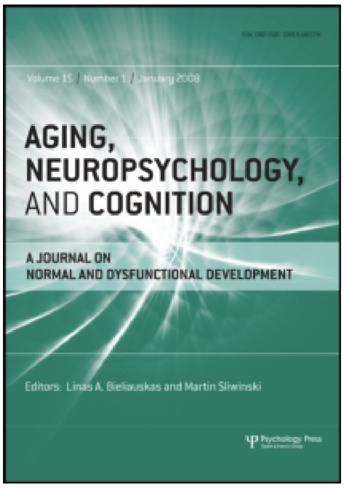

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The Effects of Practice and External Support on Older Adults' Control of Reflexive Eye Movements

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The Effects of Practice and External Support on Older Adults' Control of Reflexive Eye Movements

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ABSTRACT

The present study examined whether external support and practice could reduce age differences in oculomotor control. Participants were to avoid fixating an abrupt onset and on some trials, were provided with a predictive cue regarding the onset location or identity. Older adults demonstrated more capture than younger adults, but both groups improved with practice. Whereas the older group benefited from a location preview (Experiment 1), neither group showed less capture when given a preview of the onset object itself (Experiment 2), suggesting that location-based inhibition, but not object-based inhibition, was sufficient to support oculomotor control within this paradigm. To test the generalizability of these skills, displays in a final block were manipulated such that the onset could appear in a different location or be a different object altogether. Viewing patterns were similar for changed vs. unchanged displays, suggesting that participants' practice-related gains could withstand a change in the task materials.

Keywords: Aging; Inhibition; Oculomotor capture; Memory; Practice.

INTRODUCTION

Relative to younger adults, older adults are less able to restrain responding when a prepotent response should be suppressed, thereby demonstrating deficits in inhibitory control (Hasher, Zacks, & May, 1999). While the bulk of this work has used manual (e.g., May & Hasher, 1998) or verbal (e.g., West, 1999) responses to measure inhibitory control, mounting evidence from eye tracking research also points to older adults' reduced ability to control

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reflexive responses (e.g., Olincy, Ross, Young, & Freedman, 1997; Munoz, Broughton, Goldring, & Armstrong, 1998; Nieuwenhuis, Ridderinkhof, De Jong, Kok, & van der Molen, 2000). For example, age differences have been reported on the antisaccade task in which a target is flashed to one side of a central fixation and the viewer is instructed to initiate a saccade in the opposite direction of where the cue was presented (i.e., an antisaccade). When presented with an abrupt onset, the prepotent response is to generate an eye movement towards the onset (i.e., a prosaccade); inhibition is required to withhold this response and generate an antisaccade (Olk & Kingstone, 2003). Older adults generate more errors (i.e., make more prosaccades) on antisaccade trials compared to younger adults (Olincy et al., 1997). Additionally, when correct antisaccades are generated, older adults are disproportionately slowed on antisaccade trials relative to younger adults, presumably because they experience difficulty in suppressing reflexive saccades towards the onset (Munoz et al., 1998; Nieuwenhuis et al., 2000; Olincy et al., 1997).

Older adults are also more affected by irrelevant distractors in oculomotor capture tasks in which a singleton target must be fixated (e.g., Cassavaugh, Kramer, & Irwin, 2003; Kramer, Hahn, Irwin, & Theeuwes, 2000; Ryan, Shen, & Reingold, 2006). For instance, on a feature singleton search task, older adults were less accurate in fixating a shape-singleton target (e.g., a green *X* among green *O*s) when a distracting colour singleton was also present in the display (e.g., a red *X*; Ryan et al., 2006). Similarly, when a task-irrelevant abrupt onset appeared within the search field, older adults' search reaction times for a singleton target were slower (Cassavaugh et al., 2003), and more erroneous saccades were made towards the abrupt onset, compared to younger adults (Kramer et al., 2000).

Despite older adults' impaired ability to inhibit reflexive eye movements, recent work suggests that they can use external support to increase their resilience to oculomotor capture. On the feature singleton search task used by Ryan et al. (2006), older adults were able to use a predictive location cue, indicating the hemifield where the target would appear, to overcome distraction by an irrelevant color singleton when the target and color singleton were located in opposite hemifields. These results suggest that provided there is sufficient spatial separation between targets and distractors, older adults can use prior knowledge of the target location to bolster their resilience to capture.

