Visual Selective Attention in Amnestic Mild Cognitive Impairment

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Objectives. Subtle deficits in visual selective attention have been found in amnestic mild cognitive impairment (aMCI). However, few studies have explored performance on visual search paradigms or the Simon task, which are known to be sensitive to disease severity in Alzheimer’s patients. Furthermore, there is limited research investigating how deficiencies can be ameliorated with exogenous support (auditory cues).

Method. Sixteen individuals with aMCI and 14 control participants completed 3 experimental tasks that varied in demand and cue availability: visual search—alerting, visual search—orienting, and Simon task.

Results. Visual selective attention was influenced by aMCI, auditory cues, and task characteristics. Visual search abilities were relatively consistent across groups. The aMCI participants were impaired on the Simon task when working memory was required, but conflict resolution was similar to controls. Spatially informative orienting cues improved response times, whereas spatially neutral alerting cues did not influence performance. Finally, spatially informative auditory cues benefited the aMCI group more than controls in the visual search task, specifically at the largest array size where orienting demands were greatest.

Discussion. These findings suggest that individuals with aMCI have working memory deficits and subtle deficiencies in orienting attention and rely on exogenous information to guide attention.

Key Words: Cues—Mild cognitive impairment—Selective attention—Working memory.

Selective attention is the ability to focus cognitive resources on task-relevant information while filtering out distracting material. Success in focusing attention depends on a variety of factors, including the ability to ignore distractions, processing speed, and the ability to efficiently shift and adjust the focus of attention in response to external information and task goals. This complex cognitive skill is dependent on the frontoparietal network (Corbetta, Sylvester, & Shulman, 2009) and is modulated by the norepinephrine, cholinergic, and dopamine systems (Posner & Rothbart, 2007). Previous research has shown that selective attention is impaired early in the course of Alzheimer’s disease (AD) and is often the first nonmemory impairment to appear (for a review, see Perry & Hodges, 1999). This is consistent with the early neuropathological changes observed in prefrontal and parietal regions, as well as the disruption in the cholinergic system (Braak & Braak, 1991; Buckner et al., 2005). Relative to healthy older adults (OA), individuals with AD are less efficient at detecting a target during visual search tasks (Tales, Muir, Jones, Bayer, & Snowden, 2004), show impaired conflict resolution (Castel, Balota, Hutchinson, Logan, & Yap, 2007), and have reduced working memory capacity (Belleville, Chertkow, & Gauthier, 2007). In addition, patients with AD show deficiencies in the ability to inhibit distractors (Levinoff, Li, Murtha, & Chertkow, 2004), spatially orient attention (Festa-Martino, Ott, & Heindel, 2004), and endogenously guide processing (Greenwood, Parasuraman, & Alexander, 1997). Interestingly, selective attention declines linearly with disease severity (Belleville et al., 2007; Castel et al., 2007; Foster, Behrmann, & Stuss, 1999). As such, it is important to investigate this cognitive ability in individuals at risk of developing AD because such factors may help predict progression to dementia.

Amnestic mild cognitive impairment (aMCI), characterized by a decline in memory with otherwise preserved cognitive abilities and normal daily functioning, is often considered the transitional stage between normal aging and AD, although not all individuals diagnosed with aMCI progress to dementia (Petersen, 2004). To date, most research has focused on memory in aMCI; however, subtle changes in visual selective attention would also be anticipated in these individuals given that such deficits are observed in the early stages of AD.

Numerous experimental paradigms have been developed to measure unique aspects of visual selective attention, including simple choice reaction time (RT) tasks and tests of target detection/discrimination, as well as visual search.
paradigms and the Simon task. During a typical visual search task, participants locate a target among a varying number and type of distracting stimuli. When a target is highly dissociable from the distractors (single feature), it will automatically capture attention and appear to “pop-out”; in contrast, when the target has no distinct feature (conjoined feature), a more controlled and strategic search is required, with participants endogenously shifting attention from item to item until the search is complete (Treisman & Gelade, 1980; Wolfe, 1998). In the Simon task (Lu & Proctor, 1995; Simon, 1969), participants are presented with a colored target on the left or right side of a central fixation point and are asked to indicate the color of the target by pressing a left or right response key. The Simon effect refers to the phenomenon of faster response times on trials in which the target location and response key are congruent relative to incongruent trials. This task involves conflict resolution and controlled processing (Botvinick, Cohen, & Carter, 2004). The relative contribution of working memory can also be manipulated in the Simon task by increasing the number of possible stimuli from two to four colors (see Bialystok, Craik, Klein, & Viswanathan, 2004).

