Wnuczko, M., Pratt, J., Hasher, L., & Walker, R. (2012). When age is irrelevant: distractor inhibition and target activation in priming of pop-out. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences, 67(3)*, 325–330, doi:10.1093/geronb/gbr114. Advance Access published on November 14, 2011

When Age Is Irrelevant: Distractor Inhibition and Target Activation in Priming of Pop-Out

Marta Wnuczko,[1] Jay Pratt,[2] Lynn Hasher,[2] and Rob Walker[3]

[1]Department of Psychology, University of Toronto, Scarborough, Ontario, Canada.
[2]Department of Psychology, University of Toronto, Ontario, Canada.
[3]Department of Psychology, University of Toronto, Mississauga, Ontario, Canada.

Objectives. Recent research suggests that inhibition at early stages of visual processing may be age invariant. We test this proposal using a priming of pop-out (PoP) measure developed by Lamy, Antebi, Aviani, and Carmel (2008. Priming of pop-out provides reliable measures of target activation and distractor inhibition in selective attention. *Vision Research, 48*, 30–41. doi:10.1016/j.visres.2007.10.009). In PoP, a unique item, which visually "pops-out" in a field of distractors, grabs our attention faster when its defining feature (e.g., color red) repeats across trials and slower when distractor- and target-defining features switch between trials. Here, we explore whether the processes underlying PoP, which prevent access to distractors and facilitate access to the singleton, remain intact with age.

Method. Participants faced a display of circles and judged the direction of a letter T inscribed within a uniquely colored circle.

Results. All underlying components of PoP were present in older and younger adults. Participants revealed distractor inhibition by responding faster to a color singleton when the color of surrounding distractors repeated and slower when the singleton assumed the color of distractors from the previous trial.

Discussion. Our findings suggest that the inhibitory processes underlying PoP remain intact with age.

Key Words: Aging—Attention—Distractor inhibition—PoP—Target activation.

IN the visual world, our attention is drawn to perceptually distinct features, such as a single red rose among yellow ones, or in the laboratory, a red target circle in a display of green distractor circles. The capture of attention, in which attention is automatically oriented to a unique item (singleton) in a field of homogeneous distractors, is referred to as the pop-out effect (e.g., Maljkovic & Nakayama, 1994). A great deal is known about the pop-out effect (Meinecke & Donk, 2002; Sagi & Julesz, 1987; Wolfe, 1992), including that the pop-out effect is age invariant (McCarley, Kramer, Colcombe, & Scialfa, 2004; Yoshida, Wake, & Osaka, 2003) and that it can be enhanced by priming, an effect termed priming of pop-out (PoP; Becker, 2008; Maljkovic & Nakayama, 1994).

Recently, Lamy, Antebi, Aviani, and Carmel (2008) developed a PoP measure that separates PoP into its individual components: target activation and distractor inhibition. Given that older adults have been shown to have deficits in inhibiting irrelevant distractors (e.g., Hasher, Stoltzfus, Zacks, & Rympa, 1991), it is possible that there are age-related differences in PoP. Alternatively, largely preserved implicit processing in older age (Jelicic, Craik, & Moscovitch, 1996) and preexisting attentional biases in PoP (Andres, Guerrini, Phillips, & Perfect, 2008) predict intact inhibitory control and, consequently, intact target activation and distractor inhibition effects in older and younger adults. Examining these two hypotheses, especially with respect to distractor inhibition, is the focus of the present study.

Like target activation, distractor inhibition operates at all stages of information processing (Fox, 1995). Target activation shifts attention toward target features, whereas distractor inhibition is the means by which irrelevant information is ignored. Target activation is typically conceived as the amplification of attentional sensitivity to the target-defining feature (e.g., color red), associated with the increase in the magnitude of the target signal (or target representation) itself (Becker, 2008; Maljkovic & Nakayama, 1994; Tipper, 1991). Distractor inhibition, then, is the reduced processing of irrelevant information associated with the suppression of the distractor signal (Fox, 1995).