Age differences in oculomotor capture may also be reduced as older adults develop memory representations for the distracting information (Ryan, Shen, Turk-Browne, & Hasher, 2007). In Ryan et al. (2007), younger and older adults were shown a series of displays each containing three novel objects; one of the objects served as an abrupt onset which participants were instructed to ignore. Although older adults initially directed more viewing towards the onset than younger adults, age differences in oculomotor capture were significantly reduced in later blocks. Memory for the displays, some of which repeated across blocks, may have contributed, at least in part, to the decrease in capture. If participants remembered some attribute of the onset object in each scene – either where it appeared or what it looked like – this may have obviated the need to fixate the object in subsequent blocks, thereby increasing participants' ability to inhibit eye movements towards it. Related work suggests that memory *does* contribute to object- and location-based inhibition. Long-term inhibition of return (IOR), the phenomenon of slowed responses to previously attended objects and regions of space, is at least partially dependent on memory for spatial (Castel, Pratt, & Craik, 2003) and object information (Paul & Tipper, 2003; Tipper, Grison, & Kessler, 2003). Inhibitory states may become associated to specific locations and object representations during initial processing and upon subsequent presentation, these inhibitory tags serve to dampen overt attention to those particular objects or locations (Grison, Paul, Kessler, & Tipper, 2005). If the avoidance of oculomotor capture, as in the Ryan et al. paradigm, also relies on location- and/or object-based inhibition, then providing participants with information regarding either the location or the identity of an upcoming onset object may improve their resilience to capture.

The present study examined the effects of external support on age differences in oculomotor control. Using the same procedure as in Ryan et al. (2007), participants were shown a series of displays containing three novel objects, one of which served as an abrupt onset which participants were to avoid fixating. Participants were given a preview of either the onset location (Experiment 1) or the onset object (Experiment 2) or were provided with no preview of the abrupt onset (Experiments 1 and 2). If participants can apply an inhibitory tag to either spatial or object information that is maintained in memory, and subsequently invoke such inhibition when the onset occurs, participants should show less capture on preview versus no-preview trials. Contrasting performance between younger and older adults will reveal whether any observed age differences in oculomotor capture can be reduced when external support is provided.

A second aim of this study was to examine the extent to which practice with the task demands can affect older adults' ability to restrain reflexive eye movements. As already mentioned, Ryan et al. (2007) reported marked improvements in older adults' viewing patterns after just a short period of practice. While some of those reductions in capture may have been due to the influence of memory, some reduction in capture may have simply been the result of extended practice with the task requirements. Changes in behavior due to practice have been demonstrated in older adults across a variety of cognitive domains (for a review, see Kramer & Willis, 2003), including task switching (Kramer, Larish, & Strayer, 1995), preparatory attention (Bherer & Belleville, 2004), visual search (Scialfa, Jenkins, Hamaluk, & Skaloud, 2000), and the Stroop task (Davidson, Zacks, & Williams, 2003). Therefore, we examined whether oculomotor capture was reduced throughout training for scenes that were either novel or repeated across blocks, and for scenes that were either preceded by a preview or not. Additionally, one thing paramount to any training paradigm is the demonstration that gains obtained through training can then be transferred to a different task or a unique set of stimuli (Bherer et al., 2005; Schmidt & Bjork, 1992). Thus, in order to determine if any obtained reductions in oculomotor capture would be maintained for a different set of stimuli, both experiments included a final test block in which some of the previously viewed displays were manipulated. For manipulated displays, either the abrupt onset appeared in a different location or a new object served as the abrupt onset within a previously viewed display. In this block, no previews were provided and participants' task remained the same: to avoid looking at the onset object. Reductions in oculomotor capture will be considered to have been maintained if the amount of capture is similar for repeated versus manipulated displays. The inclusion of such conditions allows us to examine whether any age-related differences are observed in the ability to generalize inhibitory control to an altered set of stimuli. All together, the current work will outline whether external support and/or task practice can reduce oculomotor capture from abrupt onsets and provide tools by which age-related deficits in inhibitory control can be remediated.

EXPERIMENT 1

Experiment 1 examined whether prior knowledge regarding the spatial location of an abrupt onset can reduce oculomotor capture in younger and older adults. If participants can bolster their resilience to capture by inhibiting a specific region in space, then less viewing should be directed towards the late-onset object when a preview is provided regarding the location of the onset. Participants were expected to show reduced capture with a location preview and with practice on the task. If these effects of prior knowledge and practice are sustainable, at least in the short term, then reduced capture should also be observed for manipulated scenes in the final block.

Method

Participants

Twenty-four younger (17–33; *M* = 22.29, *SD* = 3.46; 8 males) and 24 older (61–84; *M* = 71.29, *SD* = 6.78; 3 males) adults participated in exchange for monetary compensation. Participants were recruited from the Rotman Research Institute participant pool; all participants had normal or corrected-to-normal vision and reported no incidence of traumatic brain injury. Older adults had an average of 15.71 (*SD* = 3.01) years of education and a mean score of 34.54 (*SD* = 5.42) on the Shipley Vocabulary Test (Shipley, 1946). Younger adults did not differ from older adults in either years of education

(M = 16.08, SD = 2.30), $t(46) = 0.48$, $p > .05$, or performance on the vocabulary test (M = 32.33, SD = 3.73), $t(46) = 1.65$, $p > .05$.

