Inhibition of Return and Age: Older Adults are Slower to Double-Check

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Abstract

Inhibition of Return (IOR) is a reflexive behaviour localized within our superior colliculus, which aids our efficiency at scanning the visual field for distinct information, by suppressing our attention to locations we have already scanned recently to prevent wasting cognitive resources on redundant information. The aim of this study is to observe how this effect changes under different conditions of time between stimulus presentation, and across the age of different participants. We hypothesized that age will have a negative relationship with IOR, as will the time delay between different stimuli; the Stimulus Onset Asynchronousy (SOA). In an experiment of 60 young adults and 60 older adults, we enacted a three-factor mixed design comparing Age, SOA (at 900, 1100, and 1300ms), and Cue Condition (Cued and Uncued) to measure participants' eye-tracked reaction times on a looking task. While no relationship interacting between Age and SOA was found, a significant positive relationship was found between Age and Cue, such that older adults actually present a stronger IOR effect than younger adults; in conflict with surrounding literature. These findings present implications with regard to the methodology and relevant factors involved in future research to IOR, the superior colliculus, and the functions they carry out.

Inhibition of Return and Age: Older Adults are Slower to Double-Check

Inhibition of Return (IOR) is a mechanism by which our superior colliculus suppresses our visual attention from returning to the same place in our visual field after we've already looked there (Sapir, Soroker, Berger, & Henik, 1999), for a short period of time. Posner and Cohen (1984) suggest that through evolution, we have adopted this mechanism to enhance our object searching/visual scanning efficiency, to "maximize sampling of the visual environment". It is suggested that we gain a considerable leap in efficiency by not attending back to the same location within a short time frame, as there is less likely to be new information there compared to the rest of the visual field.

This is proposed to have been an adaptation to facilitate behaviours such as foraging (Sapir et al., 1999), and while that isn't quite as relevant in today's world, the underlying mechanisms still aid us in a variety of other tasks that rely on our visual attention, such as driving. Driving safely depends heavily on our ability to constantly shift our attention amongst the potential hazards of our immediate surroundings, constantly adjusting and shifting too accommodate them (Bédard, Leonard, Mcauliffe, Weaver, Gibbons, & Dubois, 2006). Bédard et al. (2006) investigated participants of age 55 and over on both their IOR and general driving ability, and while age within this group was a strong negative predictor of driving ability, and that IOR may be a strong predictor of driving ability, they note that the variability in IOR amongst the subjects may be simply due to individual differences. This could potentially due to their limitation of age range to only 55 and above.

Lupiáñez, Milán, Tornay, Madrid, and Tudela (1997) carried out a variety of experiments comparing the methodologies under which we test IOR, discrimination versus detection tasks, recording reaction time via choice button pressing versus eye tracking, and on a variety of different Stimulus Onset Asynchronousy (SOA) levels, particularly interested in if the effects of IOR are generic; specific to particular activities; or even if the effects might occur over different timespans for different activities. Lupiáñez et al. (1997) found that indeed there appears to be different time courses at work for discrimination and detection tasks, suggesting that IOR builds up and also decays faster for discrimination tasks, such that while discrimination tasks dropped off by nearly half by 1300ms of SOA, detection tasks still had observable effects. In these experiments however, Lupiáñez et al. (1997) don't appear to test or state the age of their participants.

McCrae and Abrams (2001) carried out an experiment which tested whether or not modifying the SOA between presenting a cue and a target could potentially display a difference of younger and older adults in their IOR. This experiment only found a significant difference in age when comparing on the shortest SOA they used (467ms), and none at the other levels (1167, 2467, and 3967ms). This is interesting considering the main effect of SOA on it's own was present, similar to Posner and Cohen's (1984) results showing a significant decrease in the participant's reaction time on a similar test, between the SOAs of 600 and 1450ms; or Lupiáñez et al. (1997) comparing 100, 400, 700, 1000, and 1300ms. This jump in particular seems similar to the jump between McCrae and Abrams' (2001) jump between 467 and 1167ms respectively, after which the larger SOAs seem to experience very large diminishing returns on the reaction time decreases. McCrae and Abrams (2001) attempted to address that older adults failed to show IOR where younger adults succeeded due to not requiring more time to develop the IOR using a longer SOA, however it may be possible that the diminishing returns they experienced on the longer SOAs may actually be due to them being too long; Introducing a potential floor effect in which older adults may be having the IOR effect wear off entirely due to a long enough time having passed, rather than it not having enough time to develop. This study hypothesizes that if a similar experiment were carried out with a tighter group of SOAs inside a ranger closer to Posner and Cohen's (1984) or Lupiáñez et al. (1997), the interaction of SOA and age may be present without obstruction of such a floor effect, which would explain the difference between younger and older adults IOR being that the suppression ends at a different time, rather than not developing at all.

