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Adult Age Differences in the Time Course of Inhibition of Return

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Inhibition of return (IOR) occurs when people are slower to detect a target that appeared at a previously cued location. Prior research has shown that younger and older adults display similar amounts of IOR, but this research has not examined the time course of the process. Because elderly people may be slower to engage or disengage spatially based attention, the present experiment examined age differences in IOR at stimulus-onset asynchronies ranging from 50 ms to 3,000 ms. The results show that the peak magnitude of IOR was similar for younger and older adults, but the onset of IOR occurred approximately 300 ms later in elderly persons. Older adults also showed a greater degree of facilitation at shorter stimulus-onset asynchronies. The results suggest that there is a change in the temporal dynamics of inhibition that occurs with age.

THE ability to efficiently direct visual attention to salient features in the environment is a critical function of the visual system. Efficiency involves enhancing detection of stimuli at locations that are currently attended and directing attention away from locations that were recently attended. The observation that people are slower to detect a target that appeared at a recently cued location has been referred to as inhibition of return (IOR; Posner & Cohen, 1984; Posner, Rafal, Choate, & Vaughn, 1985). This inhibitory effect has proven to be very robust, and it is thought to occur in order to allow an efficient search of the visual environment by limiting the number of resources directed at previously attended locations.

Aging has numerous effects on the cognitive, perceptual, and motor systems, and the manner in which older adults orient attention across the visual field may be different from that of younger adults. Specifically, older adults may have difficulty disengaging attention from a cued location in order to shift attention to a target at another location (e.g., Madden, Connelly, & Pierce, 1994). In other words, older adults may show a greater cost for moving attention to uncued locations. This finding has important implications in terms of the facilitation and inhibitory components that guide attention, and it can be examined in studies that use many different delay periods between the onset of the cue and the onset of the target (i.e., stimulus-onset asynchrony, or SOA) in a target-detection task. In general, peripheral cues that are not predictive of the target's upcoming location (i.e., uninformative cues) typically produce attentional cueing effects or facilitation at short SOAs (<300 ms) and IOR at longer SOAs.

Several studies have examined age-related differences in the inhibitory effect associated with uninformative cues at longer SOAs. Although they showed that older adults display a reduction in "object-based" inhibition, McCrae and Abrams (2001) also found equivalent IOR for younger and older adults in static displays. Indeed, at the 467-ms SOA used, the older adults actually showed, in absolute terms, a larger IOR effect. Hartley and Kieley (1995) found an equivalent IOR in younger and older participants at SOAs of both 450 and 750 ms, suggesting that inhibitory control does not decline with age. Other studies have found that healthy older adults and older adults with Alzheimer's disease also display IOR at various SOAs (i.e., 800-, 1,300-, and 1,800-ms SOAs, Faust & Balota, 1997; 500- and 800-ms SOAs, Dankert, Maruff, Crowe, & Currie, 1998; 950- and 3,500-ms SOAs, Langley, Fuentes, Hochhalter, Brandt, & Overmier, 2001), suggesting that the neural mechanisms responsible for IOR are intact in older adults.

It is possible that age differences in IOR have not been found because the designs that have been used are not sensitive enough to detect such differences as a result of the limited range of SOAs. Moreover, the studies just mentioned used fixation cues (presented after the peripheral cue and before the peripheral target) to reflexively draw attention from the peripheral location back to the fixation location. This can produce IOR at relatively short SOAs, thus eliminating time-course effects (Pratt & Fischer, 2002). To the best of our knowledge, no study has examined IOR with younger and older adults with a wide time range and without fixation cues.

The present study was designed to examine age-related differences in IOR over an extensive time range. Eleven SOAs ranging from 50 ms to 3,000 ms were used (without fixation cues) in order to determine when IOR occurs and whether the magnitude of IOR was uniformly similar in younger and older adults. In general, if there are no differences in IOR between younger and older adults, then this should occur over the entire time course of the inhibitory effect.

METHODS

Participants

Twenty older adults, that is, 12 women and 8 men, mean age = 68.3 years (*SD* = 6.5), and education = 16.1 years (*SD* = 2.8), and 20 younger adults, that is, 16 women and 4 men, mean age = 21.3 years (*SD* = 1.3), and education = 16.3 years (*SD* = 1.1), participated in the experiment. The older adults were community-dwelling seniors, and the younger adults were