Design

The design was a 2 (age) × 2 (preview type, only in blocks 1 and 2) × 3 (third block change) mixed factorial with age (young, older) as a between-subjects factor and both preview type (no-preview, location-preview) and third block change (same, location, object) as within-subjects factors.

Stimuli

Stimuli were presented on a 17” Dell monitor and each display measured 1024 × 768 pixels and subtended approximately 33.4° of visual angle 25 in. (63.5 cm) from the monitor. In each block, participants viewed 60 displays; each containing three unique abstract objects placed on a real-world background (see Figure 1). The objects were designed using Corel Draw

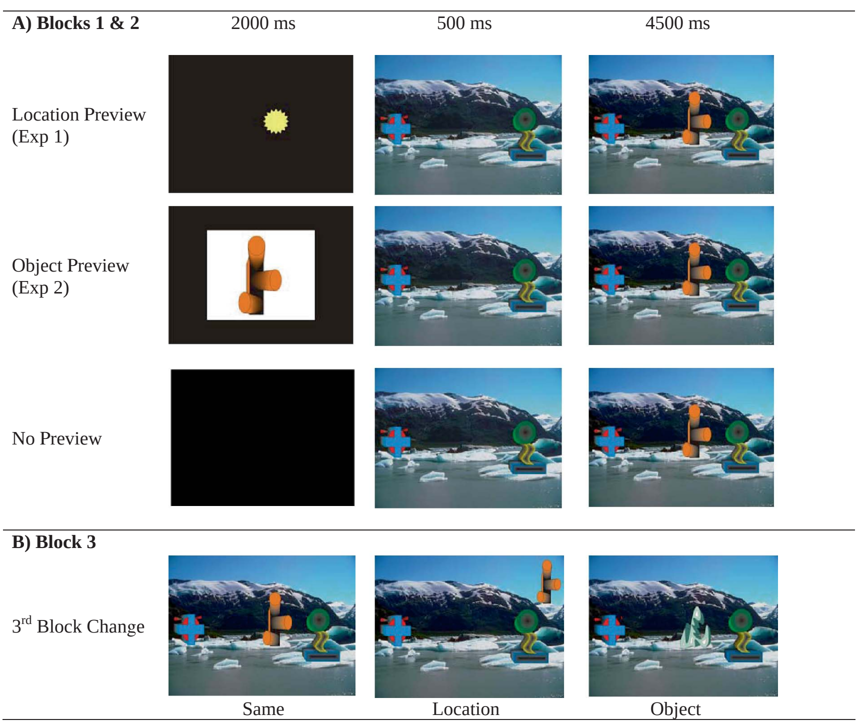


FIGURE 1. (A) Depiction of a typical trial sequence for location-preview (Experiment 1), object-preview (Experiment 2), and no-preview trials in the first and second training blocks. The same trial procedure was used in the final block (all no-preview trials) for both experiments. (B) Examples of the three trial types used in the final block. [To view this figure in colour, please visit the online version of this Journal.]

(v12) and the real-world scenes were taken from the gallery of outdoor scenes in Corel Draw. In total, 240 abstract objects and 60 real-world scenes were used. In preparing the displays, four objects were randomly paired with each background: two objects were presented in the same location throughout the trial (objects 1 and 2), one object served as the original onset object (object 3a), and one object served as the alternative onset object (object 3b). Four versions of each display were created: an original version (3a appears in location 1), an object change version (3b appears in location 1), a location change version (3a appears in location 2), and an alternative location change version (3b appears in location 2). Stimuli were fully counterbalanced, such that each version of a display was viewed as either an original version, object change, or location change, across participants. This procedure permits comparisons of viewing across physically identical stimuli to control for stimulus-specific effects on eye movement behavior.

Participants viewed 60 displays in each of the first two blocks in a different random order. The displays were repeated from the first to the second block.

Half of the trials in the first and second blocks were location-preview trials for which participants were given a cue regarding where the onset object would appear (see Figure 1a). The preview symbol was a large yellow asterisk placed at the approximate centre of mass of the onset object. Scenes that received a location preview in block one also received a preview in block two; likewise, scenes that did not receive a preview in block one also did not receive a preview in block two. In the final, third, block, one-third of the displays were repeated in the same form as shown in the first and second blocks (Repeat displays), one-third contained a change in the onset location from previous viewings (Location displays), and one-third contained a change in the onset object itself (Object displays). In the Object displays, a new onset object was presented in a previously viewed display; however, the onset location remained the same as in previous viewings. No previews were provided during the third block. In all three blocks, the task remained the same: participants were instructed to avoid viewing the sudden onset object.

Procedure

In an effort to equate the groups on circadian arousal, participants were tested at their respective age group's optimal time of day (Hasher et al., 1999). Older participants were tested in the morning (9–11 am) and younger participants were tested in the afternoon (12–5 pm).