Interesting also about McCrae and Abram's (2001) experiment was the fact that their stimuli were moving up until the point of stimulus onset, which McAuliffe, Chasteen, and Pratt (2004) recognized as a potential confound, and suggested that it could not be clear if the results could be solely based on an age difference of IOR, or if something to do with attending to the tracking of moving objects could interfere. McAuliffe et al.'s (2004) experiment without the moving stimuli found once again a difference in younger and older participant's IOR, and that the moving stimuli were not related, but also that it could not strictly be the case of age-related deficits leading to the IOR. However again in McAuliffe et al.'s (2004) experiment, there was no variation in the SOA used, instead setting at a single 400ms delay, again centered around a similar point to which McCrae and Abram's (2001) 467ms significant difference was found. So although McAuliffe et al.'s (2004) study set to correct the confound of the moving stimuli, it still may fall short of identifying any difference in the SOA's relationship to age in generating IOR.

This study seeks to examine the Age differences in IOR (McCrae & Abrams, 2001; McAuliffe et al., 2004; Bédard et al. 2006), in combination with a potentially more appropriate range of SOA (Posner & Cohen, 1984; Lupiáñez et al., 1997; McCrae & Abrams, 2001), and taking note of Lupiáñez et al. (1997) methodology of eye tracking to detect both accurate reaction time and error checking, as well as a single consistent detection task to compare on, with no moving component (McAuliffe et al., 2004). We hypothesize that we will observe similar negative relationships between age and IOR, and a negative relationship between SOA and IOR, and finally that SOA will amplify the relationship between age and IOR.

Method

Participants

The first of the two groups in this study was composed of 60 young adults, in the range of 18 to 30 years old (*M* = 21, *SD* = 3). Among these young adults were 22 males and 38 females, all of whom were recruited from the University of Otago in association with a course. The young adults group had 55 right-handed participants, 5 left-handed, and on average this group had 15 years of education. The second group was composed of an additional 60 older adults, in the range of 60 to 88 years old (*M* = 71, *SD* = 6), among which 22 were male and 38 were female. The older adults group had 54 right-handed subjects and 6 left-handed, and an average of 14 years of education. The older adults were recruited from the Dunedin community, and were reimbursed NZD$20.

All participants in this study reported having normal or corrected-to-normal vision, as well as being both neurologically and psychiatrically healthy. Additionally, all members of the older adults group were subject to a dementia screening via the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). The MMSE is a short questionnaire with a maximum score of 30, and all of the older adults group scored at least 25, indicating they are not demented.

Apparatus & Stimuli

Each participant was situated at a desk with computer, with a chin-rest set to maintain a viewing distance of 57cm, such that a 1cm long stimulus presented on the screen subtended 1° of visual angle. The computer used specialized software coded using MATLAB, which presented a single instruction screen, followed by a set of timed trials in which visual stimulus were presented on the screen, in three possible states; Fixation, Cue, or Target (see Figure 1). An eye tracker was used to record participant's eye movements during the trials, in order to detect errors and measure their reaction time to look at the various stimuli. The software would subject the participant first to 10 practice trials using these states to ensure the participant understood the task, followed by 60 recorded trials. The software was also used by the experimenter to record data.

