during the search task. Repeated trials were the repeated configurations that were shown in the search task. Presented once trials were shown one time during the search task.

To examine the Meaningfulness × Configuration interaction, I examined meaning effects for the different configuration types. Meaning effects were observed for new configurations, $F(1, 71) = 11.25$, $p = .001$, and repeated configurations, $F(1, 71) = 9.13$, $p = .004$, but not for presented once configurations, $F(1, 71) = 1.0$, $p = .320$. In new configurations, participants had greater proportions of old responses (false alarms) to inverted images than upright images (0.31 vs. 0.22, respectively). For repeated configurations, participants had greater proportion of old responses (hits) to upright images than inverted configurations (0.82 vs. 0.74, respectively). Thus, together these results indicate better accuracy (higher hits and lower false alarms) for upright images than inverted images.

Table 7
Mean Responses for the Recognition and Localization Task for Experiment 2 for Inverted Images

Recognition Task

	Young Adults	Older Adults
	M (SD)	*M (SD)*
New	0.25 (0.16)	0.36 (0.27)
Repeated	0.71 (0.20)	0.45 (0.36)
Presented Once	0.38 (0.23)	0.47 (0.33)

Localization Task

	Young Adults	Older Adults
	M (SD)	*M (SD)*
New	N/A	N/A
Repeated	13.4 (3.0)	13.7 (3.1)
Presented Once	12.0 (2.6)	13.2 (2.7)

Note. Responses for the recognition task are the proportion of old responses (the proportion of times the participant responded "yes" to recognizing images). Responses for the localization task are the distance between where the target letter appeared in the array and where the participant placed a black dot (in cm). M = mean; SD = standard deviation; N/A = not applicable. New trials were randomly generated configurations that were not shown during the search task. Repeated trials were the repeated configurations that were shown in the search task. Presented once trials were shown one time during the search task.

In order to examine the Age Group × Configuration interaction, I examined configuration effects for each age group. Older adults showed significant configuration effects, $F(2, 70) = 95.35$, $p < .0001$, as did young adults, $F(2, 70) = 187.86$, $p < .0001$. The configuration effects demonstrated that both groups had the highest proportion of old responses for repeated configurations, followed by presented once configurations, and new configurations had the lowest proportion of old responses. I examined age differences for the different configurations. Older adults had a higher proportion of old responses than young adults for new configurations (.34 vs. .19, respectively), reflecting higher false alarms, $F(1, 70) = 12.67$, $p = .001$. Significant age differences were not observed for repeated, $F(1, 70) = .03$, $p = .863$, or presented once configurations, $F(1, 70) = 1.45$, $p = .233$.

Target Localization Task

The localization response was a measure of the accuracy with which the participants localized the target relative to the actual location of the target letter (in cm). Localization error was analyzed for repeated images and images that were presented once in the search task (Brockmole & Henderson, 2006). The localization distance was submitted to a 2 × 2 × 2 mixed ANOVA with age group (young and older adults) as the between subjects variable and meaningfulness (upright and inverted) and configuration (repeated and presented once) as the within subjects variable. Data for the localization responses are presented in Table 6 (upright images) and Table 7 (inverted images).

There was a main effect of configuration, $F(1, 70) = 30.51$, $p < .0001$, which demonstrated that participants placed the dot closer to the target location for presented once trials than repeated trials. The configuration effect was modified by an Age Group × Configuration interaction, $F(1, 70) = 6.50$, $p = .013$. No other main effect or interactions were significant, ps > .05.

To explore the interaction, I examined configuration effects for each age group. Young adults showed significant configuration effects, $F(1, 35) = 48.60$, $p < .0001$. Contrary to predictions, young adults placed the target closer to the target location on presented once trials than on repeated trials (11.4 cm vs. 13.7 cm, respectively). Older adults showed marginal configuration effects, $F(1, 35) = 3.33$, $p = .077$, likewise placing targets more accurately for presented once trials than repeated trials (12.8 cm vs. 13.6 cm, respectively). The interaction reflected that young adults showed stronger trial type effects than older adults.