Eye movements were recorded for all blocks with the Eyelink II eye-tracking system (SR Research Ltd., Mississauga, Ontario, Canada) and sampled at a rate of 500 Hz with a spatial resolution of 0.1°. A 9-point calibration was performed at the start of the experiment followed by a 0-point accuracy test. Calibration was repeated if the error at any point was more than 1°. For the task, participants were told that novel objects would be seen on a real-world background; two objects would initially be on the screen and then, after a brief moment, a third object would suddenly appear. Across the three blocks, participants were told to ignore (i.e., not look at) the late-onset object at all times but to otherwise freely view the other objects and the background scene. Participants were additionally told that on some of the trials in the first two blocks, they would receive a preview of the location of the abrupt onset and on other trials, they would receive no preview.

At the start of each trial, a screen indicating the type of trial ('location preview' or 'no preview') was shown for 2000 ms, followed by either a location preview screen or a blank screen for 2000 ms (see Figure 1a). This was immediately followed by the initial two-object scene and after 500 ms, the onset object appeared. The entire scene was displayed for a total of 5000 ms. The same trial structure was used for all three blocks, although the final block consisted only of no-preview trials. Each trial was initiated by the participant who was required to maintain central fixation while pressing a button on a keypad. Thus, the only delay between trials was the time taken for the participant to fixate at the central point and press the button. Participants were given a 2-min break between each of the blocks. Following the experiment, participants were given the Shipley Vocabulary Test and a background questionnaire.

Measures

Eye movements were analyzed with respect to the experimenter-drawn interest areas corresponding to the location of the late-onset object. Our primary measure of interest was duration of viewing (ms) to the late-onset object from the time of onset to the end of the trial period. However, as this measure may be influenced by general age-related slowing (leading older adults to be slower to disengage attention from the onset), we also examined the number of trials on which the late-onset object was fixated (i.e., resulted in oculomotor capture).

Results

Training Blocks

Duration of viewing time and number of trials fixated were submitted to separate analyses of variance (ANOVA) with age (young, old) as a between-subject factor and preview type (no-preview, location-preview) and block (block 1, block 2) as within-subject factors. Effects were considered significant at $p < .05$. Means and standard errors for the first two blocks are presented in Table 1.

Location Preview Effects

In line with previous work reporting age-related differences in the control of reflexive eye movements, older adults directed more erroneous

TABLE 1. Average Duration of Viewing Time (ms) and Number of Trials on which the Late-onset was Fixated in the First and Second Training Blocks

	Younger Adults				Older Adults			
	No Preview		Preview		No Preview		Preview	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Experiment 1								
Block 1								
Viewing time (ms)	67.26	10.52	68.98	21.47	274.80	41.42	186.90	28.51
No. of trials fixated	3.38	0.43	2.75	0.89	12.25	1.58	7.67	1.31
Block 2								
Viewing time (ms)	41.99	9.05	43.08	12.33	110.81	22.92	75.72	15.12
No. of trials fixated	3.38	0.60	2.38	0.57	6.54	1.08	4.33	0.86
Experiment 2								
Block 1								
Viewing time (ms)	100.06	16.41	86.86	24.69	161.73	44.73	174.03	33.72
No. of trials fixated	4.54	0.85	3.71	0.51	7.54	1.11	7.17	0.96
Block 2								
Viewing time (ms)	65.69	13.07	52.82	9.80	141.18	47.15	85.52	16.65
No. of trials fixated	4.00	0.61	4.04	0.65	6.21	1.18	5.04	0.72

viewing towards the late-onset object, $F(1, 46) = 19.76$, $p < .001$, partial $\eta^2 = .30$, and fixated it on more trials, $F(1, 46) = 16.62$, $p < .001$, partial $\eta^2 = .27$, than younger adults. Participants' viewing time, $F(1, 46) = 4.06$, $p = .05$, partial $\eta^2 = .08$, and number of trials fixated, $F(1, 46) = 13.54$, $p < .01$, partial $\eta^2 = .23$, were affected by the location preview, and this effect was qualified by a significant age by preview interaction for both viewing time, $F(1, 46) = 4.44$, $p < .05$, partial $\eta^2 = .09$, and number of trials fixated, $F(1, 46) = 5.10$, $p < .05$, partial $\eta^2 = .10$. The three-way interaction between age, preview, and block was not significant for duration of viewing, $F(1, 46) = 2.36$, $p =.13$, partial $\eta^2 = .05$, but was significant for number of trials fixated, $F(1, 46) = 4.84$, $p < .05$, partial $\eta^2 = .10$.