One index of target activation and distractor inhibition is the change in reaction times (RT) relative to baseline. In PoP, one may identify the direction of the red singleton among green distractors more quickly when both colors repeat across two successive trials than when the singleton turns green and distractors turn red on a subsequent trial (Lamy et al., 2008). Target activation is associated with a faster response to the singleton when a target-defining feature repeats between trials and a slower reaction when a target-defining feature on trial $n - 1$ becomes the distractor-defining feature on trial n. Similarly, distractor inhibition is associated with a faster response to the singleton when

Received September 17, 2010; Accepted September 7, 2011
Decision Editor: Robert West, PhD

distractor-defining feature repeats between trials and a slower response when the distractor-defining feature on trial $n - 1$ becomes the target-defining feature on trial n. A lack of inhibitory control would presumably result in no difference between performance on baseline trials and trials where the distractor-defining feature repeats or swaps with the target-defining feature between trials.

The hypothesis that inhibition deteriorates with age, proposed by Hasher and Zacks (1988), is widely supported by research (e.g., Hasher et al., 1991; Pratt & Chasteen, 2007; Radvansky, Zacks, & Hasher, 2005; Tipper, 1991). Some of the support for this idea comes from negative priming (NP), which follows the same principles as PoP, but does not build on the preexisting pop-out effect (i.e., in NP, the target is not a singleton). Consistent with the proposal of age-related decline in inhibition, the performance of older adults does not typically improve when distractor features repeat in NP (e.g., Hasher et al., 1991).

Of importance are the qualitative differences between PoP and NP and their underlying components. According to Andres and colleagues (2008), the more automatic inhibition becomes, the less it deteriorates with age (for his proposal of inhibition taxonomy, see Nigg, 2000). Although priming is inherently implicit, its effects are modulated by the types of stimuli on which it operates. Priming of stimuli that rely less on explicit memories and involve primarily implicit or automatic processing may be more resilient to aging (Lamy et al., 2008; Soldan, Hilton, Coooper, & Stern, 2009). Given that the target is specified by the attention-grabbing singleton in PoP, rather than by a specific top-down instruction in NP (e.g., identify the red item), it follows that PoP may be more stimulus-driven than NP (Fox, 1995). Further, as noted by Lamy and colleagues, the coupling between a target-defining feature and a response-related feature is weaker in PoP than in NP. In NP, a single stimulus, such as a specific letter, may simultaneously define the target and trigger a response. In PoP, a stimulus that defines the target is distinct from a stimulus that triggers a response. It is perhaps due to the weak coupling between target-defining and response-related features that PoP is largely attributed to priming of features unrelated to a response by which target is selected (Becker, 2008). In contrast, NP is thought to operate on priming of response-related features (Fox, 1995). Thus, the qualitative differences between PoP and NP suggest that age-related deficits in inhibition in NP may not readily generalize to PoP.

Few studies have looked at age-related differences in distractor inhibition in PoP. Yoshida and colleagues (2003) used a PoP paradigm outlined by Maljkovic and Nakayama (1994) in which targets varied from distractors on a color dimension. In their study, older adults, like younger adults, were quicker to respond when the distractor-defining color repeated and the target-defining color was constant across consecutive trials. This finding suggested preserved inhibitory control in older adults. However, the distractor inhibition