Discussion

The findings from Experiment 2 demonstrated that contextual cueing effects were resistant to modification with age. Analyses on transformed data indicated that generalized slowing did not mask age-related reductions in contextual cueing effects. Both young and older adults were able to use scene context to guide search, regardless of the meaningfulness of the scene. Young and older adults could explicitly recognize the background images but there was no evidence that they explicitly encoded the target-background associations. Instead, the location of the target relative to the scene was implicitly encoded.

I predicted that meaningfulness would impact both groups, and that older adults would be more impacted by meaningfulness than young adults. However, rotating the image to reduce meaningfulness did not diminish context effects for either group. Brockmole and Henderson (2006) found that meaningfulness impacted young adults' performance. In their study, when background images were presented in an upright fashion, young adults showed greater contextual cueing effects that occurred earlier than with images that were inverted. In Experiment 2, I found that young adults' and older adults' contextual cueing effects, and the development of those effects, were not impacted by the meaningfulness of the background image. The reduced influence of context meaningfulness could not be attributed to the within-subject manipulation of image orientation; meaningfulness effects were not increased when constraining the analyses to the between-subjects manipulation of image orientation

The memory results showed that young and older adults were able to recognize the background images but did not explicitly encode the target locations within the images. Brockmole and Henderson (2006) found that young adults were able to explicitly encode the target-background association for meaningful contexts. The methodological differences between Brockmole and Henderson (2006) and the current experiment are numerous. In Brockmole and Henderson’s study, participants localized targets only on images they explicitly remembered. In this experiment, participants localized targets for every image, regardless of their explicit knowledge of that image. Localizing targets only from explicitly-retrieved images may have increased the possibility that the target location would also be explicitly retrieved. Another potential reason for poor explicit retrieval of target locations could be the delay between when participants learned the images and when their memory was assessed. In Brockmole and Henderson’s study, participants’ memory was tested immediately after learning the upright images in the search task. In the present task, participants’ memory was tested after learning two sets of images (upright and inverted). The longer delay between learning and test might have led to decay of the target-background information. Also, there were twice as many images to learn (16 in the present experiment, 8 in the Brockmole and Henderson study) with fewer trials to learn them (18 total blocks in the present experiment, 34 total blocks in the Brockmole and Henderson study). Thus, increased memory load, reduced learning opportunities, and delayed retrieval may have weakened explicit encoding of spatial associations between targets and background images.

Considering the results of the search and memory tasks, these findings suggest that meaningfulness did not impact the efficiency with which people learned and used context. An alternative interpretation is that the meaningfulness manipulation did not work as planned. An inverted image continues to maintain a relatively high level of meaningfulness. (with real objects that retain their relative position to one another). Thus, the level of meaningfulness for inverted images may have been sufficient to allow efficient development of contextual cueing effects.

CHAPTER 4: GENERAL DISCUSSION

The purpose of the present study was to examine if older adults can use context to guide attention in visual scenes. In Experiment 1, I found that older adults showed greater contextual cueing effects compared to young adults. When general slowing was accounted for, contextual cueing did not vary by age. The development of the contextual cueing effects occurred rapidly for both age groups (within 5 repetitions) in the absence of meaningful (i.e., semantic) information. Participants could not explicitly recognize or recall the spatial contextual information (associations between the targets and backgrounds). However, both groups used context to guide attention to find targets more efficiently. This information, taken together, demonstrated that both groups implicitly learned and used the context even when information was not intrinsically meaningful.

Experiment 2 demonstrated with a different contextual cueing task that young and older adults used context to guide spatial attention. Using images of real world scenes, contextual effects occurred quickly (within 6 repetitions) for both meaningfulness conditions (upright and inverted images) for both age groups. Participants explicitly recognized the photographed scenes but, unlike the findings of Brockmole and Henderson (2006), they were unable to recall the location of the target within the scene. The findings suggest that young and older adults were able to learn and use context but that target-background associations remained implicitly encoded. I predicted that the development of contextual cueing would be affected by meaningfulness, and, in particular, that older adults would utilize context later than young adults under low-meaningfulness conditions. Meaningfulness did not affect the magnitude or development of contextual cueing effects for either age group. In other words, both age groups benefitted from context, but there was not an additional benefit for increased meaningfulness.