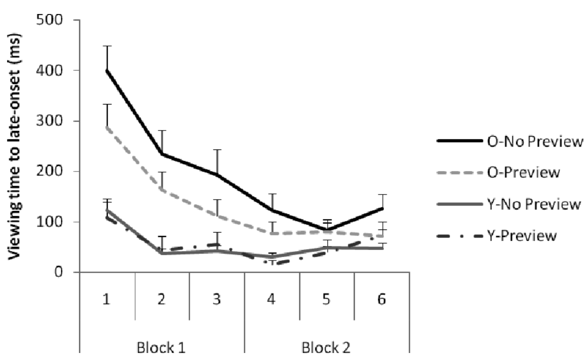
An examination of the means in Table 1 reveals that older adults directed less viewing towards the late-onset object when they received a preview of the onset location compared to when no preview was given, $t(23) = 2.13$, $p < .05$ and $t(23) = 3.21$, $p < .01$ for viewing time and number of trials fixated, respectively. By contrast, viewing of the onset object did not differ across the preview conditions for younger adults, $t(23) < 1$ and $t(23) = 1.86$, $p = .08$ for viewing time and number of trials, respectively, presumably because their performance was already close to ceiling.

Practice Effects

Both younger and older adults improved across blocks, directing less viewing towards the late-onset object, $F(1, 46) = 45.17$, $p < .001$, partial $\eta^2 = .50$, and fixating it on fewer trials, $F(1, 46) = 30.81$, $p < .001$, partial $\eta^2 = .40$, in the second block of trials compared to the first block. However, the significant interaction between age and block for both viewing time, $F(1, 46) = 21.29$, $p < .001$, partial $\eta^2 = .32$,[1] and number of trials fixated, $F(1, 46) = 26.10$, $p < .001$, partial $\eta^2 = .36$, suggests that these gains in performance were greater in the older group than in the younger group.

Participants' improved performance in the second block may have been due to their experience with the task; however, it may also have been due to their memory for the displays and corresponding onset objects which repeated from the first to the second block. Thus, in order to gain a better sense of how performance changed over time, independent of display repetitions, we divided each block into 3 epochs with 10 trials per epoch. The average number of trials fixated and the average duration of viewing time directed towards the late-onset object in each epoch was calculated separately for older and younger adults, as well as for preview and no preview trials. As can be seen in Figure 2, performance was characterized by a gradual decrease in the amount of time spent looking at the late-onset object. Crucially, this decrease in viewing to the onset object occurs within the first block of trials before the scenes began to repeat, as revealed by a main effect of epoch in the first block for both viewing time, $F(2, 92) = 24.47$, $p < .001$, partial $\eta^2 = .35$, and number of trials fixated, $F(2, 92) = 24.86$, $p < .001$, partial $\eta^2 = .35$. Moreover, these improvements were more pronounced for the older adults, as indexed by a significant age by epoch interaction in the first

FIGURE 2. Experiment 1: Average duration of viewing time (ms) to the late-onset region during the first and second training blocks, divided into epochs of 10 trials each (O, olders; Y, youngers).



[1]The age by block interaction remained significant after a logarithmic transformation was applied to the duration of viewing measure, $F(1, 46) = 26.23$, $p < .001$, partial $\eta^2 = .36$, suggesting that the interaction was not driven by general age-related slowing alone (e.g., Cerella, 1985).

block for both viewing time, $F(2, 92) = 5.01$, $p < .01$, partial $\eta^2 = .10$,[2] and number of trials fixated, $F(2, 92) = 10.11$, $p < .001$, partial $\eta^2 = .18$. Thus, the large drop in viewing time from block one to block two appears to be due, at least in part, to general skill learning of the task demands and is not wholly dependent on the repetition of displays across blocks.

Final Block

No previews were provided in the final block and there was no difference in viewing of the onset object based on whether a scene had previously been a preview or no-preview trial in the first two blocks. Thus, we collapsed across preview type and submitted duration of viewing and number of trials fixated to separate ANOVAs with age (young, old) as a between-subject factor and third block change (same, location, object) as a within-subject factor. Means and standard errors are presented in Table 2.

Older adults continued to direct more viewing towards, $F(1, 46) = 11.26$, $p < .01$, partial $\eta^2 = .20$, and fixate the late-onset object on more trials, $F(1, 46) = 8.98$, $p < .01$, partial $\eta^2 = .16$, than younger adults. However, neither group directed more viewing towards the late-onset object when either the object appeared in a different location or when it was a different object altogether, main effect and interaction F values < 1. Thus, despite changes to the onset stimulus, both groups were able to maintain their improved performance, showing no change from block two to block three in either viewing time or number of trials fixated, t values (23) < 1.

Discussion

Older adults can improve their control of reflexive eye movements, and reduce oculomotor capture, when given external support and additional practice with a task. Consistent with previous findings (e.g., Kramer et al., 2000), older adults directed more erroneous viewing towards the late-onset object than younger adults. However, only the older group benefited from knowledge regarding the location of the onset object; less viewing was directed towards the onset object by older adults when a location preview was provided compared to when no preview was given. Both older and younger adults benefitted from practice with the task demands; decreases in viewing to the onset object were observed across trials in the first block, when all displays were novel. Finally, reductions in oculomotor capture were maintained in the final block despite changes to either the onset location or the onset object itself. Thus, participants were capable of generalizing their improved oculomotor control to a modified set of stimuli.