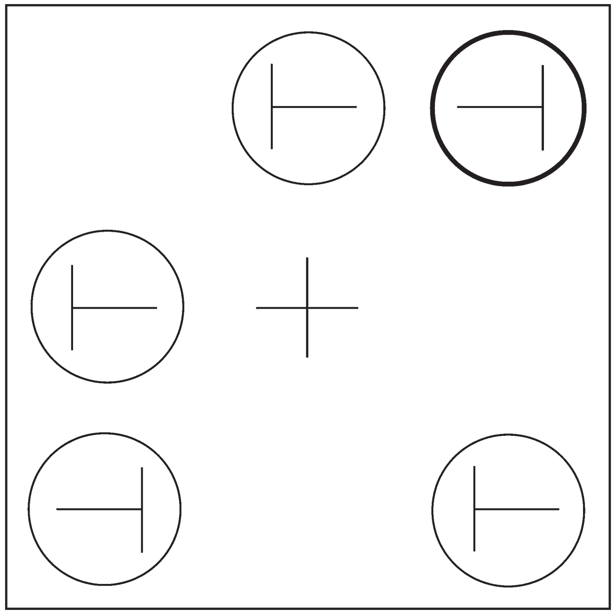

Figure 1. Example of the stimulus display. The task was to identify the direction of the head or the tail of the "T" inside the uniquely colored circle. The target (thick stroke) and the distractors (thin stroke) appeared at random locations within an invisible 3 × 3 matrix, around the central fixation cross. The colors of circles were randomly drawn from four possible colors. The orientation of "T" randomly varied from left to right across circles and trials. Stimuli are not drawn to scale.

effect found by Maljkovic and Nakayama may have been confounded by top-down factors (Lamy et al., 2008). Because older adults may rely more heavily on top-down processing than younger adults (Whiting, Madden, Pierce, & Allen, 2005), it is imperative to use a PoP measure with less predictable sequences of target- and distractor-defining features than in the study of Yoshida and colleagues. Thus, we chose the measure developed by Lamy and colleagues.

In the study by Lamy and colleagues (2008) and our study, the singleton was a uniquely colored circle surrounded by homogeneous distractor circles (Figure 1). Participants responded to the direction (left/right) of the letter "T" inside the singleton. PoP was measured as the difference in RT between trials on which both target and distractor colors repeated (condition, RR) and trials on which target and distractor features switched (SS). We chose the baseline condition that consisted of new target- and new distractor-defining color (NN)—colors that were not present in the preceding trial. This baseline allowed for the separation of PoP components, yielding two measures of distractor inhibition and two measures of target activation, described in Table 1. Hence, distractor inhibition was measured as the difference in RT between the NN baseline and (a) repeated distractor (NR) trials or (b) switched target (SN) trials. Target activation was measured as the difference in RT between the NN baseline and (a) repeated target (RN) trials or (b) switched distractor (NS) trials.

Our first objective was to replicate the results reported by Lamy and colleagues (2008) on younger adults with the NN

Table 1. Description of Intertrial Effects Underlying Distractor Inhibition and Target Activation in Priming of Pop-Out

PoP component	Description of intertrial changes in color
Distractor inhibition	
Distractor repetition	Distractor color on trial n = distractor color on trial $n + 1$
Target switch	Distractor color on trial n = singleton color on trial $n + 1$
Target activation	
Target repetition	Singleton color on trial n = singleton color on trial $n + 1$
Distractor switch	Singleton color on trial n = distractor color on trial $n + 1$

condition as the baseline. Our second objective was to examine whether or not target activation and distractor inhibition underlying PoP remain intact with age. If inhibition underlying PoP deteriorates with age, then older adults may not show distractor inhibition effects, leaving target activation as the primary contributor to PoP. If the inhibition underlying PoP is resilient to aging, then participants in both age groups should react faster relative to baseline when the distractor-defining color repeats between trials and slower relative to baseline when the distractor color from the preceding trial becomes the target-defining color.

Table 2. Intertrial Effects Underlying PoP in Younger and Older Adults

	RT (ms) difference	
	Younger	Older
Effect[a]	*M* (*SE*)	*M* (*SE*)
PoP		
SS – RR	75.50 (6.10)	130.92 (13.33)
Distractor repetition		
NN – NR	18.90 (5.84)	23.48 (9.85)
Target switch		
NN – SN	−16.62 (5.99)	−38.84 (11.02)
Target repetition		
NN – RN	14.45 (5.51)	16.84 (12.42)
Distractor switch		
NN – NS	−20.93 (5.63)	−32.95 (11.30)

Notes. PoP = priming of pop-out; RT = reaction time; *SE* = standard error; SS = switched target color, switched distractor color; RR = repeated target color, repeated distractor color; NN = new target color, new distractor color; NR = new target color, repeated distractor color; SN = switched target color, new distractor color; RN = repeated target color, new distractor color; NS = new target color, switched distractor color.

