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Original Research Report

Specificity of Age-Related Differences in Eye-Gaze Following: Evidence From Social and Nonsocial Stimuli

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Abstract

Background. Eye-gaze following is a fundamental social skill, facilitating communication. The present series of studies explored adult age-related differences in this key social-cognitive ability.

Method. In Study 1 younger and older adult participants completed a cueing task in which eye-gaze cues were predictive or non-predictive of target location. Another eye-gaze cueing task, assessing the influence of congruent and incongruent eye-gaze cues relative to trials which provided no cue to target location, was administered in Study 2. Finally, in Study 3 the eye-gaze cue was replaced by an arrow.

Results. In Study 1 older adults showed less evidence of gaze following than younger participants when required to strategically follow predictive eye-gaze cues and when making automatic shifts of attention to non-predictive eye-gaze cues. Findings from Study 2 suggested that, unlike younger adults, older participants showed no facilitation effect and thus did not follow congruent eye-gaze cues. They also had significantly weaker attentional costs than their younger counterparts. These age-related differences were not found in the non-social arrow cueing task.

Discussion. Taken together these findings suggest older adults do not use eye-gaze cues to engage in joint attention, and have specific social difficulties decoding critical information from the eye region.

Key Words: Aging—Arrows—Attention—Eye-gaze—Orienting.

Eye-gaze following refers to the ability to identify what an individual is looking at in the social environment and follow these eye-gaze cues to orient attention to that same stimulus, allowing the quick and efficient detection of socially relevant information (Langton, O'Donnell, Riby, & Ballantyne, 2006). It is the main way of engaging in joint attention with others and therefore this ability is important for facilitating social interactions and communication with others (see Langton, Watt, & Bruce, 2000; Mundy, Sigman, & Kasari, 1990; Riby & Doherty, 2009; Sigman & Ruskin, 1999; Stone & Yoder, 2001). The current research examined age-related differences in this key social-cognitive ability.

Experimental studies assessing eye-gaze following typically involve cueing participants with a centrally presented face cue displaying eye-gaze averted to the left or right. Direction of eye-gaze is either congruent or incongruent with the subsequent location of a target that participants must respond to (see Frischen, Bayliss, & Tipper, 2007, for a review). Eye-gaze following is indexed by more rapid responses to targets that have been gazed at. By manipulating how informative these eye-gaze cues are research in younger adults has investigated both automatic, involuntary and controlled, strategic shifts of attention in response to eye-gaze direction. For example, using spatially nonpredictive cues (i.e., the eyes of the face cue point toward target location on only 50% of trials) isolates automatic, involuntary orienting, whereas using spatially predictive cues (i.e., the eyes of the face cue point toward target location in two thirds of trials) assesses the ability to voluntarily and strategically shift attention in response to eye-gaze direction. Findings from these studies suggest that young individuals follow eye-gaze even when there is no strategic motivation to do so (Driver et al., 1999; Friesen & Kingstone, 1998; Tipples, 2002). While, further research argues that younger adults' attention shifts in response to eye-gaze are resistant to suppression, as even when participants are informed of where the target will appear prior to each trial, their responses still show evidence of interference from eye-gaze cues when these are incongruent with target location (Galfano et al., 2012).

To date, only two studies have assessed the eye-gaze following ability of older adults. Both studies found that there were age-related differences in eye-gaze following with evidence of an age-related reduction in the eye-gaze congruency effect (Slessor, Laird, Phillips, Bull, & Filippou, 2010; Slessor, Phillips, & Bull, 2008). Consistent with findings of age-related declines in the ability to decode and interpret more complex social cues to the thoughts, feelings, and intentions of others (Phillips et al., 2011; Ruffman, Henry, Livingstone, & Phillips, 2008; Slessor, Phillips, & Bull, 2007), this result is indicative of older adults showing less evidence of following others' eye-gaze cues than their younger counterparts. These findings led Slessor and coworkers (2008; 2010) to conclude that age-related differences in eye-gaze following ability reflect a social impairment in the ability to engage in joint attention in old age.

However, due to the methodologies employed in these previous studies, it is not possible to rule out several other competing explanations for these age-related difficulties in eye-gaze following. For example, Slessor et al. (2008; 2010) have tended to assess age-related differences in the ability to make controlled and voluntary shifts of spatial attention in response to eye-gaze. Specifically, the task employed in Slessor and coworkers (2008) used a design with predictive/endogenous eye-gaze cues and thus assessed strategic attentional shifts. In addition, although a nonpredictive cueing paradigm was used in Slessor and coworkers (2010), the main aim of this study was to assess whether the age of faces used to cue participants influenced eye-gaze following effects. As a result, a longer stimulus onset asynchrony (SOA; 500 ms) was employed, which could allow endogenous mechanisms of attention to influence responses (Driver et al., 1999). Therefore, previous aging research has not isolated exogenous/involuntary orienting mechanisms when exploring age-related differences in the ability to follow eye-gaze.

This distinction between exogenous and endogenous orienting of attention might have particularly important implications for age-related differences in eye-gaze following. Research exploring other cognitive skills has argued that aging selectively impairs cognition with declines in effortful, controlled processes, but not those that are more automatic (Folk & Hoyer, 1992; Nissen & Corkin, 1985). Of particular relevance to the current research, Folk and Hoyer (1992) found that the sudden onset of a peripheral cue (i.e., a flash of light) resulted in strong involuntary shifts of attention among younger and older adults, even when participants were aware that the cue was invalid on 100% of the trials. Importantly, there was no evidence of age-related declines in this task and, if anything, exogenous attentional shifts occurred more rapidly in older, than younger, adults. In contrast, a second experiment revealed age-related differences in endogenous shifts of attention in response to centrally presented arrow cues, with older adults' responses being less influenced by the cue. Taken together, these findings suggest that while exogenous shifts of spatial attention remain intact with age, endogenous attentional mechanisms are more vulnerable to decline.