[2]This interaction was also significant for the log-transformed data, $F(2, 92) = 9.83$, $p < .001$, partial $\eta^2 = .18$.

TABLE 2. Average Duration of Viewing Time (ms) and Number of Trials on which the Late-onset was Fixated in the Final Block

	Younger Adults						Older Adults					
	Same		Object		Location		Same		Object		Location	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Exp 1												
Viewing time (ms)	52.09	12.51	35.12	8.18	52.38	12.46	89.88	16.66	97.83	18.81	101.58	14.64
No. of trials fixated	2.17	0.35	1.71	0.31	2.29	0.41	3.63	0.54	3.92	0.69	3.92	0.50
Exp 2												
Viewing time (ms)	71.64	14.13	47.87	8.82	46.79	10.65	121.08	52.77	111.99	48.93	97.83	38.76
No. of trials fixated	2.83	0.54	2.50	0.39	1.83	0.33	3.13	0.76	3.63	0.86	4.00	0.89

Cuing the onset location presumably gave older adults time to inhibit eye movements towards that area of space and/or plan eye movements to other regions within the display. In this case, inhibition would have been solely location-based, as participants did not know which abstract object would appear and thus, had no object representation in memory to which inhibition could be applied. Experiment 2 examines whether oculomotor capture can also be reduced when information regarding an object's identity, rather than its location, is provided.

EXPERIMENT 2

The aim of Experiment 2 was to test whether object-based inhibition can also help participants (particularly older adults) to avoid oculomotor capture. Instead of a preview of the onset location, participants received a preview of the onset object itself. If, as previous work suggests, inhibition can be applied to object representations (e.g., Grison et al., 2005), and if object-based inhibition can reduce oculomotor capture, then participants should direct less viewing towards the late-onset object on object-preview trials compared to trials in which no preview was provided.

Method

Participants

Twenty-four younger (19–31; $M = 24.75$, $SD = 3.54$; 10 males) and 24 older (60–84; $M = 66.67$, $SD = 6.00$; 8 males) adults participated in this experiment in exchange for monetary compensation. Participants were recruited from the Rotman Research Institute participant pool; all participants had normal or corrected-to-normal vision and reported no incidence of traumatic brain injury. Older adults had an average of 16.42 ($SD = 3.87$) years of education and a mean score of 36.54 ($SD = 4.08$) on the Shipley Vocabulary Test. Younger adults did not differ from older adults in years of education ($M = 16.40$, $SD = 2.35$), $t(46) = 0.02$, $p > .05$, but they did score lower on the vocabulary test ($M = 30.92$, $SD = 4.20$), $t(46) = 4.71$, $p < .01$.

Design, Stimuli, and Procedure

The design, stimuli, and procedure were the same as those used in Experiment 1. The only difference was that participants now received a preview of the late-onset object, instead of the location where it would appear (see Figure 1a). The object preview was presented in the centre of the screen for 2000 ms. Half of the trials were preview trials; on the other half of the trials, no preview was presented. The same eye movement measures and analyses were used here as in Experiment 1.

Results

Training Blocks

Duration of viewing time and number of trials fixated were submitted to separate ANOVAs with age (young, old) as a between-subject factor and preview type (no-preview, object-preview) and block (block 1, block 2) as within-subject factors. Means and standard errors for the first two blocks are presented in Table 1.

Object Preview Effects

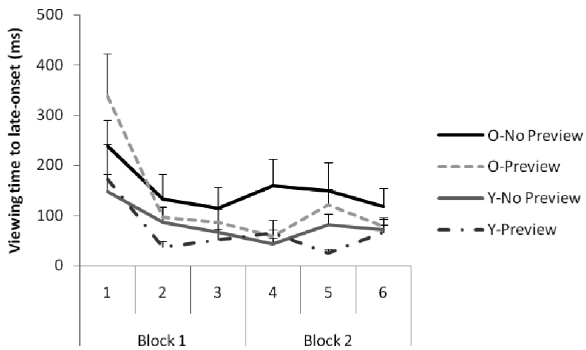
Replicating the age differences found in Experiment 1, older adults directed more erroneous viewing towards the late-onset object, $F(1, 46) = 3.64$, $p = .06$, partial $\eta^2 = .07$, and fixated it on more trials, $F(1, 46) = 5.30$, $p < .05$, partial $\eta^2 = .27$, than younger adults. However, in contrast to the benefits afforded by the location preview in Experiment 1, providing participants with a preview of the onset object itself did not improve their performance. The main effect of preview was not significant for either viewing time, $F < 1$, or number of trials fixated, $F(1, 46) = 2.77$, $p = .10$, and nor was any of the interactions with preview, F values < 3, p values $> .10$. Both groups directed similar amounts of viewing towards the late-onset object regardless of whether or not they had a representation of it in memory.

