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Aging Increases Inattentional Blindness to the Gorilla in our Midst

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Abstract

When engaged in an attention demanding task, people are surprisingly vulnerable to inattentional blindness, the failure to notice an unexpected event. Two theories of cognitive aging, attentional capacity models and inhibitory deficit models, make opposite predictions about age differences in susceptibility to inattentional blindness. We tested these predictions using an inattentional blindness paradigm developed by Simons and Chabris (1999) and found that older adults were more likely to experience inattentional blindness than young adults. These results are compatible with attentional capacity models of cognitive aging, but not with current inhibitory deficit models.

Inattentional blindness is the failure to explicitly notice an unexpected event when engaged in an attention-demanding task (Mack & Rock, 1998). It occurs even when the unexpected event involves a large, unusual, and dynamic object fully visible for several seconds (Neisser & Becklen, 1975). Indeed, Simons and Chabris (1999) reported that participants engaged in a challenging visual task of counting the number of basketball passes frequently failed to notice an additional person in a gorilla costume walking through the players. Surprisingly, age differences in susceptibility to inattentional blindness have not been investigated even though this phenomenon is relevant to influential theories of cognitive aging. Aging-related declines in attentional capacity (e.g., Rabbitt, 1968; Craik & McDowd, 1987) and in the ability to regulate attention through inhibition (e.g., Hasher, Lustig & Zacks, 2007; Hasher & Zacks, 1988) have been postulated as key mechanisms that cause age differences in cognitive performance. The inattentional blindness paradigm provides a test of contrasting predictions of these attentional models of cognitive aging.

Most, Scholl, Clifford, and Simons (2005) accounted for inattentional blindness using a model based on Neisser's (1976) perceptual cycle framework. They argued that an unexpected stimulus in the environment invokes a "transient, implicit shift of attention" (Most, et al. p 226). This implicit capture of attention is followed by sustained attentional processing to the extent that the unexpected stimulus is consistent with expectations about perceptual features of the target. Following Most et al., we refer to these expectations that

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trigger top-down attentional processing as “attentional set.” Thus, an unexpected stimulus may be attended implicitly, but top-down processes triggered by the attentional set are responsible for bringing the stimulus into conscious awareness by continually directing attention to it.

Most et al.’s (2005) model of perceptual cycles offers a middle ground between theories of attentional processing that prioritize automatic attentional capture by new stimuli (Theeuwes, 2004) and those that emphasize the role of top-down goals or expectations that drive attentional capture (Leber & Egeth, 2006).¹ Most et al.’s framework suggests that an unexpected stimulus can automatically attract transient, implicit attention, but top-down attentional set determines the amount of additional attention directed toward the stimulus which eventually can produce explicit attention, i.e., awareness.

Most et al. (2005; Most et al., 2001) demonstrated the impact of attentional set on inattention blindness in a series of experiments that manipulated the visual similarity of the unexpected new stimulus to the target material. Their participants tracked multiple moving objects in a display containing both targets and non-targets that could be distinguished on the basis of color or shape. They systematically varied the similarity between the targets and the unexpected stimuli using either shape or color. For example, participants saw a display containing 4 white shapes (squares and circles) and 4 black shapes (squares and circles). When asked to count the number of times that white shapes bounced off the edge of the display, all participants ($n = 16$) failed to notice an additional black circle make a horizontal path across the middle of the screen. By contrast, when participants were asked to count bounces made by the black shapes, only 12% failed to notice the additional black circle.

Most et al. (2005, 2001) argued that participants were making use of an attentional set based on color to guide additional attention to the new, unexpected stimulus, making it more likely to reach the level of explicit awareness. An unexpected stimulus that did not match the attentional set received some implicit and transient attention, but this was frequently insufficient to bring it to a level of explicit or conscious awareness. Counting accuracy was reduced in the presence of the unexpected stimulus, and the reduction in counting accuracy among non-noticers was taken as evidence of possible implicit attentional capture. Although Most et al.’s (2005) model of attentional set does not specifically address age differences, it provides a framework for predictions of two types of cognitive aging models of attention: Attentional Capacity models and Inhibitory Deficit models.

Aging and Attentional Capacity Models

This class of models assumes that attention is finite and is shared by different mental operations that occur simultaneously or in close succession (Kahneman, 1973). Successful completion of cognitive operations depends on the availability of sufficient attention to meet the requirements of the operations. This model of attention has been applied to some aging-related declines in cognitive performance by postulating that aging decreases overall attentional capacity. This approach is popular, for example, in explaining why age differences are greater in a dual task paradigm compared to a single task: Older adults’ smaller attentional capacity is less likely to be adequate for the greater attentional demands of dual tasks (see Kramer & Madden, 2008 for a review).