It is important to note that findings of age-related declines in endogenous shifts of spatial attention are contentious, with some evidence of no differences in the ability to shift attention in response to centrally presented arrow cues (Brodeur & Enns, 1997; Hoyer & Familant, 1987). Nevertheless, given the consistent findings of an age-related stability in exogenous orienting, it is possible that aging may not affect the ability to automatically orient attention in response to eye-gaze direction. If so, the previous findings of age-related declines in eye-gaze following (Slessor et al., 2008) may be a manifestation of older adults having less strategic control over the movement of attention, rather than reflecting an impairment in social skills as we have argued elsewhere (see Landry & Burack, 2009 for a similar explanation for problems engaging in joint attention in autism).

Following eye-gaze cues (both predictive and nonpredictive) involves a number of executive processes, which are known to decline with age (see Phillips & Henry, 2008 for a review). These include attentional engagement, inhibition of irrelevant information, and the ability to plan and execute a response. Impairments in executive functioning have been found to contribute toward age-related differences in other aspects of social cue decoding such as emotion processing (Circelli, Clark, & Cronin-Golomb, 2013; Krendl & Ambady, 2010) and interpreting the mental states of others (Bailey & Henry, 2008; German & Hehman, 2006; Phillips et al., 2011). Therefore, it is also possible that problems with executive processes could influence age-related differences in eye-gaze following. For example, declines in attentional engagement processes, which allow older adults to maintain and manipulate task relevant information, might lead to difficulties in following congruent eye-gaze cues.

Alternatively, it has been argued that, despite age-related declines in the ability to inhibit nonsocial information

(Phillips & Henry, 2008), rather than an impairment in following congruent eye-gaze cues, weaker eye-gaze congruency effects in old age may be reflective of older adults simply being better at disengaging from incongruent eye-gaze. Slessor and coworkers (2008; 2010) employed a typical eye-gaze cueing paradigm in which the centrally presented face gazed at (congruent trial) or away from (incongruent trial) the location of a target that participants must respond to, allowing the investigation of eye-gaze congruency effects (i.e., response time [RT] difference between trials in which eye-gaze is congruent and incongruent with subsequent target location). Using this paradigm it is not possible to indentify whether age-related differences in eye-gaze following are due to impairments in the ability to follow congruent eye-gaze cues or improvements in the ability to ignore or disengage from distracting incongruent cues.

To resolve this issue, it is important to also conduct cost/benefit analyses, similar to those carried out when exploring shifts of visual attention to a centrally presented cue (Folk & Hoyer, 1992; Greenwood & Parasuraman, 1994; Mayer, Dorflinger, Rao, & Seidenberg, 2004; Thiel, Zilles, & Fink, 2004). This additional analysis aims to assess the strength of the attentional advantage that participants receive from congruent cues and the attentional slowing or cost that incongruent cues produce. It involves comparing congruent cues (i.e., that predict subsequent target location) and incongruent cues (i.e., that misinform perceivers about subsequent target location) with a neutral condition that does not provide perceivers with information about target location. A facilitation effect, which probes attentional engagement, reflects the difference between responses to congruent and neutral trials, with participants orienting attention significantly more quickly to cued trials. An attentional cost (the difference between incongruent and neutral trials) reflects slowing in target detection when participants are previously miscued to the opposite side of space as target location and assesses attentional disengagement.

Previous research assessing the eye-gaze following ability of younger adults has found that eye-gaze cues result in a strong facilitation effect. Participants respond significantly more quickly to congruent trials than to trials where eye-gaze remains directed toward the perceiver and thus provides participants with no cue to subsequent target location (Akiyama et al., 2008; Friesen & Kingstone, 1998; Kuhn & Benson, 2007). However, the findings regarding attentional costs are mixed, with some studies suggesting that incongruent eye-gaze cues produce attentional costs (Hietanen, 1999; O'Donnell & Langton, 2003; Sato, Kochiyama, Uono, & Yoshikawa, 2009), while others find no difference in reaction times to targets preceded by incongruent and neutral eye-gaze trials (Akiyama et al., 2008; Friesen & Kingstone, 1998). To date, facilitation effects and attentional costs from eye-gaze cues have not been assessed among older adults.

Given these competing explanations, in order to argue that older adults have a specific social impairment in engaging in joint attention with others by following eye-gaze cues, it is important to further investigate the mechanisms underlying age-related differences in eye-gaze following ability. By manipulating the methodology employed by Slessor and coworkers (2008), the present study aims to explore the nature and specificity of age-related differences in eye-gaze following across three experiments. Study 1 assessed age-related differences in making automatic and controlled shifts of attention in response to eye-gaze direction. A second study then explored the effect of aging on attentional engagement and disengagement from eye-gaze cues. Finally, the third study investigated the specificity of age-related differences in eye-gaze following by also assessing older adults' ability to shift attention in response to a nonsocial, arrow cue.

Study 1

Study 1 assessed whether age-related differences in eye-gaze following were found only when making strategic shifts of attention to predictive eye-gaze information or also evident when automatically orienting attention in response to nonpredictive eye-gaze cues. To this end, a group of young and older participants completed two eye-gaze following tasks in which the eye-gaze direction of a centrally presented face cue was either predictive (i.e., in two thirds of trials eye-gaze accurately predicts target location) or nonpredictive (i.e., in only half of the trials eye-gaze accurately predicts target location) about the probable location of a target. If, declines in the strategic control of visual attention underlie age-related differences in eye-gaze following then aging should only affect performance when participants are required to use predictive eye-gaze information. However, if age-related differences in eye-gaze following reflect a more specific social impairment, then the effects of age should be evident for both eye-gaze following tasks.

Method

Participants

Two groups of participants were recruited: 41 young adults (37 females) aged 18–31 (mean *[M]* = 20.67, standard deviation [*SD*] = 2.67), all being students who completed the study for course credit, and 34 older adults (28 females) aged 60–88 (*M* = 72.71, *SD* = 6.82), recruited through the local participant panel and reimbursed for their time. All were fluent in English and reported being free from past or present neuropsychological disorders. All participants who required corrective lenses wore them while completing the experiment. Older adults were screened for cognitive impairment using the Test your Memory (Brown, Pengas, Dawson, Brown, & Clatworthy, 2009), with all participants achieving a score of 42 or greater (*M* = 47.44; *SD* = 2.43), which is the recommended cutoff point.