Practice Effects

Both younger and older adults directed less viewing towards the late-onset object in block two than in block one, $F(1, 46) = 14.62$, $p < .001$, partial $\eta^2 = .24$, and $F(1, 46) = 5.43$, $p < .05$, partial $\eta^2 = .11$, for viewing time and number of trials fixated, respectively. Furthermore, practice-related gains were more similar between older and younger adults in this experiment, as the age by block interaction was not significant for duration of viewing, $F < 1$, although it was significant for the number of trials fixated, $F(1, 46) = 4.26$, $p < .05$, partial $\eta^2 = .09$.

Once again, we divided each block into 3 epochs of 10 trials to examine the change in viewing behavior over time. As shown in Figure 3, both younger and olders adults directed less viewing towards the onset object across epochs in the first block, $F(2, 92) = 17.77$, $p < .001$, partial $\eta^2 = .28$, and $F(2, 92) = 7.40$, $p < .01$, partial $\eta^2 = .14$, for viewing time and number of trials fixated, respectively. Furthermore, both groups appear to have improved to the same extent in this block, as the interaction between age and epoch was not significant for either viewing time, $F(2, 92) = 1.53$, $p = .22$, or number of trials fixated, $F(2, 92) = 2.33$, $p = .10$. These results suggest that the reduction in oculomotor capture is due, at least in part, to general skill learning in addition to any benefits obtained through the repetition of displays across blocks.

FIGURE 3. Experiment 2: Average duration of viewing time (ms) to the late-onset region during the first and second training blocks, divided into epochs of 10 trials each (O, olders; Y, youngers).



Final Block

As in Experiment 1, viewing behavior in the final block did not differ based on whether the display was presented in a preview or no-preview trial during the initial two blocks, and thus, we collapsed across preview type in the final block. Duration of viewing time and number of trials fixated were submitted to separate ANOVAs with age (young, old) as a between-subject factor and third block change (same, location, object) as a within-subject factor. Means and standard errors are presented in Table 2.

In the final block, older adults spent significantly more time viewing the late-onset object than younger adults, $F(1, 46) = 11.26$, $p < .01$, partial $\eta^2 = .20$, but only fixated the onset on marginally more trials, $F(1, 46) = 2.00$, $p = .16$, partial $\eta^2 = .04$. Neither the main effect of third block change nor the interaction between third block change and age were significant for viewing time, *F* values < 1. In contrast, the interaction between age and third block change was significant for the number of trials fixated, $F(2, 92) = 3.33$, $p < .05$, partial $\eta^2 = .07$, reflecting the different pattern of means within each group. However, when analyzed separately, neither older adults, $F(2, 46) = 1.41$, $p = .26$, nor younger adults, $F(2, 46) = 2.02$, $p = .14$, directed significantly more fixations towards the late-onset object on change trials. Thus, despite changes to the onset stimulus, both older and younger adults were able to maintain their improved performance, showing no change from block two to block three in viewing duration, *t* values (23) < 1, or number of trials fixated, $t(23) < 1$ and $t(23) = 1.53$, $p = .14$, for older and younger adults, respectively.

Discussion

In contrast to the benefit afforded to older adults' performance by the location preview in Experiment 1, viewing to the late-onset object was not altered by providing participants with a preview of the onset object itself. That is, having a representation of the object in memory did not improve participants' ability to avoid being captured by its sudden onset. Older adults, once again, directed more erroneous viewing towards the late-onset object, reflecting their decreased ability, relative to younger adults, to restrain reflexive eye movements. However, both groups improved with practice and directed similar amounts of viewing towards the onset object in the third block regardless of whether it appeared in a different location or was a different object altogether, suggesting that participants were able to maintain their improved performance despite changes to the onset stimulus.

GENERAL DISCUSSION

The present work examined whether age-related differences in oculomotor capture could be ameliorated by providing participants with *a priori* knowledge regarding either the location or the identity of an upcoming onset object and/or by providing participants with extended practice with the task demands. Across two experiments, older adults initially directed more erroneous viewing towards a sudden onset than younger adults, an effect consistent with previous work (Kramer et al., 2000; Munoz et al., 1998). Importantly, this effect was not only found using a duration of viewing time measure, but was also found using a measure of the number of trials on which the late-onset was fixated, suggesting that older adults' deficit is one of oculomotor control and not simply a slowed ability to disengage their eyes from the onset. Furthermore, only older adults benefited from a preview of the onset location; less viewing was directed towards the abrupt onset when older adults knew where the onset would appear. However, neither age group benefited from a preview of the onset object itself; similar amounts of viewing were directed towards the abrupt onset regardless of whether or not participants received an advance viewing. Finally, both older and younger adults benefitted from extended practice with the task. Dividing each block into epochs revealed that participants directed less viewing towards the late-onset object over time, particularly in the first block of trials before the scenes began to repeat. Thus, participants' improvement across blocks seems to be due to general skill learning above and beyond memory for either the location/identity of the onset object, or the rest of the display elements.