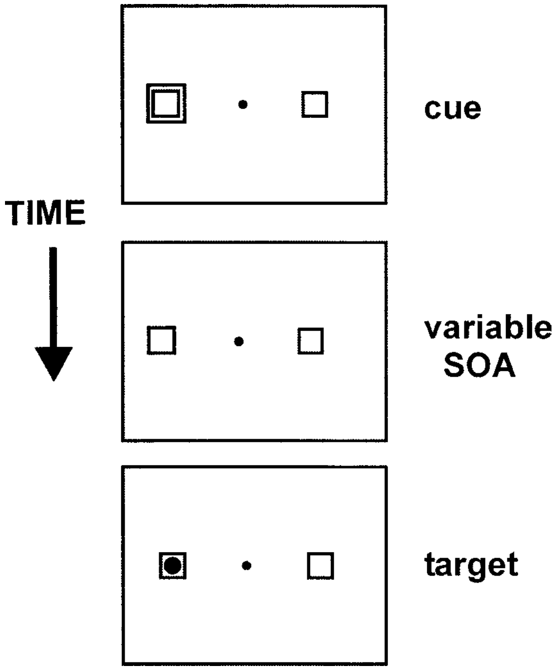

Figure 1. The sequence of events for a given noncatch trial (SOA = stimulus-onset asynchrony).

undergraduate students at the University of Toronto. All of the participants reported corrected-to-normal vision, were naive with regard to the purpose of the experiment, and were paid 10 dollars for their participation.

Apparatus and Procedure

The experiment took place in a dimly illuminated, sound-attenuated room. Participants were seated 44 cm in front of a computer monitor. The viewing distance was held constant with the use of an adjustable head–chin rest. The computer keyboard was directly in front of the participant and was used as the response device. Participants were asked to fixate on a central cross (0.1° × 0.1°) and to make no eye movements during the experimental trials. The sequence of events is shown in Figure 1, although in reality all of the stimuli were presented in white (77.0 cd/m^2) on a black background (0.5 cd/m^2). The initial display was presented for 1,000 ms and consisted of two placeholder boxes located on the horizontal meridian to the left and right of the fixation point. The boxes were centered 5° from the fixation point and were 1° square. One of the boxes was then cued by outlining the perimeter for 50 ms. One of 11 randomly assigned SOAs then followed the onset of the cue (50, 100, 250, 500, 750, 1,000, 1,250, 1,500, 2,000, 2,500, or 3,000 ms). After the variable SOA, a target circle (0.7°) appeared in one of the two boxes (on 80% of the trials; the remaining 20% served as catch trials in which no target was presented). Participants were asked to respond to the target as quickly and as accurately as possible by pressing the space bar (regardless of the location of the target) and to remain fixated throughout each trial. The next trial began 500 ms later.

In order to ensure that eye movements were not made during the trials, a closed-circuit TV system (similar to the design used by McCrae & Abrams, 2001) was used to observe and monitor participants' eyes for half of the participants in each group (n = 10). These participants were informed that their gaze would be monitored by a closed-circuit TV system with a camera mounted below the computer screen. During the experimental session, the experimenter visually monitored the eye movements for these participants and provided verbal feedback if it appeared that a participant was having difficulty maintaining fixation. This occurred rarely and usually only in the first block of trials (if at all). The majority of the participants (both young and old) had little difficulty maintaining fixation during the trials, as is typically found in such simple cue target-detection tasks (e.g., Kosnik, Kline, Fikre, & Sekuler, 1987).

Table 1. Mean RTs and Percentage of Detection Errors for Cued and Uncued Locations for the Younger and Older Groups

	Younger Group		Older Group	
SOA	Cued	Uncued	Cued	Uncued
50	427 (0.8)	447 (0.4)	476 (0.8)	543 (0.4)
100	418 (1.3)	422 (0.8)	462 (0.8)	522 (0.8)
250	419 (0.8)	408 (1.7)	476 (1.7)	502 (1.3)
500	448 (0.8)	417 (1.3)	507 (2.5)	501 (2.9)
750	448 (0)	414 (0.4)	510 (1.7)	493 (0.4)
1,000	428 (0.4)	398 (0.4)	504 (1.3)	482 (0.8)
1,250	427 (0)	391 (0)	492 (0.8)	469 (1.3)
1,500	414 (0)	391 (0.8)	489 (0.4)	459 (1.7)
2,000	425 (0.4)	401 (0.8)	490 (0.8)	466 (0.8)
2,500	424 (0.8)	402 (0)	484 (0.8)	477 (1.3)
3,000	429 (0)	419 (0.8)	493 (1.3)	491 (1.3)

Notes: Percentages of detection errors are given parenthetically. RT = reaction time (given in milliseconds); SOA = stimulus-onset asynchrony.

Design

The entire session consisted of 660 trials, with cues and targets being equally likely to occur at the left and right locations. The participants were given short breaks between blocks of 110 trials, and the experiment took less than 90 min to complete.

Results

An analysis of variance (ANOVA) was carried out on the reaction time (RT) data for all correct trials by use of four independent variables: fixation control (none or controlled), age (young or old), SOA (all 11 SOAs), and trial type (cued or uncued). Of note, there was no main effect of fixation control, that is, $F < 1.3$ and $p > .25$, nor did it interact with any other variable(s), that is, Fs < 1. Because of this, all of the reported mean RTs are collapsed across the two fixation control conditions. The mean RTs for correct trials are provided in Table 1, with the mean cueing effects (facilitation and IOR) displayed in Figure 2.