Patients with AD show a robust decline in performance on visual search paradigms and Simon tasks corresponding to disease severity (Castel et al., 2007; Foster et al., 1999). However, to date, there is minimal research investigating performance on these measures in aMCI. Selective attention deficits in aMCI have been identified using standardized neuropsychological measures (Brandt et al., 2009) and simple and choice RT tasks (Gorus, De Raedt, Lambert, Lemper, & Mets, 2008; Levinoff, Saumier, & Chertkow, 2005; Okonkwo, Wadley, Ball, Vance, & Crowe, 2008; Perry & Hodges, 2003; Tales, Snowden, Haworth, & Wilcock, 2005). These deficits are consistent with the neurological changes seen in aMCI within the prefrontal cortex, parietal lobes, and cholinergic system (Stephan et al., 2012), as well as the decreased connectivity observed in the frontoparietal network in the prodromal stages of AD (Neufang et al., 2011). However, to the best of our knowledge, there are only three published visual search studies (McLaughlin, Borrie, & Murtha, 2010; Tales, Bayer, et al., 2011; Tales, Haworth, Nelson, Snowden, & Wilcock, 2005) and no Simon task studies involving aMCI. Tales, Haworth, et al. (2005) and Tales, Bayer, et al. (2011) had aMCI participants determine the direction an arrow was pointing (left or right) when presented alone or with seven distractors. They showed that aMCI participants are disproportionately affected by distractors relative to controls, which they attributed to inefficiencies in processing speed and shifting efficacy. Interestingly, they reported poorer visual search performance among individuals who progressed to dementia within 2.5 years relative to aMCI individuals who remained stable (Tales, Bayer, et al., 2011). Both of these studies varied the number of items to be searched, but did not manipulate search condition, target presence, or the distribution of items (i.e., the test stimuli were presented in a clock-face configuration), which are important factors modulating impairment in AD (Foster et al., 1999). McLaughlin and colleagues (2010) explored these factors and showed that aMCI participants have impaired conjoined visual search abilities, particularly on larger array sizes and when the target was absent. Importantly, that study did not examine whether such deficiencies can be ameliorated with exogenous support.

The goal of the present study was to replicate McLaughlin and colleagues’ (2010) visual search findings, investigate performance on the Simon task, and determine whether aMCI-related deficiencies in visual selective attention can be mitigated with auditory cues. Previous research has shown that spatially orienting visual (Greenwood & Parasuraman, 2004) and auditory (Guerreiro, Adam, & Van Gerven, 2012; McLaughlin, Rich, Anderson, & Murtha, 2012; Spence & Driver, 1997) cues can facilitate selective attention in young adults and OA, with valid visual cues enhancing and invalid visual cues exacerbating conflict resolution (Fan et al., 2007). Furthermore, informative (i.e., highly predictive) orienting visual and auditory cues have been shown to (at least partially) mitigate age-related declines in controlled processing (McLaughlin & Murtha, 2010; McLaughlin et al., 2012). Spatially neutral alerting cues can also enhance response time performance by increasing phasic alertness (Fernandez-Duque & Posner, 1997); however, such cueing techniques do not appear to facilitate conflict resolution (Andres, Parmentier, & Escera, 2006; Fan et al., 2007) or ameliorate age-related declines in controlled processing (McLaughlin et al., 2012).

Individuals with aMCI (Tales, Snowden, et al., 2005, 2011) and AD (Parasuraman, Greenwood, & Alexander, 2000; Tales, Snowden, Brown, & Wilcock, 2006) also benefit from exogenous support. In fact, larger visual cueing effects have been observed in aMCI and AD participants relative to controls when the cue spatially orients attention (Festa-Martino et al., 2004; Tales et al., 2006; Tales, Snowden, et al., 2005, 2011). In contrast, individuals with aMCI and AD show similar (Tales et al., 2006, 2005) or reduced (Festa-Martino et al., 2004; Levinoff et al., 2005) cueing effects relative to controls when provided with an alerting cue. These findings suggest an aMCI- and AD-related deficiency in orienting attention (Festa-Martino et al., 2004; Tales et al., 2006; Tales, Snowden, et al., 2005). That is, individuals with aMCI and AD have difficulty endogenously orienting attention and therefore rely on exogenous information to guide attention processing (see Humphrey & Kramer, 1997, for similar effects in healthy elderly adults). Nevertheless, it is unclear whether informative cues improve selective attention in aMCI by reducing the orienting demands of the task (e.g., reducing the number of items to be searched) or by enhancing controlled processing (e.g., conflict resolution and working memory), as suggested in healthy young adults (Fan et al., 2007). In the present study, we used
auditory cues because visual cues appear to be less effective in complex visual environments relative to cross-modal cueing techniques (Sarter, 2000). Furthermore, auditory cues can capture attention without interfering with ongoing visual tasks (Sarter, 2000).