Stimuli and procedure

Grayscale photographs (10 × 8 cm) of four actors (two males) with neutral expressions were selected from the

Facial Expressions of Emotions: Stimuli and Test (FEEST; Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002). Eye-gaze direction of these images was manipulated using Adobe Photoshop, creating face images with eye-gaze averted 6 pixels (0.38° from direct eye-gaze which was 1.5° from the centre of the screen) to the left or right.

Participants completed two eye-gaze following tasks. Each task consisted of 96 trials in total. In one task, eye-gaze was predictive in that, two thirds of trials were congruent with the subsequent location of the target (an asterisk of ~1 × 1 cm), and one third was incongruent with target location (i.e., 64 congruent trials and 32 incongruent trials). However, in a second task, eye-gaze was nonpredictive as in only half of trials eye-gaze predicted subsequent target location (i.e., 48 congruent trials and 48 incongruent trials).

Participants were asked to focus on the fixation cross and hold their attention in that location until the target appeared, returning their eye-gaze to the fixation cross after making their response. After 1,000 ms, the fixation cross was replaced by a photograph of a face with eye-gaze averted to the left or right, which remained on screen for 220 ms. This image then disappeared and the target appeared approximately 10.5 cm to the left or the right of the centre of the screen (see Figure 1).

Participants sat approximately 45 cm from the computer monitor on which the stimuli were presented. They were told that on the screen, they would see a photograph of a person looking to the left or right and following this image a target would appear to either the left or right of the screen. They were asked to respond to the location of the target as quickly and accurately as possible with the appropriate key press. Cue direction, target position, and actor occurred equally often and were presented in a random order. The order in which the tasks were completed was fully counterbalanced across participants. Prior to completing each task, participants were specifically instructed about the predictive utility of the eye-gaze cue. For instance, in the predictive eye-gaze-cueing task, participants were told that eye-gaze direction would predict target location on the majority of trials, while in the nonpredictive task, they were told that eye-gaze direction would not predict target location.

Results and Discussion

Error rates were low (total errors < 2%) and therefore in accordance with previous research (Slessor et al., 2008; 2010), only RTs were included in the analysis. Trials in which errors were made were excluded and then median RTs for congruent and incongruent trials in each task were calculated individually for each participant. The descriptive statistics for the performance of younger and older adults on the eye-gaze cueing task can be seen in Table 1. The following analyses were designed to examine whether age-related differences in eye-gaze following vary as a function of the nature of the task (i.e., whether the eye-gaze cue was predictive or nonpredictive). To this end, a 2 (age group: young, older) × 2 (cue-target congruency: congruent, incongruent) × 2 (task: predictive, nonpredictive) mixed design analysis of variance (ANOVA) was conducted. There was a main effect of cue-target congruency, $F(1,73) = 69.14$, $p < .001$, $\eta_p^2 = .49$, such that participants were faster to respond to congruent (M = 396 ms) than incongruent (M = 418 ms) trials. A main effect of age group was also found, $F(1,73) = 50.25$, $p < .001$, $\eta_p^2 = .41$, with older adults (M = 491 ms) responding more slowly overall than younger participants (M = 323 ms). These findings were qualified by a Cue-target congruency × Age group interaction, $F(1,73) = 10.78$, $p < .01$, $\eta_p^2 = .13$. None of the other main effects or interactions reached significance, including the main effect of task $F(1,73) = 0.02$,

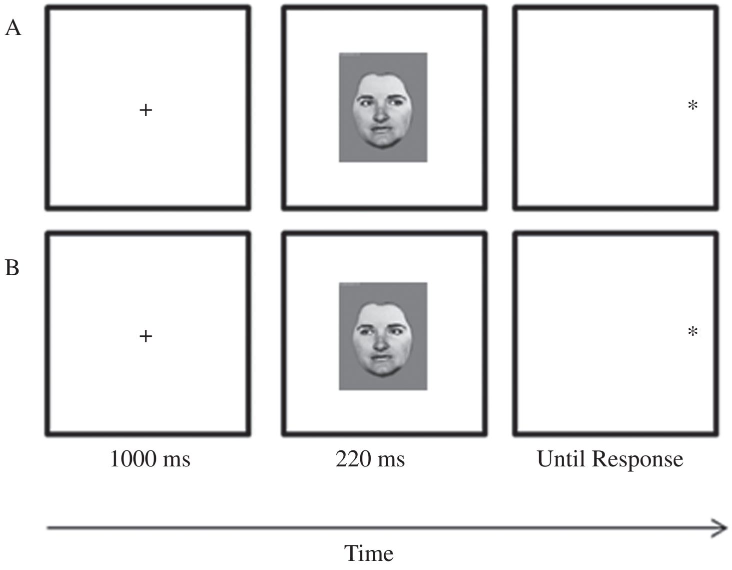

Figure 1. Example of the trial sequence for the (A) congruent eye-gaze condition and (B) incongruent eye-gaze condition.

Table 1. Mean RT (ms) and *SD* for the Eye-Gaze Cueing Task in Study 1, Broken Down by Task Type (i.e., predictive or nonpredictive), Trial Type (Congruent and Incongruent) and Age Group

	Young		Older	
	M	*SD*	*M*	*SD*
Predictive eye-gaze cues				
Congruent	303	49.12	487	155.42
Incongruent	336	50.85	501	153.96
Nonpredictive eye-gaze cues				
Congruent	314	66.38	482	145.52
Incongruent	341	59.53	494	138.19

Note. M = mean; RT = response time; SD = standard deviation.

p = .89, η_p^2 = .00; the Task × Age group interaction, $F(1,73)$ = 0.79, p = .38, η_p^2 = .01; the Task × Cue-target congruency interaction, $F(1,73)$ = 1.00, p = .32, η_p^2 = .01; and the three-way interaction, $F(1,73)$ = 0.28, p = .60, η_p^2 = .00.