Similarities and Differences between Experiment 1 and 2

The tasks for Experiments 1 and 2 share some characteristics. Both are visual search tasks. Context is created by repeating the relative locations of a target and the background items. The association between the target and background is novel (not established in long term memory). Participants benefit from context by learning the spatial consistencies of the background (context) and its association with the target and using that knowledge to guide attention. Both studies demonstrated that young and older adults benefitted from repeated configurations and were able to use that context to guide attention in visual search.

One difference between the tasks was that Experiment 2 used meaningful background visual scenes and Experiment 1 used arrays of the same letter placed in random locations. Brockmole and Henderson (2006) found that participants (young adults) showed an additional benefit in the development of contextual cueing when stimuli were meaningful (upright) than when they were less meaningful (inverted).In Experiment 2, I found that young and older adults benefitted from context, and although contextual cueing effects were larger than in Experiment 1, there was no additional benefit associated with the meaningfulness manipulation. Contextual cueing effects were of the same magnitude, and developed at approximately the same time, for upright and inverted images. Why did participants not show an additional benefit? It may be that meaningfulness, although muted in the inverted images, was high enough within photographed natural scenes to show maximal contextual cueing benefits.

Another difference between the two tasks is the different memory processes that were tapped for these tasks. Chun and Jiang (1998) and Howard et al. (2004) found that participants (young and older) implicitly learned and used context to guide attention. Brockmole and Henderson (2006) found that when meaningful stimuli were used, participants (young adults) explicitly learned and used context. I found evidence that both young and older adults used implicit memory. In Experiment 1, young and older adults could not reliably recognize or recall the target location. In Experiment 2, participants were able to explicitly recognize background images but could not reliably place the target in the correct location in the image. Why did I find that participants implicitly encoded the target-background associations in Experiment 2? First, there was a delay in learning the context and testing the memory for context due to participants learning two sets of images (upright and inverted). Second, Brockmole and Henderson only tested memory for a single set of images. In Experiment 2, participants were given more images and target-background associations to learn coupled with fewer trials to learn that information. The memory load may have been such that implicit benefits had time to develop, but more practice was needed to develop explicit recollections of the many images. Thus, it is possible with more time to learn images, young and older adults would explicitly learn the target-background association. Regardless of how context was learned, young and older adults benefitted from that context.

Context Processing Theory and Aging

What do the results from these studies tell us about older adults' ability to learn and use context? Contrary to the context processing theory proposed by Braver and Barch (2002), older adults, in this study, were able to learn *and* use context. Braver and colleagues (2001; 2005) found that older adults had difficulties using novel associations between stimuli to bias responses (i.e., use context), unless given sufficient exposure to the task (Paxton et al., 2006). The present experiments have shown that not only can older adults use context similarly to young adults, but that they can use that context quickly to guide attention. These studies provide further evidence that, contrary to context processing theory, older adults efficiently use context to guide attention.

Langley et al. (2008) and Gayzur (2008) found that, on a task that used meaningful associations between pairs of words, older adults were able to use context similarly to young adults. In Experiment 1, I found that older adults were able to use context quickly without meaningful associations between the target and surrounding information. Would the meaningfulness of the associations alter older adults' ability to learn and use context? Gutchess and Park (2009) examined if older adults were able to recognize objects that were related or unrelated to the scene background (e.g., a cow in a farm scene or a cow in a laundromat). Young and older adults studied these different scenes and were given a recognition task. The authors found that both young and older adults were able to recognize objects in the scene well. What was interesting was that older adults recognized objects regardless of the meaningfulness of the scene (related or unrelated). Also, there were no age differences in this effect. Overall, older adults benefit from context.