In sum, we investigated the influence of spatially informative orienting and spatially neutral alerting auditory cues in aMCI using two paradigms that measured distinct aspects of visual selective attention. Based on previous findings (Gorus et al., 2008; McLaughlin et al., 2010), we predicted that as the tasks required additional controlled processing, aMCI-related decrements in performance would emerge. Specifically, aMCI participants would show deficiencies when endogenously controlled orienting (visual search), response inhibition, and working memory (Simon task) were required. We also predicted that the auditory cues would facilitate response time performance. Based on the visual cueing literature (Tales, Snowden, et al., 2005) and attention control hypothesis (Craik, 1986), we expected larger cueing effects for the aMCI group relative to controls when the cues were spatially informative. If orienting cues facilitate controlled processing and conflict resolution in aMCI, then the orienting cue would be most beneficial during task conditions that require controlled processing (Simon task). In contrast, if cues improve performance by reducing the orienting demands, then the auditory cues should be most beneficial during task conditions with greater orienting requirements (visual search task, particularly on larger array sizes). Therefore, we investigated whether cues facilitated response times by reducing the orienting demands and/or enhancing conflict resolution. Finally, we expected the alerting cues to improve performance independent of task characteristics without reducing aMCI-related decrements in selective attention.

METHOD

Participants

Fourteen healthy older adults (ages 66–82 years) and 16 individuals with aMCI (ages 66–84 years) participated in the study. Individuals were recruited from the Baycrest research participant pool and through local advertisements, or from the Jewish General Hospital/McGill Memory clinic (nine aMCI participants). All participants provided informed consent, were fluent in English, and had self-reported normal or corrected-to-normal vision (e.g., no history of degenerative conditions, glaucoma, cataracts significant enough to impede vision, or color blindness) with no significant hearing loss. Participants were excluded if they had a history of stroke, transient ischemic attack (TIA), neurological or psychiatric illness, head injury, substance abuse, or elevated scores on the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983).

Participants were administered a neuropsychological battery that measured general cognitive functioning (Mini-Mental State Examination, MMSE; Folstein et al., 1975, modified Telephone Interview of Cognitive Status; Welsh, Breitner, & Magruder-Habib, 1993), verbal and nonverbal intelligence (Vocabulary and Matrix Reasoning; Wechsler, 1999), processing speed (Digit-Symbol Coding; Wechsler, 1997), simple attention and cognitive flexibility (Digit Span; Wechsler, 1997, Trail Making Test—Parts A and B; Strauss, Sherman, & Spreen, 2006), memory (Brief Visuospatial Memory Test [BVMT]—Revised; Benedict, 1997, Hopkins Verbal Learning Test [HVLT]—Revised; Brandt & Benedict, 2001, Digit-Symbol Incidental Learning; Wechsler, 1997), language (Boston Naming Task [BNT]; Strauss et al., 2006), and executive processing (Stroop; Mitrushina, Boone, Razani, & D’Elia, 2005, Letter and Category Verbal Fluency; Strauss et al., 2006). Groups were well matched on demographic variables, with no significant difference in age, education, or sex. See Table 1 for descriptive demographic information and a summary of the neuropsychological test scores for each group.