To explore the cue-target Congruency × Age group interaction in more detail, congruent and incongruent RT were collapsed across both tasks and then two paired samples *t*-tests were carried out separately for each age group. This analysis revealed that younger adults responded more significantly more quickly to congruent (M = 308 ms) than incongruent trials (M = 338 ms), $t(40)$ = 9.42, p < .001, d = 1.47. Older adults also showed faster responses to congruent (M = 484 ms) than incongruent trials (M = 497 ms), $t(33)$ = 3.11, p < .01, d = 0.53.

We then examined age-related differences in the strength of the eye-gaze congruency effect, collapsed across both tasks. It has been demonstrated that overall slowing affects RT difference scores as these scores increase as overall RT increases (Chapman, Chapman, Curran, & Miller, 1994). As noted above, older adults responded significantly more slowly overall on both eye-gaze cueing tasks. Therefore, in order to control for this age-related slowing and in accordance with previous spatial attention research (Hartley, Kieley, & Slabach, 1990; Tellinghuisen, Zimbra, & Robin, 1996), the strength of the eye-gaze congruency effect was represented as one proportional difference score (i.e., $RT_{incongruent} - RT_{congruent}/RT_{congruent}$). An independent samples *t*-test revealed that, across both tasks, younger adults (M = 0.10; SD = 0.07) had a significantly stronger eye-gaze congruency effect than older participants (M = 0.03; SD = 0.04), $t(73)$ = 5.05, p < .001, d = 1.18.

Similar to Slessor and coworkers (2008), although both younger and older adults responded more quickly to targets that were congruent (vs. incongruent) with eye-gaze direction, older adults had a smaller eye-gaze congruency effect than younger participants when eye-gaze cues were predictive of target location. Extending these findings results indicated that age differences in eye-gaze following were not influenced by the characteristics of the task (i.e., whether the eye-gaze cue was predictive or nonpredictive). Therefore, older adults showed less evidence of eye-gaze following even when the eye-gaze cue was nonpredictive and exogenous attentional mechanisms were isolated. Taken together, these findings suggest that age-related differences in eye-gaze following ability are not explained by declines in the strategic control of visual attention.

Study 2

Consistent with Slessor and coworkers (2008; 2010), Study 1 employed an eye-gaze cueing paradigm in which the eye-gaze cue was only ever either congruent or incongruent with subsequent location of a target. Study 2 aimed to further investigate the nature of age-related differences in eye-gaze following by assessing whether weaker eye-gaze congruency effects in older adults could be attributed to smaller facilitation effects, attentional costs, or both. Therefore, in addition to congruent and incongruent eye-gaze cues, in the present study, a neutral cue condition was also included (i.e., in which the eye-gaze direction of the individual cueing participants remained straight ahead throughout the trial).

In keeping with previous aging research, Study 1 also used an eye-gaze cueing paradigm in which the centrally presented cue was an image of the whole face. However, according to the results of previous studies, when viewing faces older adults spend proportionally longer than younger adults looking at the mouth and less time fixating on the eye region (Murphy & Isaacowitz, 2010; Sullivan, Ruffman, & Hutton, 2007). It might therefore be argued that previous findings of age-related declines in eye-gaze following using full faces (Slessor et al., 2008; 2010) were influenced by older adults diverting their attention away from the eye region, toward the mouth. To control for this issue, in the present study, photographs of only the eye region alone were presented to participants in an eye-gaze following task.

If age-related differences in eye-gaze following ability are a consequence of improvements in disengaging from or inhibiting distracting social information (i.e., incongruent eye-gaze cues) with age, then there will be an age-related reduction in attentional costs from incongruent eye-gaze cues. However, if weaker eye-gaze congruency effects in older adults reflect a social impairment in the ability to extract important information from the eye region in order to engage in joint attention with others, then older adults will show a smaller facilitation effect from congruent eye-gaze cues than younger adults.

Method

Participants

A separate sample of 46 young adults (36 females) ranging in age from 17 to 47 (M = 21.02, SD = 5.84), and 44 older adults (37 females) ranging in age from 60 to 82 (M = 72.64, *SD* = 5.50) participated in Study 2. Recruitment procedures and inclusion criteria were similar to Study 1.

Stimuli and procedure

The same images of individuals with eye-gaze directed leftwards and rightwards were used in Study 1. However, each image was cropped to isolate the eye region to 2 × 6 cm.

The procedure employed in Study 2 was identical to Study 1 with the exception that, in addition to congruent and incongruent trials, there were neutral trials in which eye-gaze direction remained straight ahead throughout the duration of the trial (see Figure 2). Furthermore, participants completed only one eye-gaze following task. This task consisted of 160 trials, including 64 congruent and 32 incongruent trials as well as 64 neutral trials, in which eye-gaze direction remained straight ahead throughout the duration of the trial.

Results and Discussion

Error rates were low (total errors < 2%) and thus similar to Study 1, only RTs were included in the analysis. Trials in which errors were made were excluded and then median RTs for each condition (congruent, incongruent and neutral) were calculated individually for each participant. The descriptive statistics for the performance of younger and older adults on the eye-gaze cueing task can be seen in Table 2. To assess whether there were any age differences in performance on the eye-gaze cueing task, a mixed design ANOVA was conducted with one within-subjects factor (cue-target congruency: congruent, incongruent or no-cue) and one between-subjects factor (age group: young, old). This analysis revealed a significant main effect of cue-target congruency, $F(2,176) = 77.11$, $p < .001$, $\eta_p^2 = .47$. Bonferroni pair-wise comparisons revealed that participants were faster to identify targets when eye-gaze was congruent (*M* = 394 ms) compared to either neutral (*M* = 402 ms) or incongruent eye-gaze cues (*M* = 416 ms); participants were also faster to identify targets when eye-gaze was neutral than when incongruent. There was also a significant main effect of age group, $F(1,88) = 40.80$, $p < .001$, $\eta_p^2 = .32$, as older adults (*M* = 474 ms) performed more slowly overall across all trials than younger participants (*M* = 333 ms). This was qualified by a significant Cue-target congruency × Age group interaction $F(2,176) = 18.69$, $p < .001$, $\eta_p^2 = .18$.