The current findings revealed that for older adults, oculomotor control was supported by knowledge regarding location, but not identity, of an upcoming abrupt onset. Previous work has also shown that under certain circumstances, older adults are capable of inhibiting specific regions in space, thereby allowing attention to be directed elsewhere. For instance, older adults show intact IOR to previously cued locations (e.g., Hartley & Kieley, 1995) and this effects lasts up to 2000 ms after a cue is presented (Castel, Chasteen, Scialfa, & Pratt, 2003). Note that in the current paradigm, the presentation delay between preview and onset fell within the time range in which IOR is observed and thus, older adults may have relied on a similar location-based inhibitory mechanism to support oculomotor control in this case. While younger adults did not benefit from the location preview, this is most likely because their performance was at ceiling from early on within the first block of trials. Presumably if the task were made more challenging for younger adults, then they too would show an advantage on location preview trials.

In contrast to findings of preserved location-based IOR with age, recent work suggests that older adults are incapable of object-based IOR (McCrae & Abrams, 2001; McAuliffe, Chasteen, & Pratt, 2006), consistent with the present findings that older adults did not use knowledge regarding the object identity to support oculomotor control. Older adults may be less able to associate inhibitory states to object representations in memory (Grison et al., 2005). Alternatively, older adults in this study may have been unable to develop a representation of the abstract object in memory during the relatively brief preview duration (2000 ms). By contrast, studies have shown that younger adults are capable of inhibiting object representations within this time frame (e.g., Jordan & Tipper, 1998) and therefore, it is possible that older adults' resilience to capture may be improved by providing them with a longer preview of the onset object. However, it should be noted that even the younger adults in the current work did not show reduced viewing of the abrupt onset as a result of the object preview, in contrast to prior work in which younger adults could successfully apply object-based inhibition (e.g., Grison et al., 2005; Paul & Tipper, 2003). However, previous work on object-based inhibition has tended to use identifiable or nameable objects (such as shapes and faces), while the present study used novel, abstract objects. It remains a possibility that upon the initial presentation of the displays in the first block, even the younger adults did not have adequate time to form an object representation to which inhibition could be applied. Further, as younger and older adults received additional training trials, the effects of preview began to wane by the second block, likely as a result of extended practice that caused both younger and older adults to perform close to ceiling. Perhaps if younger and older adults were given repeated exposures to the novel objects prior to the experiment proper, both age groups would be able to form object representations to which inhibition could be applied, and an object preview would then be effective in reducing oculomotor capture.

The second aim of this study was to examine the effects of practice on older adults' resilience to capture. Both younger and older adults showed reduced oculomotor capture as they gained more experience with the task. Further, such reductions were maintained in a final block in which some of the displays were altered. Although older adults continued to direct more viewing towards the late-onset compared to younger adults, participants of both age groups were equally able to inhibit the onset object when the display remained unchanged as when a change was introduced to either the onset location or the onset object. Moreover, the amount of viewing directed to the onset object in the final block was not significantly higher than the amount of viewing directed to the onset object in the immediately preceding block in which no changes were introduced to the displays. Thus, older and younger adults alike were able to generalize the benefits of their brief training to the manipulated stimuli, suggesting that gains in performance reflected some improvement in endogenous control mechanisms and not simply familiarity with the onset stimuli.

Previous work has shown that older adults can benefit as much as (if not more than) younger adults from experience with a task (e.g., Davidson et al., 2003; Scialfa et al., 2000) and that they can maintain these practice-related gains even when the task demands or stimuli are altered (Bherer & Belleville, 2004; Bherer et al., 2005; Kramer et al., 1995;). To our knowledge, the present study is one of the first to demonstrate that practice can benefit older adults' control of reflexive eye movements and that these benefits can be generalized to a moderately different set of stimuli. Admittedly, the displays used in the test block were not completely novel and thus, it remains a possibility that larger changes in the stimuli and/or extending the time between practice and test could eliminate the training effects seen here. Furthermore, the present study only examined the effects of simple practice on oculomotor control and did not provide participants with a particular strategy to use or individualized feedback regarding their performance, as has been done in other training studies (e.g., Bherer et al., 2005; Kramer et al., 1995). Thus, the present work most likely underestimates the extent to which training can improve older adults' control of reflexive eye movements. Considering the importance of oculomotor control to everyday activities such as driving and visual search, finding sustainable ways to improve this ability remains a vital aim for future research.

In summary, the present study demonstrates that age differences in oculomotor capture can be reduced by providing participants with information regarding the location of an upcoming onset and by allowing participants to familiarize themselves with the task. These results suggest that older adults' poor inhibitory control is not irreversible: with appropriate external support and additional practice, older adults' looking behavior can match that of younger adults.

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