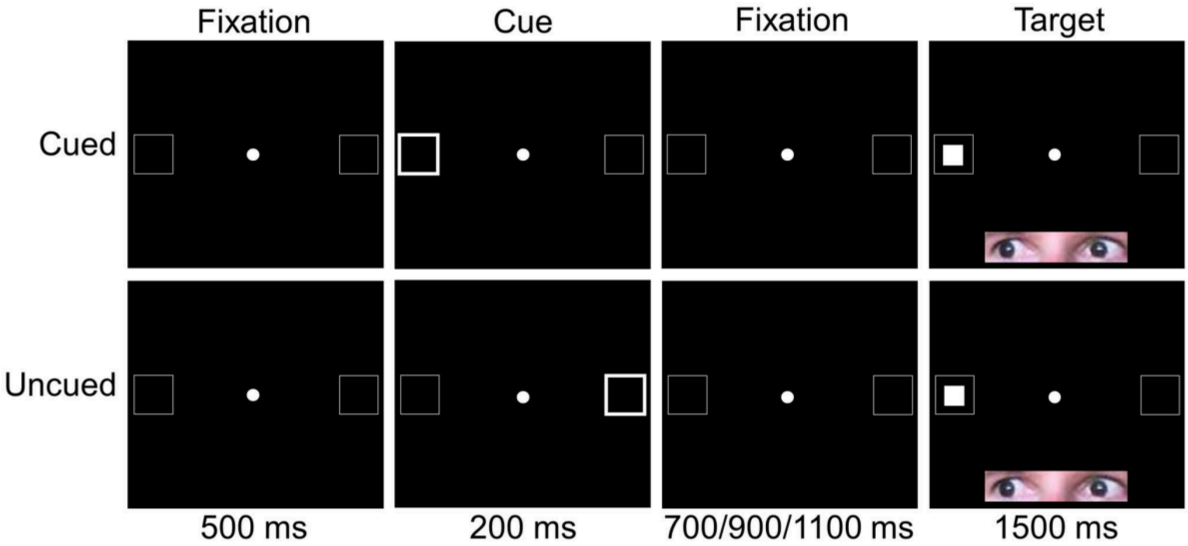

Figure 1. The software’s trial states, in the typical order they would be presented, depending on the level of the Cue variable. Notably, the squares are to be positioned to occupy 1° of visual angle on each side, the central focus circle occupies 0.3°, and the filled target square occupies 0.5°. The Cue square is simply a thickened white version of the normally grey Fixation square.

Design & Procedure

The manipulated variables in the present experiment were the Cue state, the SOA, and the Age Group of the Participant. The Cue state was a within-subjects variable with two levels; Cued, in which the side that the cue square was highlighted was the same square the target appeared on later in the same trial, or Uncued, in which the target appeared on the alternate side. Each participant experienced each of these levels half of the time, randomized and counterbalanced to prevent practice effects. The SOA was also a within-subjects variable, with three levels; such that the amount of time spent on the Fixation state between the Cue and

Target states varied between 700ms, 900ms, or 1100ms, which also was randomized and counterbalanced. The amount of time used would be added to the 200ms of stimulus presentation time, to create the actual SOA values used in analysis; 900, 1100, and 1300 respectively. The Age Group was a between-subjects variable, as this is a participant characteristic. This experiment was a mixed three-factor design, as within each of the between-subjects Age Groups, each participant experienced all levels of the Cue State and SOA variables.

For each participant, the procedure began with the instruction screen indicating to maintain focus on the central circle, until a filled white square (the target) appeared in the periphery, and then look at the target as quickly as possible, returning to the central focus afterward. When the trial began, the Fixation state would be displayed for 500ms, before changing to the Cue state for 200ms. After this, the participant is returned to the Fixation state for an amount of time depending on the SOA level used for that trial, after which presenting the Target state, on the side determined by the Cue state for that trial. After 1500ms in the Target state, and their reaction time is recorded for how long they took to look toward the target, and the Cue and SOA variables are also recorded. The participant is then returned to the Fixation state to begin the next trial. If the participant's reaction time was below 80ms, it was regarded as the participant attempting to anticipate the target, or if the time was longer than 1500ms, it was recorded as an error and the tone was played.

Results

The measured variable in this study was the Inhibition of Return effects (IOR), defined for our purposes here as the difference in Reaction Time (RT, in milliseconds) or Error Rate (%E, percentage of errors) between the Uncued and Cued conditions, such that if the Uncued

RT was faster for Uncued stimuli than Cued stimuli, the value of IOR = Uncued – Cued would be negative. In the case that this value is negative and statistically significant, we would take this as evidence in support of IOR having an effect, as it would represent that we are worse at looking back to a location we have looked previously; the Cued condition, than one we have not yet explored; the Uncued. Likewise, if this value was positive and significant, we would take this as evidence against Inhibition of Return. The data collected was averaged within each age group and across the SOA variable (see Table 1).

Table 1

Mean Reaction Times (in ms) and Errors (in %) in Young vs Older Adults

	Young (n = 60)		Older (n = 60)		Age Difference (Older – Young)		
	M (SD)	*%E*	*M (SD)*	*%E*	*M*	*ES*	*95% CI*
Cued	290 (59)	3.3	395 (67)	8.8	105***	1.68	[82, 128]
Uncued	262 (58)	5.1	331 (52)	6.9	69***	1.25	[49, 89]
IOR	**-28*****	**1.8***	**-64*****	**-1.9***	**-36*****	**0.98**	**[-49, -23]**

Note: IOR = Uncued – Cued. ES (Effect Size) = Cohen's *d*. * $p < .05$. *** $p < .001$