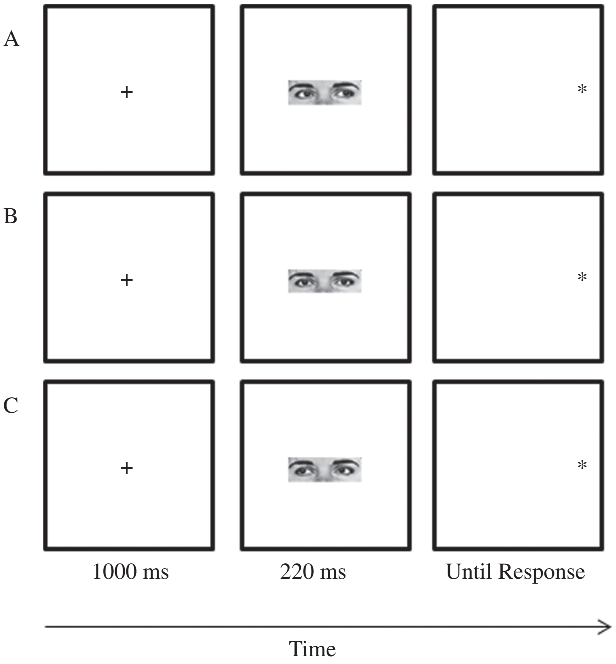

Figure 2. Example of the trial sequence for the (A) congruent eye-gaze condition, (B) neutral eye-gaze condition, and (C) incongruent eye-gaze condition.

To further investigate the significant Age group × Cue-target congruency interaction, two repeated-measures ANOVAs, with cue-target congruency as the within subjects factor, were conducted separately for each age group. For younger participants, this analysis revealed a main effect of cue-target congruency, $F(2,90) = 90.23$, $p < .001$, $\eta_p^2 = .67$. Bonferroni comparisons indicated that younger participants showed evidence of a facilitation effect and cue congruency effect responding more quickly to congruent trials than neutral ($p < .001$) and incongruent ($p < .001$), respectively. In turn, they also showed a significant attentional cost responding more quickly to neutral (vs. incongruent) trials ($p < .001$).

The analysis of older adults' responses also revealed a main effect of cue-target congruency, $F(2,86) = 10.22$, $p < .001$, $\eta_p^2 = .19$. Similar to younger adults, older participants showed evidence of a cue congruency effect and attentional cost responding more slowly to incongruent trials than congruent ($p < .001$) and neutral trials ($p < .01$), respectively. There was no significant difference between their RT to congruent and no-cue trials ($p = 1.00$) and thus older adults did not show a significant facilitation effect from congruent eye-gaze cues.

Similar to Study 1, there was evidence of overall age-related slowing on the task and thus proportional difference scores were calculated for each of the three conditions. This resulted in the following scores being calculated for the cue congruency effect ($\mathrm{RT}_{\mathrm{incongruent}} - \mathrm{RT}_{\mathrm{congruent}}/\mathrm{RT}_{\mathrm{congruent}}$), the facilitation effect ($\mathrm{RT}_{\mathrm{no\ cue}} - \mathrm{RT}_{\mathrm{congruent}}/\mathrm{RT}_{\mathrm{congruent}}$), and

Table 2. Mean RT (ms) and *SD* for the Eye-Gaze Cueing Task in Study 2, Broken Down by Trial Type (Congruent, Neutral, and Incongruent) and Age Group

	Young		Older	
	M	*SD*	*M*	*SD*
Congruent	317	33.15	470	147.54
Neutral	332	31.22	472	142.67
Incongruent	351	34.46	481	149.40

Note. M = mean; RT = response time; SD = standard deviation.

the attentional cost ($RT_{incongruent} - RT_{no\ cue}/RT_{no\ cue}$). Age-related differences in the strength of these proportional difference scores were then investigated by conducting a series of independent samples *t*-tests (see Figure 3). These analyses revealed that the strength of the congruency effect was significantly smaller in older compared to younger adults, $t(88) = 6.93$, $p < .001$, $d = 1.48$. Older adults also showed a significantly weaker facilitation effect from congruent eye-gaze cues than their younger counterparts, $t(88) = 5.22$, $p < .001$, $d = 1.12$. Finally, the strength of the attentional cost shown by older adults was significantly smaller than younger participants' responses, $t(88) = 4.08$, $p < .001$, $d = 0.86$.

Replicating the findings of Study 1, older adults showed less evidence of eye-gaze following than their younger counterparts. Therefore, age-related differences in eye-gaze following were still evident when only the eye region of the cueing stimulus was presented, suggesting that the previous findings of declines in following eye-gaze direction with age do not reflect older adults fixating on other areas of the face than the eye region when viewing the stimulus cue (Murphy & Isaacowitz, 2010; Sullivan et al., 2007).

Also consistent with previous findings (Hietanen, 1999; O'Donnell & Langton, 2003; Sato et al., 2009), further analysis of the mechanisms underlying eye-gaze following revealed that younger adults showed significant facilitation effects (i.e., faster responses to congruent eye-gaze than neutral trials). However, unlike younger participants, older adults did not receive an advantage from eye-gaze cues that were congruent with target location, compared to those giving no information about target location. Therefore, older adults did not demonstrate a facilitation effect from congruent eye-gaze and thus showed no evidence of decoding critical cues from the eye region to facilitate detection of a target object.