Dual task paradigms have been an important source of support for aging and attentional capacity models, but these paradigms require an assumption that the division of attention to both tasks is age invariant (Salthouse, 1988). Although this assumption may be plausible and

¹We thank a reviewer for raising this distinction between attentional theories that emphasize bottom-up or top-down control of attention.

parsimonious, it is difficult to test empirically. The inattentional blindness paradigm escapes this assumption. Participants are aware of only a single task, e.g., counting basketball passes, so that both young and older participants should be equally likely to allocate necessary and available attention to this single task. Because participants are unaware that a secondary task will occur, there is no motivation for them to hold some attention in reserve in preparation for the secondary task.

In the inattentional blindness paradigm, noticing the unexpected stimulus depends on the availability of attention to be directed to the stimulus to bring it into conscious awareness (Most et al., 2005). If aging decreases attentional capacity, then relatively more of older adults' attention would be consumed by the primary task, leaving less available attention compared to young adults for processing the unexpected stimulus to a level of conscious awareness. This predicts greater inattentional blindness in older than young adults.

Aging and the Inhibition Deficit Model

Hasher, Zacks and colleagues (e.g., Hasher & Zacks, 1988; Hasher et al., 2007) argue that aging diminishes the efficiency of inhibitory processes that prevent irrelevant information from entering or remaining in focal attention or working memory. Inhibitory processes are essential to prevent irrelevant information from gaining access to conscious awareness and for deleting from awareness information that is no longer relevant. Their inhibitory deficit theory postulates that inhibitory processes "keep consciousness free of irrelevant information that can impede the successful and efficient completion of a current goal" (Hasher et al., 2007, p. 228). Under the model, inhibitory deficits are responsible for aging-related declines in working memory which are caused by irrelevant information that clutters working memory more for older than young adults.

Much of the evidence for inhibition deficits is indirect, inferred from findings showing a larger decline for older than young adults in task performance under conditions of distraction versus no distraction (Carlson, Hasher, Connelly, & Zacks, 1995; Connelly, Hasher, & Zacks, 1991; Dywan & Murphy, 1996; Lustig, Hasher, & Tonev, 2006; Tun, O'Kane, & Wingfield, 2002). For example, in Connelly et al. participants read passages containing distracting words or phrases randomly inserted in the text. Older adults' reading times were slowed more than young adults' when the distractors were present compared to a no-distractor condition. Within the inhibitory deficit framework, the slowing of reading speed occurs because older adults are less able to inhibit goal-irrelevant distractors which gain access to consciousness thereby impeding completion of the goal of reading the target text (Hasher et al., 2007).

The slowing of reading times when there is distraction, however, does not directly assess whether the distracting material has entered working memory and become the focus of attention. Rather, the access of the distracting material to working memory is inferred from the slowing of reading times in the distraction condition. Similarly, Hasher and colleagues argue that superior performance for older than young adults on other indirect measures, e.g., production of distracters in a remote associations task (Kim, Hasher & Zacks, 2007) or a fragment completion task (Rowe, Valderrama, Hasher, & Lenartowicz, 2006) is evidence that older adults are less able to prevent distracters from gaining focal attention on a prior task. Within the Most et al. (2005, 2001) model, however, implicit attentional capture does not indicate explicit attentional capture and awareness. The inattentional blindness paradigm directly assesses whether task-irrelevant information has become the focus of attention and is active in working memory by measuring whether or not the participant is aware of the unexpected stimulus.

Under an inhibitory deficit model, older adults have a reduced ability to prevent irrelevant stimuli from accessing conscious awareness and thus older adults should notice the unexpected stimulus more, thereby exhibiting less inattention blindness than young adults. By contrast, attentional capacity models posit that older adults have less attention available to bring the unexpected stimulus into awareness, increasing their susceptibility to inattention blindness relative to young adults. Thus these two theories of cognitive aging make opposite predictions for age differences in inattention blindness.

Method

Participants

Young participants (age range = 17–22 years) were undergraduates and older participants lived independently in the community (age range = 61–81 years). We assigned 31 young and 26 older adults to an *attend white shirts* (WHITE) condition and 20 young and 35 older adults to an *attend black shirts* (BLACK) condition. Participants were screened for Snellen visual acuity of 20/40 or better ($M_{\text{young}} = 21.96$, $SD = 3.01$; $M_{\text{older}} = 28.36$, $SD = 7.00$, $t(110) = 6.08$, $p < .001$), and older participants for Mini-Mental State Exam (Folstein, Folstein, & McHugh, 1975) scores of 27 or better. No participant had seen an inattention blindness video previously.