Aging and Visual Search

Previous studies have shown that older adults were able to learn and use context in non-spatial attention tasks (e.g., associative learning; Langley et al., 2008; Paxton et al., 2006). The present experiments demonstrated that young and older adults were able to use context to guide the spatial deployment of attention on visual search tasks. A variety of studies have shown that older adults perform worse on attentionally demanding visual search tasks (top-down guidance of attention) compared to young adults. Why do these age-related declines in attentionally demanding search exist? Some would argue that age-related changes in central vision (Gottlob & Madden, 1998; Scialfa & Thomas, 1994) and other perceptual changes (Madden, Pierce, & Allen, 1996; Sliwinski & Hall, 1998) affect older adults' ability to efficiently guide attention in a visual search task. One thing that these previous studies did not investigate was how context of scenes can affect older adults' performance. Visual scenes are highly complex and contain significant amounts of information. It is difficult to prioritize information in these scenes unless you know what you are looking for. Chun (2000) stated that context can make scenes less complex, which can increase search efficiency. On a variety of tasks, reducing complexity has been shown to improve older adults' performance (Baltes & Lindenberger, 1997). The present study has shown that context can improve older adults' search performance on a visual search task. In other words, older adults can use repeated contexts to reduce the complexity of visual scenes to effectively and efficiently guide attention.

Future Directions

I found that older adults were able to use context to guide attentional deployment in visual scenes. However, the set of experiments did not measure how context is utilized by older adults. One way to measure how context guides attentional deployment is to measure eye movements. Since the contextual cueing task is a learning task, one could see: (a) if older adults change how they search in a scene when context becomes learned and (b) how quickly context utilization develops in older adults. For instance, at early epochs, context may not be recognized because it does not have a strong association (e.g. context is not yet learned); participants may make more fixations before finding the target. At later epochs (context association is stronger), participants may make fewer fixations (i.e., search more efficiently), which would suggest that participants are using context to guide attention in the visual scenes. Peterson and Kramer (2001) examined this with Chun and Jiang's (1998) contextual cueing task. They examined how context affects the number of fixations after context is learned and found that context can guide attention by reducing the number of fixations that young adults make before they find the target (search more efficiently) for repeated configurations. Thus, context can change how efficiently young adults search in cluttered arrays; however, this has not been examined with older adults.

Future studies should examine alternative means of manipulating meaningfulness. Expertise has been shown to more efficiently guide attention. Brockmole, Hambrick, Windish, and Henderson (2008) studied novice and expert chess players. Participants located a small “T” or “L” that was located randomly on a chessboard. The chess pieces on the board could be arranged in actual game play configuration or in a random configuration, and those arrays could be repeated or new. Expert chess players developed contextual cueing effects faster than novice players when actual game arrays were used rather than random arrays (about four times faster). Brockmole and colleagues concluded that meaningfulness impacted how quickly participants learned and used the target-background association. Expertise may play a role in how older adults navigate through real-world environments. Studies have shown that older adult chess experts decline in their performance on chess as they age (Charness & Bosman, 1990). However, expertise can help older adults offset age-related declines. For instance, I previously stated that older adults show general age-related declines on top-down attentional guidance in visual search (Madden et als). Charness (1981) found that older adult chess experts showed fewer age-related declines in chess visual search. Thus, expertise has been shown to aid older adults search performance. One way to measure this is to examine familiar locations that older adults have experience with that younger adults do not (e.g., an older adults’ home). This sense of familiarity would make the older adult an “expert” with the visual environment, while the young adults would not have the same “expert” experience.

Conclusions

Together, the present experiments have shown that older adults were able to learn *and* use context. Context processing theory states that older adults can learn but not efficiently use context when context associations are not intrinsically meaningful (Braver et al., 2001; Braver & Barch, 2002). However, the present studies showed that older adults maintained the ability to use context but did not show additional context benefits for meaningful stimuli, but neither did younger adults.

Findings from the memory tasks found that older adults benefitted from context. They can use context to help them overcome many age-related declines associated with explicit memory (Craik, 1984; Smith et al., 1998). These studies have shown that context benefits extend to the spatial attention domain. Older adults can use context, similarly to younger adults, to guide attention, which can help them navigate through complex visual environments to locate goal-relevant items, even in real world settings.

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