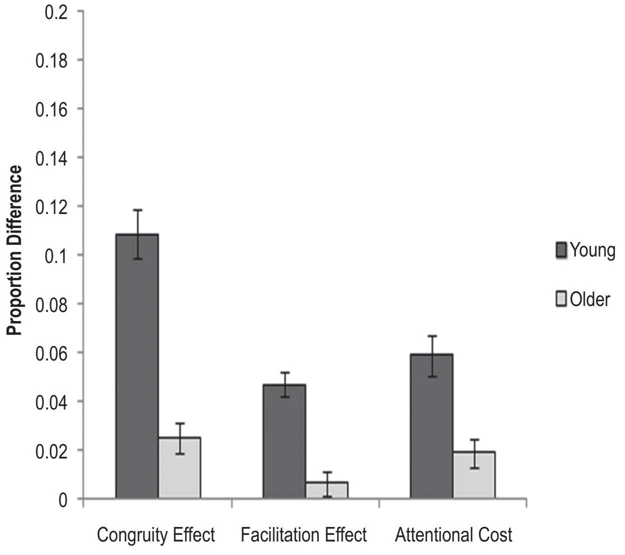

Figure 3. Graph depicting the strength of the congruency effect, facilitation effect, and attentional cost for the younger and older participants on the eye-gaze cueing task. Error bars represent standard error.

It was found that both younger and older adults demonstrated significant attentional costs on the eye-gaze cueing task (i.e., slower responses to incongruent eye-gaze than neutral trials). However, age-related differences were also evident here with this effect being weaker in older participants. This finding indicates that older adults were less distracted than their younger counterparts by incongruent eye-gaze cues.

Taken together, these results suggest that age-related differences in eye-gaze following can be attributable to a reduction in both the benefits from congruent eye-gaze cues and attentional costs from incongruent eye-gaze cues. The finding that older adults show a smaller attentional cost for incongruent eye-gaze cues indicates that they may be better than younger adults at disengaging from social cues that are misinforming them to the location of a target. However, as older adults also showed no evidence of a facilitation effect from congruent eye-gaze cues, rather than an age-related improvement in the ability to ignore distracting social cues, older adults were simply processing social cues from the eye region less efficiently than younger adults.

Nevertheless, as noted in the introduction, the eye-gaze following task employed in Study 2 required executive functions such as planning and execution of a response and general attentional demands that are known to decline with age (Phillips & Henry, 2008). Thus, age-related difficulties on this task may reflect problems with executive functioning or declines in processing speed in old age. As noted above, previous research exploring the effects of aging on orienting attention in response to nonsocial stimuli has produced contradictory results, with some findings of age-related declines (Folk & Hoyer, 1992), while others suggest no differences in this ability with age (e.g., Brodeur & Enns, 1997; Hoyer & Familant, 1987). Consequently, it has been argued that age-related differences in spatial shifts of attention are dependent on a number of factors including SOA and size of stimulus (Folk & Hoyer, 1992). To this end, in order to support the claims that the findings of Study 2 are reflective of a specific social difficulty, it is important to find no evidence of age-related differences in shifting attention in response to a nonsocial cue when using a paradigm that is identical to the current eye-gaze cueing task.

Study 3

To explore the specificity of the age-related differences in eye-gaze following found in Study 2, a third study was conducted to investigate whether age differences were also found when shifting attention in response to a nonsocial cue. The spatial cueing paradigm employed was identical to Study 2 but a directional arrow replaced eye-gaze direction as the attentional cue. An arrow was chosen as this stimulus is most commonly used as a nonsocial control cue when assessing eye-gaze cueing effects (e.g., Friesen, Ristic, & Kingstone, 2004; Kuhn & Benson, 2007; Ristic, Friesen,

& Kingstone, 2002) and, unlike other potential control stimuli (such as cartoon eyes) arrows are not representative of a social stimulus in any way. If the findings of Study 2 reflect a specific social difficulty, then no age-related differences should be found when following a nonsocial arrow cue. However, if previous findings of age-related differences in eye-gaze following are attributable to general declines in processing speed and executive function, then older adults should also show weaker facilitation effects and attentional costs in the arrow cueing task.

Method

Participants

A separate sample of 35 young adults (23 females) aged 17–33 (*M* = 20.11, *SD* = 2.95) and 37 older adults (26 females) aged 61–84 (*M* = 73.11, *SD* = 6.20) participated in this study. Recruitment procedures and inclusion criteria were similar to Study 1 and 2.

Stimuli and procedure

The procedure carried out in Study 3 was identical to Study 2 except that instead of a photograph of the eye region, the cueing stimulus was an arrow (2 × 6 cm). Again there were three conditions: congruent, incongruent, and neutral. In the congruent and incongruent condition, the arrow cues had one arrow head which pointed to either the left or right of the screen. In the neutral condition, the arrow had two heads pointing to both the left and the right (see Figure 4).

Results and Discussion

Error rates were low (total errors < 2%) and therefore only RTs were included in the analysis. Trials in which errors were made were excluded and then median RTs for each condition (congruent, incongruent, and neutral) were calculated individually for each participant. The descriptive statistics for the performance of younger and older adults on the arrow cueing task can be seen in Table 3. To assess whether there were any age differences in performance on the arrow cueing task, a mixed design ANOVA was conducted with one within-subjects factor (cue-target congruency: congruent, incongruent, or no-cue) and one between-subjects factor (age group: young, old). This analysis revealed a significant main effect of cue-target congruency, $F(2,140) = 134.66$, $p < .001$, $\eta_p^2 = .66$. Bonferroni pair-wise comparisons revealed that participants were faster to identify targets when the arrow was congruent (*M* = 389 ms) compared to either neutral (*M* = 415 ms) or incongruent arrow cues (*M* = 447 ms); participants were also faster to identify targets when the arrow was neutral than when incongruent. There was a significant main effect of age group, $F(1,70) = 103.12$, $p < .001$, $\eta_p^2 = .60$, as older adults (*M* = 508 ms) performed more slowly overall across all trials than younger participants (*M* = 326 ms). This was qualified by a significant Cue-target congruency × Age group interaction $F(2,140) = 11.96$, $p < .001$, $\eta_p^2 = .15$.