All controls scored within normal limits for their age and education on neuropsychological testing. The aMCI participants were diagnosed by consensual agreement between two neuropsychologists (N. D. Anderson, J. B. Rich) using Petersen’s (2004) criteria. Specifically, a classification of aMCI was given to an individual who (a) reported a memory complaint, (b) exhibited memory impairment on at least two of three memory measures, and (c) had intact instrumental activities of daily living and general cognitive functioning (MMSE ≥ 24). Nine participants had an isolated memory impairment, and seven had impaired memory plus an impairment on at least one measure in another cognitive domain (i.e., language, simple attention, and/or cognitive flexibility). Impairment was considered to be present when an individual obtained an age-corrected scaled score 1.5 SD below their estimated intellectual functioning (Wechsler, 1999). Thirteen of our participants had a previous diagnosis of aMCI, and all aMCI participants met criteria at the time of testing.

Experimental Tasks

Participants were administered three cued experimental tasks designed for this study: visual search–alerting, visual search–orienting, and the Simon task. Across tasks, only valid cues were used, and attention was never misdirected. Prior to the experimental tasks, a simple baseline RT test was administered. Participants were required to make a speeded response to a central target (red circle) presented at varying interstimulus intervals (ISI: 700–1,000 ms). A total of 30 trials (15 right handed, 15 left handed) were presented. In addition, standardized measures of sound localization and color discrimination were administered to ensure that individuals were able to adequately locate the
**Table 1. Demographic Variables, Neuropsychological Test Scores, and Baseline RT for Each Group**

<table>
<thead>
<tr>
<th>Variable</th>
<th>OA</th>
<th>aMCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>72.6</td>
<td>76.2</td>
</tr>
<tr>
<td>Education (years)</td>
<td>14.9</td>
<td>14.9</td>
</tr>
<tr>
<td>Sex (F:M)</td>
<td>8:6</td>
<td>4:2</td>
</tr>
<tr>
<td>Handedness (R:L)</td>
<td>12:2</td>
<td>14:2</td>
</tr>
<tr>
<td>Ethnicity (% Caucasian)</td>
<td>100%</td>
<td>87.5%</td>
</tr>
<tr>
<td>HADS-anxiety</td>
<td>5.2</td>
<td>4.2</td>
</tr>
<tr>
<td>HADS-depression</td>
<td>2.1</td>
<td>2.8</td>
</tr>
<tr>
<td>MMSE**</td>
<td>29.1</td>
<td>27.4</td>
</tr>
<tr>
<td>TICS-m***</td>
<td>38.5</td>
<td>33.3</td>
</tr>
<tr>
<td>Vocabulary SS</td>
<td>12.7</td>
<td>13.1</td>
</tr>
<tr>
<td>Matrix Reasoning SS*</td>
<td>15.1</td>
<td>12.9</td>
</tr>
<tr>
<td>Digit Symbol—copy SS***</td>
<td>14.4</td>
<td>10.5</td>
</tr>
<tr>
<td>Digit Symbol—incidental learning (raw)***</td>
<td>13.4</td>
<td>4.5</td>
</tr>
<tr>
<td>Digit Span SS</td>
<td>12.6</td>
<td>11.5</td>
</tr>
<tr>
<td>HVLT-immediate SS***</td>
<td>10.2</td>
<td>5.5</td>
</tr>
<tr>
<td>HVLT-delay SS***</td>
<td>10.3</td>
<td>4.8</td>
</tr>
<tr>
<td>BVMT-immediate SS***</td>
<td>11.3</td>
<td>5.6</td>
</tr>
<tr>
<td>BVMT-delay SS***</td>
<td>11.5</td>
<td>4.6</td>
</tr>
<tr>
<td>TMT-Part A SS</td>
<td>10.9</td>
<td>9.4</td>
</tr>
<tr>
<td>TMT-Part B SS</td>
<td>11.7</td>
<td>10.1</td>
</tr>
<tr>
<td>Boston Naming Test (raw)*</td>
<td>54.1</td>
<td>47.0</td>
</tr>
<tr>
<td>FAS Fluency SS</td>
<td>10.4</td>
<td>11.3</td>
</tr>
<tr>
<td>Animal Fluency SS**</td>
<td>11.0</td>
<td>7.8</td>
</tr>
<tr>
<td>Stroop SS*</td>
<td>12.7</td>
<td>10.0</td>
</tr>
<tr>
<td>Baseline RT (ms)</td>
<td>258</td>
<td>330</td>
</tr>
</tbody>
</table>