Materials and Procedure

Participants watched a 30 second video clip (Viscog Productions, 2003) featuring three people wearing white shirts and three wearing black shirts, moving and passing basketballs to people with the same color shirt. The unexpected stimulus occurred midway through the video and consisted of a seventh person, dressed in a gorilla costume, walking through the scene and visible for approximately 10 seconds. Participants in the WHITE condition counted the number of times people wearing white shirts passed the ball to one another (17 passes), while participants in the BLACK condition counted passes made by the people wearing black shirts (25 passes). After viewing the video, participants were asked if they had noticed anything unusual. Participants were *noticers* if they reported seeing the gorilla or an additional person. Participants were *non-noticers* if they failed to mention the gorilla or an additional person, and were surprised by the gorilla when the video was replayed.

Results

Young adults noticed the gorilla more often than older adults in both the WHITE, $\chi^2(1, n = 57) = 14.77$ and BLACK conditions, $\chi^2(1, n = 55) = 11.79$, both p 's $< .001$ (see Figure 1, left panel). Both age groups noticed the gorilla more often in the BLACK condition in which the attended material was more visually similar to the gorilla, compared to the WHITE condition; for young, $\chi^2(1, n = 51) = 10.12$, and for older $\chi^2(1, n = 61) = 13.21$, both p 's $< .001$. This effect was previously observed in young adults (Simons & Chabris, 1999).

Accuracy on the primary counting task was calculated by subtracting any under or over counts from the correct total, and determining the percentage of total passes correctly counted. Accuracy was higher for young than older adults, $F(1, 108) = 22.47$, $p < .001$, and marginally higher in the WHITE than BLACK condition, $F(1, 108) = 3.54$, $p < .07$. Age interacted with color condition, $F(1, 108) = 5.12$, $p < .03$, with shirt color condition affecting counting accuracy for older but not young participants (see Figure 1, right panel). Ceiling effects for young adults likely contribute to this interaction.

To assess the possibility that noticing the gorilla was related to counting accuracy or visual acuity, we used t-tests to compare noticers to non-noticers on each measure. In the WHITE condition, the mean accuracy rate for the three older noticers was 96% compared to 89% for

non-noticers, $t(24) = 0.86, p = .40$. The mean accuracy rates for young noticers and non-noticers were 94% and 96% respectively $t(29) = -0.81, p = .42$. In the BLACK condition, the mean accuracy rate for older noticers was 85% compared to 79% for non-noticers $t(33) = 1.51, p = .14$. The comparable analysis was not possible for young adults in the BLACK condition as all young noticed the gorilla. Similar analyses of visual acuity also failed to find a relationship between noticing and acuity scores (all t 's $< 1.60, p$'s $> .12$). Within the older adult sample, there was a trend toward noticers being younger than non-noticers (M age = 71.7 and 74.0, respectively; $t(59) = 1.66, p = .10$).

Discussion

Inattentional blindness paradigms differ from traditional tasks used to evaluate attentional capture in that they specifically assess explicit attentional capture, i.e. awareness of the unexpected, irrelevant stimulus. The present findings highlight the importance of directly and explicitly measuring awareness of distracting events rather than inferring it from performance on other tasks. Older adults have shown at least as much attention to an irrelevant or unexpected stimulus as young adults when measured implicitly, for example, by eye movements (Kramer, Hahn, Irwin, & Theeuwes, 2000; Colcombe et al., 2003), repetition priming (Kim et al., 2007; Rowe et al., 2006) or primary task performance (Connelly et al., 1991). Older adults' susceptibility to implicit attentional capture contrasts with their relative immunity to explicit capture, that is, their inattentional blindness, demonstrated here for the first time.

Most et al. (2005) proposed that explicit awareness requires a sustained series of processes in which early implicit attentional orientation to sensory stimuli is followed by top-down, higher level interpretation guided by attentional set. Within this framework, the pattern of age differences in this and previous studies suggests that the deficit causing older adults' greater inattentional blindness (i.e., reduced explicit awareness) is in the top-down interpretative processes which occur after early processes that are sufficient for implicit attentional capture.