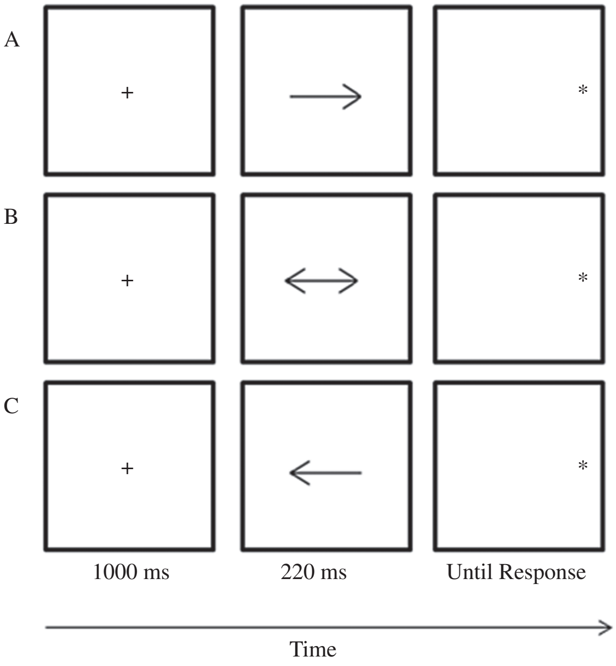

Figure 4. Example of the trial sequence in the (A) congruent arrow condition, (B) neutral arrow condition, and (C) incongruent arrow condition.

To further investigate the significant Cue-target congruency × Age group interaction two repeated-measures ANOVAs, with cue-target congruency as the within subjects factor, were conducted separately for each age group. This analysis revealed a main effect of cue-target congruency for younger participants, $F(2,68) = 55.28$, $p < .001$, $\eta_p^2 = .62$. Bonferroni comparisons revealed that younger participants showed evidence of a facilitation effect and cue congruency effect responding more quickly to congruent trials than neutral ($p < .001$) and incongruent ($p < .001$), respectively. In turn, they also showed a significant attentional cost responding more quickly to neutral (vs. incongruent) trials ($p < .001$).

The analysis of older adults' responses also revealed a main effect of cue-target congruency, $F(2,72) = 83.77$, $p < .001$, $\eta_p^2 = .70$. Similar to younger adults, older participants showed evidence of a facilitation effect and cue congruency effect responding more quickly to congruent trials than neutral ($p < .001$) and incongruent ($p < .001$), respectively. They also demonstrated a significant attentional cost responding more slowly to incongruent trials than neutral trials ($p < .01$), respectively.

Consistent with Study 1 and 2, as there was evidence of general age-related slowing on the arrows task proportional difference scores were calculated for each of the conditions (cue congruency effect, facilitation effect, and attentional cost) to control for this issue. To investigate age-related differences in the strength of these effects, a series of independent samples *t*-tests were conducted using these proportional difference scores (see Figure 5). These analyses revealed that there were no significant age differences in the strength of the congruency effect, $t(70) = 1.19$, $p = .24$, $d = 0.28$, facilitation effect, $t(70) = 1.02$, $p = .31$, $d = 0.24$, or attentional cost, $t(70) = 0.96$, $p = .34$, $d = 0.23$.

The findings of Study 3 suggest that younger and older participants shifted their attention in response to a directional arrow cue with both groups responding more quickly to congruent than incongruent trials. Both age groups also demonstrated significant facilitation effects and attentional costs in response to the arrow cue, which is consistent with findings of previous research investigating age-related differences in spatial attention at similar SOAs (Brodeur & Enns, 1997; Hoyer & Familant, 1987). After controlling for general age-related slowing, there were no significant age-related differences in any of these effects, indicating that spatial cueing of attention using a nonsocial cue, such as an arrow, remains intact with age. This differential pattern of results for eye-gaze and arrow cueing suggests that any age-related difficulties in spatial cueing of attention are specific to social cues such as eye-gaze direction.

Table 3. Mean RT (ms) and *SD* for the Arrow Cueing Task in Study 3, Broken Down by Trial Type (Congruent, Neutral, and Incongruent) and Age Group

	Young		Older	
	M	*SD*	*M*	*SD*
Congruent	306	31.45	472	97.62
Neutral	325	32.53	506	99.85
Incongruent	347	41.48	547	111.74

Note. M = mean; RT = response time; SD = standard deviation.

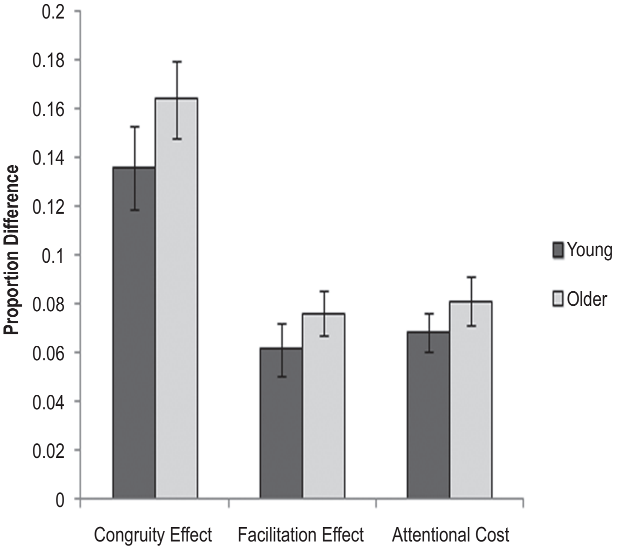

Figure 5. Graph depicting the strength of the congruency effect, facilitation effect, and attentional cost for the younger and older participants on the arrow cueing task. Error bars represent standard error.