**Notes.** aMCI = amnestic mild cognitive impairment; BVMT = Brief Visuospatial Memory Test—Revised (Benedict, 1997); FAS = phonemic fluency to the letters F, A, and S (Strauss et al., 2006); HADS = Hospital Anxiety and Depression Scale (raw score out of 21; Zigmond & Snaith, 1983); HVLT = Hopkins Verbal Learning Test—Revised (Brandt & Benedict, 2001); MMSE = Mini-Mental State Examination (raw score out of 30; Folstein et al., 1975); OA = older adults; RT = reaction time; SS = age-corrected scaled score; TICS-m = modified Telephone Interview of Cognitive Status (raw score out of 50; Welsh et al., 1993); TMT = Trail Making Test (Strauss et al., 2006). Two of the aMCI participants were of South Asian descent, with the remaining participants being Caucasian. The TICS-m scores are based on 15 aMCI participants. The Stroop SS scores are based on 13 OA participants. The Boston Naming Test scores (out of 60) were calculated based on the odd 30-item version (Strauss et al., 2006). Multiple independent sample t tests were completed on the neuropsychological test data. Significant difference between groups: *p < .05. **p < .01. ***p < .001.

orienting cue and identify the colors used. The test session lasted approximately 2 hr.

**Visual search.**—Two cued visual search tasks (alerting, orienting) manipulating target presence (present, absent), cue availability (cued, noncued), and array size (5, 9, 17 items) were administered over two search conditions that varied in cognitive demand: single feature search (SFS) and conjoined feature search (CFS). During both visual search tasks, participants indicate whether a red vertical rectangle (target) was present or absent by pressing the appropriate response key (labeled PRESENT and ABSENT, with response key location counterbalanced across groups). In the SFS condition, the distractors were green vertical rectangles (salient target); in the CFS condition, the distractors were red horizontal and green vertical rectangles (target was not salient). Varying the number and type of distractor stimuli increased the orienting demands by requiring the participant to engage in a more strategic search for the target.

In the **alerting task**, an auditory cue was presented through both speakers on 25% of the trials (3 times for every 12 trials to ensure equal distribution across blocks; cf. Andres et al., 2006). Participants were told that the cue was there to remind them to stay focused on the task and did not predict the location of the target. For the **orienting task**, an auditory cue was presented through the left or right speaker on 50% of the trials, indicating the side the target could appear (if present). Participants were told that the orienting cue was there to help them find the target and that it was 100% valid (i.e., the target, if present, would appear only on the cued side).

**Procedure.** Each trial began with a central fixation cross for 1,500 ms followed by the test stimuli, which remained on the screen until a response was made. On cued trials, a 200-ms tone burst was presented 1,000 ms after the fixation cross initially appeared (see Figure 1). The computer screen was (invisibly) divided into a 16 × 10 matrix, and the test stimuli were randomly placed throughout the matrix. No stimuli were presented in the outer two cells of the matrix perimeter, and the target could appear in each location of the matrix except for the center two columns (to ensure attention would be oriented distinctly to the left or right of the computer screen). Search condition, target presence, array size,
and cue availability were counterbalanced and presented to participants in a pseudorandom order in both visual search tasks. To ensure consistency in display density, a distractor replaced the target when the target was absent.

A total of 480 trials were presented over four alerting blocks of 60 trials and four orienting blocks of 60 trials, with search conditions (SFS, CFS) presented in separate blocks. Blocks were presented in a fixed order for each task: Block 1 SFS, Block 1 CFS, Block 2 SFS, and Block 2 CFS. Each block took approximately 2–3 min to complete, and neuropsychological tests were administered between blocks. Practice trials were completed prior to each search condition, and the presentation order of the alerting and orienting tasks was counterbalanced across groups.

Simon task.—A cued Simon task was adopted from previous research (Lu & Proctor, 1995). Participants were asked to determine the color of a target circle presented on the left or right side of the computer screen by pressing the appropriate response key (see Figure 1). Response keys were counterbalanced across groups (left shift key = BLUE; right shift key = RED, or vice versa) and were clearly marked with a colored dot. The target location was either congruent (i.e., same side) or incongruent (i.e., opposite side) with the response key. An auditory cue was presented out of the left or right speaker on 50% of the trials. Participants were told that the cue was there to help them and that it indicated the location of the circle with 100% accuracy. Two conditions of varying cognitive demand were included: two stimuli or four stimuli.