The finding of greater blindness for an unexpected event for older than young adults is inconsistent with the inhibitory deficit account of cognitive aging (Hasher et al., 2007; Hasher & Zacks, 1988). Inasmuch as aging leads to a decreased ability to inhibit task-irrelevant information thereby allowing it to become active in working memory, then older adults should have been more likely to notice the unexpected stimulus than the young adults (see Rowe et al., 2006). Previous research measuring explicit attention to task-irrelevant stimuli by assessing subsequent memory for these stimuli has also failed to find evidence that older adults attend more to irrelevant stimuli. Both Carlson et al. (1995) and Connelly et al. (1991) included multiple choice comprehension questions immediately following visual target text passages presented with to-be-ignored irrelevant text. While older adults were less accurate in answering the questions overall, they were no more likely than young adults to select the irrelevant text as the answer. Although these results are consistent with the present results in providing no evidence that irrelevant stimuli enter working memory more for older than young adults, off-line memory tests are not an ideal measure for determining this because of age differences in text processing that affect subsequent text memory (Stine-Morrow, Miller, & Hertzog, 2006).

The inhibition deficit model emphasizes the deliberate control of working memory through inhibition that responds to currently active goals (Zacks & Hasher, 1997). Indeed, inhibition deficits are used to explain age-related declines in working memory because they allow irrelevant stimuli to access and remain in consciousness, cluttering working memory (Hasher & Zacks, 1988; Hasher et al., 2007). The current results combined with other

studies reporting age-related increases in implicit effects of distraction (i.e. Kim et al., 2007; Rowe et al., 2006) challenge this inhibitory deficit account of cognitive aging. We demonstrated that irrelevant information is less likely to gain access to consciousness in older than young adults; Kim et al. and Rowe et al. demonstrated greater implicit effects of irrelevant information in older than young adults without requiring access to working memory. If inhibition modulates attention, this pattern suggests that age deficits in inhibition of distraction do not occur at the level of explicit conscious attention and working memory, but rather occur at an earlier more automatic stage of processing. This pattern calls for revision of the emphasis on age differences in inhibitory control of access to consciousness in the inhibition deficit model (e.g., Rowe et al.; Zacks & Hasher).

Under attentional capacity models postulating that aging reduces attention, older adults engage a greater proportion of their attention than young adults in the primary counting task in the present paradigm. This would leave older adults with relatively less attention available than young adults to bring a new stimulus through the perceptual cycles necessary for achieving explicit awareness (Most et al., 2005; Neisser, 1976). This model predicts that older adults would be less likely to notice the unexpected stimulus than young adults, as observed. Inasmuch as counting accuracy reflects whether attention was sufficient for the counting task, then the attentional capacity model would also predict that noticers would have greater counting accuracy, indicating adequate attention, than non-noticers. The present findings do not allow a powerful test of this prediction, however, because young adults' counting was at ceiling in both the black and white conditions and for older adults there were almost no noticers in the white condition. In the black condition older adults who noticed had greater counting accuracy than non-noticers, but the difference was not significant. Further research is needed to address this issue.

Given the well documented changes in the functional visual field of older adults (e.g., Lunsman, et al., 2008), an important issue is whether such factors are responsible for older adults' greater attentional blindness in the present study. Ball and her colleagues measure useful field of view (UFOV) via the exposure duration required to identify a center target and simultaneously localize a peripheral target with or without distractors. Although this duration increases in old age, the exposure duration of the unexpected stimulus in the present study (the gorilla) is substantially greater than the normative durations required by older adults for 75% correct performance in the UFOV task (Edwards et al., 2006). Moreover, the gorilla intersected the pathway of the ball several times. Nonetheless, eye-tracking data would be helpful for further evaluation of whether age differences in eye movements place the unexpected object in more peripheral vision for older than young adults, thereby possibly contributing to older adults' attentional blindness.

Finally, on a practical level, the results suggest that older adults' safety in everyday life may be jeopardized when safety depends on noticing fully-visible unexpected objects while performing an attention demanding task. For example, the risk of automobile accidents at intersections increases dramatically in old age and has been attributed to violations of right of way or traffic controls (Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998). The ability of older adults to detect brief stimuli in their peripheral vision in the UFOV test predicts traffic accidents (Owsley et al., 1998). The present results complement these findings by suggesting that older adults' inability to detect objects of relatively long duration may also contribute to traffic accidents. This seems a promising area for future investigation.

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Figure 1.

Percentage of total participants who noticed the unexpected stimulus (left panel) and mean percentage accuracy on counting task by condition and age group (right panel).

Note. There are no error bars on the left panel, as this represents the percentage of total participants noticing the unexpected stimulus on a single trial. Error bars (right panel) represent one standard error.