Main effects were also found for age, that is, $F(1,36) = 28.05$ and $p < .0001$ (young = 419 ms; old = 490 ms); SOA, that is, $F(10,360) = 12.81$ and $p < .001$ (RTs generally decreased as SOA increased); and trial type, that is, $F(1,36) = 11.94$ and $p < .01$ (cued trials = 468 ms; uncued trials = 461 ms). These main effects are qualified by two significant two-way interactions. These are Age × Trial Type, $F(1,36) = 17.99$ and $p < .001$, and

SOA × Trial Type, $F(10,360) = 25.31$ and $p < .0001$. The remaining two-way interactions did not approach significance ($ps > .50$). The critical three-way (Age × Trial Type × SOA) interaction was significant at $F(10,360) = 3.81$ and $p < .001$, indicating that the younger and older adults displayed differences in the time course of IOR, which is shown in Figure 2.

With the three-way interaction of Age × SOA × Trial Type, planned comparisons regarding the time course of IOR were conducted to determine when IOR first occurred for each age group and when IOR dissipated. To examine the onset time of IOR, we determined the first SOA at which each observer showed an IOR effect of at least 10 ms. (The value of 10 ms was chosen over zero crossings because 10 ms typically represents a statistically significant amount of inhibition, and it was not known if there would be a zero crossing at the very late SOAs.)

A t test on these values indicated that IOR occurred earlier for younger adults (222 ms after cue onset) than for older adults (592 ms after cue onset; $p < .0005$). For the comparison of when IOR ended, the first SOA in which 10 ms or less of IOR was found (after IOR had been present in a previous SOA) was determined for each observer. In this case, no differences were found between the younger adults (2,800 ms after cue onset) and older adults (2,700 ms after cue onset).

The error rates (failure to respond within 1,500 ms, or responding on catch trials) were very low (<1%) and were analyzed with a similar 2 (fixation control) × 2 (group) × 11 (SOA) × 2 (trial type) ANOVA. No reliable differences were found ($ps > .11$), except for a trend for more errors at the shortest SOA ($p < .06$).

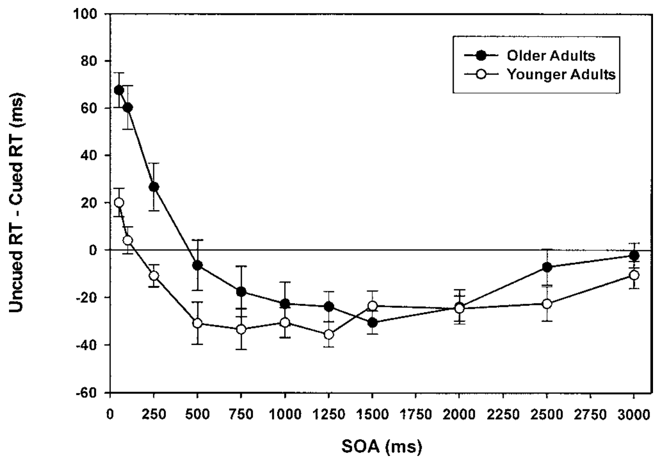

Figure 2. Mean cueing effects (uncued reaction time, or RT, minus cued RT) at each stimulus-onset asynchrony (SOA) for the younger adults and older adults. Positive numbers indicate facilitation; negative numbers indicate inhibition of return. Error bars indicate standard errors of the mean.

Discussion

The present study found that the onset of IOR is delayed in older adults, and therefore, unlike the conclusions reached by previous researchers (e.g., Dankert et al., 1998; Faust & Balota, 1997; Hartley & Keiley, 1995; McCrae & Abrams, 2001), our conclusion is that there is an age-related difference in IOR. It is important to note that robust IOR effects were still found with the older adults, indicating that given sufficient time, older adults are equally good at inhibiting the return of their attention to previously attended locations. In light of the present findings, the lack of age-related differences in IOR reported by the earlier studies was likely due to the limited range of SOAs used and the presence of fixation cues that attenuate attentional cueing. For example, McCrae and Abrams (2001) used a fixation cue (a "cued-back" design) and found a significant amount of IOR for older adults at an SOA of 500 ms, whereas the older adults in the present study (with no cue back) only started to show IOR effects at that SOA.

To our knowledge, the present study is the first to show an age-related difference in the time course of IOR. The fact that robust IOR effects were found for both age groups also indicates that the brain structures involved in producing IOR remain intact with advancing age. However, the difference in onset of IOR between the two groups indicates that other factors are involved as well. Klein (2000) has speculated that with more difficult tasks, people tend to allocate more attention, for a longer period of time, to cued locations. This, in turn, both produces larger early facilitation effects and delays the onset of IOR. Assuming that the detection task was more difficult for the older adults and that they already have some deficits in disengaging attention from cued locations, Klein's suggestion provides a good account for the age-related difference found in the present study. Although considerable research remains regarding IOR and aging, the present findings clearly indicate that although older adults show a later onset of IOR, this inhibitory effect influences how attention is allocated across the visual field throughout the life span.

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