In the two-stimuli condition, the target was either blue or red, whereas in the four-stimuli condition, the target could be blue or yellow (one response key), or red or green (other response key). Increasing the number of possible stimuli (i.e., colors) increased the cognitive demands by requiring working memory in addition to the cognitive processes.
(conflict resolution and controlled processing) required during the two-stimuli condition. During this task, the orienting demands were consistent across conditions.

Procedure. Each trial began with a central fixation cross for 1,200–1,500 ms followed by the target, which remained on the screen until a response was made. On cued trials, the 200-ms tone burst was presented 800 ms after the fixation cross initially appeared, followed by a varying ISI (200–500 ms) and then the target circle (see Figure 1). A total of 320 trials were presented over two blocks, with the two-stimuli and four-stimuli conditions presented in separate blocks of 160 trials. Congruency, target color, and cue availability were counterbalanced across trials and presented to participants in a pseudorandom order for each block. Practice trials were completed before each condition. Each block took approximately 5–6 min to complete, and neuropsychological tests were administered between blocks.

Apparatus and stimuli.—The experimental tasks were developed using Matlab 7.0 software, with Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997), and performed on a Dell Inspiron 1520 laptop (screen was 33 × 20.7 cm in area), with Bose Companion 2 Series II Multimedia speakers. The auditory cue (200-ms tone burst at 500 Hz, with gradual 10-ms rise and fall) was presented through both speakers simultaneously (alerting cue) or presented through the left or right speaker (orienting cue). Test stimuli were equivalent in saturation and luminance and were presented against a light-gray background. Between all trials, a 0.7-cm central fixation cross was presented. The viewing distance was approximately 60 cm, and the speakers were aligned with the computer screen (15 cm to left and right). For both visual search tasks, the test stimuli were 1.5 × 0.5 cm in size. For the Simon task, the target circle had a 3.1-cm diameter and was presented 6.7 cm from the center of the display.

Data Analyses

Between-group differences in median RT on the simple baseline RT task and on the neuropsychological measures were investigated using independent sample t tests. For each experimental task, a mixed-model analysis of variance (ANOVA) was conducted on the median RT data across task conditions and trial types. Median RT was calculated for each participant after discarding incorrect trials and anticipatory responses (RT faster than 75 ms). This trimming eliminated 1.4%–2.6% of trials across tasks. In the mixed-model analyses, degrees of freedom were adjusted to correct for violations of the sphericity assumption (Huynh & Feldt, 1976) and higher order interactions that were pertinent to our hypotheses were further investigated using simple-effect analyses with Bonferroni control.

Results

Baseline RT was equivalent between groups, $t(28) = 1.56$, $p = .131, d = .58$. Mean accuracy rates on both visual search tasks (91.7%–100%) and the Simon task (96.9%–99.3%) were near or at ceiling, and there were no between-group differences or group interactions observed across tasks. The RT data are presented in Table 2 and a summary of the significant findings is presented in the Supplementary Material.

Visual Search

A six-factor, group (OA, aMCI) by task (alerting, orienting) by search condition (SFS, CFS) by target (present, absent) by cue (cued, noncued) by array size (5, 9, 17), ANOVA was conducted. Several interactions were observed (see Supplementary Material), including a Group × Task × Cue × Array interaction, $F(2, 56) = 6.83, p = .002, \eta^2 = .196$, observed power (OP) = .904. As illustrated in Figure 2A, the alerting cue minimally facilitated response time performance across groups. In contrast, the orienting cue improved response times across array sizes; however, the magnitude of this effect was dependent on group and array size (Figure 2B). More specifically, the orienting cue was almost twice as beneficial to the aMCI group (103 ms, $SEM = 24.2$) relative to the controls (54 ms) on trials with an array of 17 items. No other group interactions were observed.

Simon Task

A four-factor, group (OA, aMCI) by task demand (two stimuli, four stimuli) by congruency (congruent, incongruent) by cue (cued, noncued), mixed-model ANOVA was conducted. A Group × Task Demand interaction was observed, $F(1, 28) = 5.91, p = .022, \eta^2 = .174, OP = .651$. Response times generally increased with task demand, $F(1, 28) = 97.23, p < .001, \eta^2 = .776, OP = 1.00$. This effect was disproportionately larger for aMCI participants relative to the OA group (see Figure 2C). Participants showed a reliable Simon effect in the two-stimuli condition; however, consistent with previous findings (Bialystok et al., 2004), this effect was not observed in the four-stimuli condition [Task Demand × Congruency: $F(1, 23) = 18.93, p < .001, \eta^2 = .451, OP = .986$] and was independent of group. A significant effect of cue was also observed, $F(1, 28) = 81.54, p < .001, \eta^2 = .744, OP = 22.6$ relative to noncued (mean RT = 704 ms, $SEM = 24.2$) trials. Contrary to the visual search task, this cueing effect was independent of group and task demand. No other group interactions were observed.