General Discussion

The main aim of the present research was to explore the nature and specificity of age-related differences in eye-gaze following. Extending the findings of Slessor and workers (2008; 2010), the results from Study 1 were indicative of age-related differences in both exogenous and endogenous attention shifts in response to eye-gaze direction, with older adults demonstrating reduced eye-gaze congruency effects. Thus, difficulties following the eye-gaze of others cannot be attributed to declines in the strategic control of visual attention with age. The findings from Study 2 suggested that age-related differences in eye-gaze following can be attributed to reductions in attentional engagement from congruent eye-gaze cues and increases in the speed of disengagement from incongruent eye-gaze with age, suggesting that older adults were less efficient at extracting this important information from the eye region. It also revealed that older adults showed no evidence of using eye-gaze cues to aid target detection (i.e., their responses were not facilitated by congruent eye-gaze cues). Importantly, Study 3 found no evidence of age-related differences in the engagement and disengagement of attention when a nonsocial cue was used (i.e., in an arrow cueing task).

Taken together, the findings of these three studies suggest a specific social impairment in the ability to follow another person's eye-gaze direction, which is in keeping with evidence of age-related difficulties in the ability to decode more complex social cues such as the emotions and mental states of others (Phillips et al., 2011; Ruffman et al., 2008). In particular, the results of the present research are evidence of specific age-related declines in the ability to interpret important information from the eye region. These findings contribute to a growing body of literature that suggest that older adults have particular difficulties decoding communicative cues such as eye-gaze direction and emotional expressions from the eye region (Slessor et al., 2008; 2012; Sullivan et al., 2007).

It might be argued that age-related differences in the ability to follow the eye-gaze of others is linked to age-related changes in neural networks in the frontal and temporal lobes that have been found to be responsible for social-cognitive processes, such as decoding and interpreting the mental states and intentions of others (Amodio & Frith, 2006; Fletcher et al., 1995; Goel, Grafman, Sadato, & Hallett, 1995). Of particular relevance to the current study the superior temporal sulcus, amygdala, and ventromedial cortex have been found to be implicated in decoding information from the eyes such as eye-gaze direction (Williams, Waiter, Perra, Perrett, & Whiten, 2005). These brain regions show the earliest and greatest amount of deterioration with age (Raz & Rodrigue, 2006) and thus these declines may underlie age-related problems in efficiently decoding eye-gaze information.

In order to make the stimuli more akin to eye-gaze cues shown in real-life, manipulation of eye-gaze in the present study was subtle and the stimuli were presented for a brief period of time. Consequently, it could be argued that for these reasons, older adults were unable to process the eye-gaze cues efficiently. However, there are a number of reasons why this interpretation would seem unlikely. Firstly, previous research has shown that older adults are able to identify direct and clearly averted eye-gaze (similar to that shown in the present study) and no age differences have been found in this ability (Slessor et al., 2008). In addition, it seems that older adults' eye-gaze following abilities are not influenced by the length of time the gaze-cue stimulus remains on the screen. For example, although the effects are still reduced compared to their younger counterparts, older adults have shown gaze-congruity effects at presentation times of under 50 ms (Bailey et al., in press). Finally, similar age-related differences in eye-gaze following have been found when eye-gaze cues are presented at longer SOAs (e.g., 500 ms, Slessor et al., 2010). Nevertheless, to fully resolve this issue, future research should explore age-related differences in eye-gaze following using stimuli with differing degrees of eye-gaze aversion and presented at various SOAs.

It should be noted that, although arrows are the standard control stimuli used in eye-gaze following research, they do differ considerably from eye-gaze cues not just in terms of a social component but also in their complexity. For instance, images of arrows are less complex and thus likely to be quicker and easier to process than photographs of faces. Therefore, it could be argued that another possible explanation for the specific impairment found in the ability to follow eye-gaze with age is that it reflects a visual crowding effect (Whitney & Levi, 2011). Indeed, research suggests that there is evidence of age-related increases in the magnitude of visual crowding effects (Scialfa, Cordazzo, Bubric, & Lyon, 2013).

However, in everyday life, it is necessary to process the complexities of a face in order to decode cues to eye-gaze direction. The ability to follow another person's eye-gaze to identify an object of interest in the social environment is one of the main ways of engaging in joint attention. Therefore, the finding that older adults have specific difficulties following congruent eye-gaze cues suggests that they may have fundamental problems establishing eye-contact and joint attention with others. Given the importance of joint attention in facilitating social interactions and communication (Langton et al., 2000; Mundy et al., 1990; Sigman & Ruskin, 1999; Stone & Yoder, 2001), these difficulties may have negative implications for social functioning in old age. In particular, previous research has reported that when interacting with others older adults engage in more socially inappropriate behaviors such as excessive verbosity (Henry, von Hippel, & Baynes, 2009). Eye-gaze plays an important role in signaling turn-taking in conversational settings and thus problems responding to eye-gaze with age could contribute toward age-related increases in socially inappropriate interactions with others. Further studies are required to directly investigate the link between age-related differences in attending to eye-gaze cues and social functioning.

In order to explore the role that visual crowding plays in age-related differences in eye-gaze following, future research could also assess older adults' ability to follow the eye-gaze direction of schematic faces, which are simpler and easier to process than photographs of faces. Therefore, if age-related differences are due to stimulus complexity, then these will be reduced or eliminated when schematic faces are employed. The use of schematic faces could also shed some light on another potential issue concerning the age of the stimulus cue employed in the current research. For example, in the present study, images of the eye-gaze cues of only younger adults were used as the stimulus cue. However, Slessor and coworkers (2010) found that the age of the stimulus cue had an important influence on age-related differences in eye-gaze following with younger participants' having an advantage when required to follow the eye-gaze cues of young faces. Therefore, it is important to also investigate these effects when using eye-gaze cues of older adults or age invariant stimuli, such as schematic faces.

In conclusion, older adults were found to show less evidence of making involuntary, reflexive and voluntary, controlled shifts of attention in response to eye-gaze direction. Unlike their younger counterparts, older adults did not show an advantage for congruent eye-gaze cues and therefore they showed no evidence of attending to eye-gaze cues that predicted target location. Older participants also seemed to be better at inhibiting or disengaging from eye-gaze cues that were incongruent with target location. These age differences were not found on a nonsocial arrow cueing task. Taken together, these findings indicate that older adults have specific difficulties in extracting social information from the eye region to engage in joint attention with others.

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