A mixed-model ANOVA analysis was used to examine the significance of the interactions and main effects of three factors, comparing effect-size with Cohen's guidelines (1988). Age had a significant, small-sized main effect showing that older adults were slower in general than younger adults ($F(1, 118) = 71.071$, $p < .001$, $n_p^2 = .376$). Cue Condition had a significant, medium-sized main effect showing that participants slower to respond to the Cued side than the Uncued side ($F(1, 118) = 185.589$, $p < .001$, $n_p^2 = .611$). SOA had a significant, small-sized main effect showing that participants were faster to respond when given more time between the Cue and the Target (F(2, 236) = 66.824, p < .001, n_p^2 = .362), important to note the SOA factor also includes the additional 200ms that the Cue is held before Fixation is begins, for the purposes of the analysis. The interaction effects were observed similarly: Age * Cue had a significant, although small-sized interaction showing that the slowing associated with being Cued rather than Uncued was even greater, if the participant was older (F(1, 118) = 28.551, p < 0.001, n_p^2 = .195). SOA * Cue had a significant, although even more trivially-sized effect showing that the speed increase associated with higher SOA was greater when the responding to the Cued stimulus (F(2, 226) = 3.574, p = .030, n_p^2 = .029). Both the Age * SOA and Age * SOA * Cue interactions were insignificant.

In addition to these, a two-tailed *t*-test was carried out to further investigate the Age * Cue interaction, specifically by comparing the Cued RT divided by Uncued RT (Bédard et al., 2006) for each age group. This is to look at the IOR effect for each age group and compare them, proportional to the fact that older adults were slower in general. The results (see Table 2) show a significant, moderate-sized effect, displaying that IOR was stronger for older adults (t(118) = 3.618, Cohen's d = 0.666, p < .001, 95% CI [0.038, 0.131]).

Table 2

Proportional IOR (Cued/Uncued Reaction Times) in Younger vs Older Adults

Age	Proportional IOR
	M (SD)
Young	1.114 (0.103)
Older	1.198 (0.148)

Discussion

Results Interpretation

The main effect of Age Group demonstrates clearly the common slowing of reaction time in general with Age (Woods, Wyma, Yund, Herron, & Reed, 2015). The effect of Cue on reaction time is also consistent with other findings (Posner and Cohen, 1984; Sapir et al., 1999) that when taking the average across other variables, Uncued – Cued reaction times we observe the significant IOR on average across all individuals (see Table 1). SOA's negative effect on reaction time is also consistent with increasing the amount of time between stimuli building up facilitation (McCrae and Abrams, 2001; Lupiáñez et al., 1997).

The interactive effect of Cue * SOA indicates that in general there may well be some wearing off of the IOR effect over that period of time, in addition to the increased facilitation observed by the main effect of SOA increasing facilitation of both Uncued and Cued trials (McCrae & Abrams, 2001). However, the SOA * Cue * Age interaction appearing insignificant is interesting, as it rejects the hypothesis that SOA is what modifies the relationship between Age and IOR. In addition, the SOA * Age effect being insignificant tells us that SOA gives old error younger adults no additional reaction speed increase over the baseline SOA effect, compared to one another.

Potentially most interesting though, is the significant relationship between Age and Cue represented here, as it shows a positive relationship, such that older adults actually exhibited more IOR effect, by being even slower on Cued trials than Uncued, by a magnitude greater than which younger adults showed this same effect. This stands in direct conflict with research that states older adults present less IOR under certain tasks, or even none at all (McCrae and Abrams, 2001). This warranted further investigation of the two-tailed *t*-test of these results, in which we compared both younger and older adult's Cued reaction time divided by their Uncued reaction time (Bédard et al., 2006). Results showed that indeed on average across all SOA conditions, older adults actually had an even stronger IOR effect than younger adults.

Implications & Future Research

While the exact effects being looked for with regard to SOA may not have been found, the actual range of SOAs used may have been more suited than others (McCrae & Abrams, 2001) to actually identifying the IOR effect across age groups in general, being more similar to those used by Posner and Cohen (1984) or Lupiáñez et al. (1997). Finding an increased effect of IOR for older adults is relevant to a variety of tasks, such as those investigated in driving (Bédard et al., 2006) in which older adults have worse overall driving ability or reaction times in general. This type of finding may be helpful to our understanding of the nature of the superior colliculus (Sapir et al., 1999), and the nature of how it changes with age, and what functions it performs.

Perhaps the most easily observable implication however, is that it warrants further investigation into comparing with methodologies of similar experiments (Posner & Cohen, 1984; Lupiáñez et al., 1997; McCrae & Abrams, 2001; McAuliffe et al., 2004), and to replicate this study to observe the effects of this particular test and range of SOAs across other variables not addressed in this study, such as discrimination tasks where this study only uses detection (Lupiáñez et al., 1997); or moving targets where this study only uses stationary (McCrae & Abarms, 2001; McAuliffe et al., 2004).

To summarize, we observed a consistent pattern of IOR across both age groups, however the effect appeared even stronger for older adults, in conflict with other similar studies. This is potentially a result of the specific methodological conditions used and variables observed, in contrast with other similar studies. Understanding the differences between these and testing the further extent of them will be critical to our understand of IOR, the superior colliculus, and the tasks they oversee.

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