Relationship Between Group Effects and Neuropsychological Tests

Two-tailed correlation analyses with Bonferroni control ($\alpha \leq .025$) were used to explore the relationship between the group effects observed on the experimental measures (cueing
effect on 17-item trials of the orienting task, task demand effect on the Simon task) and neuropsychological tests (MMSE, Matrix Reasoning, Digit Symbol [copy and incidental learning], HVLT, BVMT, BNT, Animal Fluency, and Stroop). For the OA group, the orienting cueing effect and the effect of task demand (increased RT on the four-stimuli relative to the two-stimuli condition) were not related to any of the neuropsychological measures. In contrast, for the aMCI group, the task demand effect on the Simon task was correlated with performance on the MMSE ($r = -0.559, p = .024$) and Animal Fluency ($r = -0.587, p = .017$). That is, aMCI participants who were more vulnerable to the task demands (i.e., showed a greater increase in RT on the four-stimuli condition) also performed worse on the MMSE and Animal Fluency. No other significant correlations were observed.

**Discussion**

Previous research has demonstrated that aMCI is associated with subtle deficits in visual selective attention,
which appear to be contingent on task characteristics. These findings are consistent with the early AD-related neuropathological changes observed in the cholinergic system as well as prefrontal and parietal regions (Buckner et al., 2005; Perry & Hodges, 1999). Despite such reports, there is minimal research exploring performance on visual search paradigms or the Simon task and how decrements can be ameliorated with exogenous support. In the present

Figure 2. Group mean reaction time (RT) (±SEM) on the visual search–alerting (A) and visual search–orienting (B) tasks on cued (dashed line) and noncued (solid line) trials as a function of array size. Group mean RT (±SEM) on Simon task (C) as a function of task condition.
study, we explored visual selective attention in aMCI and examined the influence of auditory cues on performance using a visual search paradigm and Simon task that varied in demand. Although the number of participants was relatively small and our preliminarily findings need to be replicated in a larger sample, our results show that aMCI-related decrements in visual selective attention are influenced by task requirements and cue type/availability. Contrary to previous findings (Gorus et al., 2008), impairments did not simply emerge with increased task difficulty; rather, deficiencies in performance were associated with a specific deficit on the Simon task when working memory was required. Consistent with our predictions, participants benefited from spatially informative orienting cues, whereas the spatially neutral alerting cues did not significantly influence performance. Finally, the orienting cue improved performance similarly across groups and task conditions on the Simon task. In contrast, the orienting cue was more beneficial to individuals with aMCI relative to healthy controls on the visual search task at the largest array size where the orienting demands were greatest. As groups were equivalent on a measure of baseline RT, the present findings cannot be attributed to a between-group difference in psychomotor speed.

In the present study, the aMCI participants showed difficulty on the four-stimuli condition of the Simon task and not a general deficiency in visual selective attention or an impairment related to task demand. As the four-stimuli condition required working memory, our results are consistent with previous studies that show working memory deficiencies in aMCI (Brandt et al., 2009; Gagnon & Belleville, 2011) and AD (Belleville et al., 2007). Interestingly, groups demonstrated similar congruency effects on the Simon task, suggesting that individuals with aMCI have preserved conflict resolution abilities within the context of impaired working memory. Given the between-group differences observed on the neuropsychological measures (e.g., BVMT, Digit-Symbol copy and incidental learning), it is possible that poor performance on the Simon task represented some aMCI-related deficiency in associative learning in addition to (or rather than) a working memory impairment. That is, the aMCI participants had difficulty quickly learning the response key associations on the four-stimuli condition (e.g., red/green = left key and yellow/blue = right key), which interfered with task performance. Contrary to this interpretation, neither group showed an association between task demand effects on the Simon task (i.e., performance on the four-stimuli compared with two-stimuli condition) and performance on neuropsychological measures that required associative learning (BVMT immediate and delayed recall; Digit Symbol copy). As the effect of task demand was only related to MMSE and Animal Fluency for the aMCI participants, our results suggest that a combination of factors likely contribute to poor performance on the Simon task, including working memory and general cognitive deficiencies.

Our cueing manipulation also showed specific aMCI-related deficiencies in processing, rather than a global impairment in selective attention. Similar to previous reports (Guerreiro et al., 2012; McLaughlin et al., 2012; Spence & Driver, 1997), auditory cues that spatially oriented attention facilitated visual selective attention. In contrast, spatially neutral alerting cues did not influence response time performance in the present study. Consistent with the visual cueing literature (Tales, Snowden, et al., 2011), the aMCI group displayed larger cueing effects on the visual search task at the largest array size. In contrast, the orienting cues in the Simon task improved performance similarly across task conditions and groups. Therefore, orienting cues do not appear to enhance conflict resolution (as demonstrated in young adults; Fan et al., 2007). Instead, our results show that spatially informative cues improve performance in aMCI by reducing the orienting demands of the task. These findings suggest that individuals with aMCI have difficulty endogenously orienting attention and therefore rely on exogenous information to help guide processing (cf. Craik, 1986; Humphrey & Kramer, 1997). This orienting deficiency is consistent with previous findings that show reduced shifting efficacy during visual search tasks in individuals with aMCI (McLaughlin et al., 2010; Tales, Haworth, et al., 2005) and AD (Tales et al., 2004).

In the present study, we were predominately interested in the prodromal stage of AD. As such, we excluded any participant with a history of stroke or TIA. Although this likely minimized the presence of cerebrovascular changes in our sample, a potential limitation of our study is the possibility that our aMCI group included individuals in the preclinical stages of vascular dementia and/or individuals with a mixed etiology. Individuals with vascular dementia often show deficits in executive functioning and attention in the prodromal stages (Fernandez et al., 2011; Nordlund et al., 2007).

Although our results inform our understanding of how visual selection attention is affected by aMCI, our participants’ estimated premorbid level of intelligence was above average. As such, our results may not be generalizable to all individuals with aMCI. Furthermore, the present study does not determine whether changes in selective attention can predict the progression of aMCI to dementia (see Tales, Bayer, et al., 2011). It has been hypothesized that multidomain aMCI represents a more advanced prodromal stage of dementia (Alexopoulos, Grimmer, Perneckzy, Domes, & Kurz, 2006; Tabert et al., 2006; but also see Yaffe, Petersen, Lindquist, Kramer, & Miller, 2006). Given our limited sample size, we were unable to adequately investigate this developmental hypothesis of aMCI. Therefore, future research should explore selective attention differences between single-domain and multidomain aMCI, as well as selective attention as a predictive factor in conversion to AD.

In conclusion, our results demonstrate that visual selective attention is sensitive to aMCI and task characteristics. When the task requires working memory, decrements in performance are observed in individuals with aMCI. In contrast, conflict resolution and controlled processing were
generally preserved in our aMCI group. Importantly, our results also show that auditory cues significantly improve visual selective attention in aMCI by reducing the orienting demands. This pattern of results suggests that individuals with aMCI have deficiencies in working memory, as well as orienting attention and rely on exogenous information to guide attention.

SUPPLEMENTARY MATERIAL

Supplementary material can be found at: http://psychsocgerontology.oxfordjournals.org/

FUNDING

This work was supported by a Doctoral Research Award (P. M. McLaughlin) and operating grants (H. Chertkow) from the Canadian Institutes of Health Research (MOP 82809), the Annie Kirshenblatt Memorial Scholarship (P. M. McLaughlin), operating grants from the Fonds de la recherche en santé du Québec (H. Chertkow), and an internal grant from York University, Faculty of Health (S. J. E. Murtha).

ACKNOWLEDGMENTS

We thank Trevor Caldwell for programming the experiments and Shelley Solomon for assistance in recruiting participants. P. M. McLaughlin is now a fellow at the Semel Institute for Neuroscience & Human Behavior and Easton Center for Alzheimer’s Disease Research (David Geffen School of Medicine), University of California, LA. Aspects of this study were presented at the 26th International Conference of Alzheimer’s Disease International (Toronto, March 2011) and the Rotman Research Institute and Kunin-Lunenfeld Applied & Evaluative Research Unit Annual Conference (Toronto, March 2012).

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