[a] PoP is measured as the difference in RT between SS and RR trials. The remaining effects are differences in RT between the baseline (NN) and given conditions.

Method

Participants

Twenty younger adults (4 men, 16 women; 17–28 years old, *M* = 19.8, *SD* = 2.4; 11–23 years of education, *M* = 17.1, *SD* = 3.5) and 20 older adults (3 men, 17 women; 61–75 years old, *M* = 69.4, *SD* = 4.8; 12–16 years of education, *M* = 13.4, *SD* = 1.3) participated. Younger adults were University of Toronto students who received a course credit for participation. Older adults received monetary compensation. One older and two younger adults were left handed; the remaining participants were right handed. Mean self-reported health on a 1–10 scale with 10 the best was high in both age groups (*M* [older] = 8.1, *SD* = 1.5; *M* [younger] = 7.7, *SD* = 1.3).

Stimuli

The stimulus display is shown in Figure 1. It consisted of an invisible 3 × 3 matrix, the fixation sign (+) in the central cell, and five colored circles (subtending 7.2°) in the remaining cells of the matrix. The colored circles appeared at random locations around the fixation sign.

Inscribed within each circle was a letter "T," rotated by 90° or −90° (with the tail of a "T" subtending 2.9° in length and 0.5° in width and the head of a "T" subtending 2.8° in length and 0.3° in width). The T's assumed left or right direction with an equal probability. On each trial, the color of the target circle was different from that of distractors. Four colors were used (red [RGB = 255, 0, 0], blue [RGB = 0, 0, 255], green [RGB = 0, 255, 0], and yellow [RGB = 255, 255, 0]). All target-distractor color combinations were equally probable.

Procedure

The experiment was programmed under E-Prime (Psychology Software Tools, 2001). Participants were instructed to indicate the direction of the tail or the head of a letter T inside the uniquely colored circle and pressed the "z" key on a keyboard with their left hand to indicate left direction and the far "3" key with their right hand to indicate right direction. On each trial, a 500-ms fixation display was followed respectively by a 2,000-ms stimulus display and a 500-ms blank screen. Errors or missed responses were cued with a 500-ms feedback sound.

Trials were divided into one practice block and three experimental blocks. The practice block consisted of 42 trials, and each experimental block consisted of 112 trials, for a total of 336 experimental trials. Optional 5-min breaks followed blocks of trials.

Results

The PoP effect, distractor inhibition, and target activation were separately examined in older and younger adults. Error trials, constituting 2.8% of all trials in older adults and 2.0% of all trials in younger adults, were eliminated from the data together with RTs that were 2.5 standard deviations away from the mean. RT outliers constituted 2.5% of responses in older adults and 1.2% of responses in younger adults. Intertrial effects of PoP and its components are shown in Table 2 as differences in RT between conditions.

Table 3. Error Rates (% error) Associated With Responses on Repetition Versus New Trials and Switched Versus New Trials in Younger and Older Adults

	Condition (% error)						
Age group	RR	NR	SN	NN	RN	NS	SS
Older	3.04	2.83	1.74	3.37	3.26	4.13	4.13
Younger	2.28	1.85	2.39	2.28	1.96	1.96	2.50

Notes. RT = reaction time; *SE* = standard error; SS = switched target color, switched distractor color; RR = repeated target color, repeated distractor color; NN = new target color, new distractor color; NR = new target color, repeated distractor color; SN = switched target color, new distractor color; RN = repeated target color, new distractor color; NS = new target color, switched distractor color.

The percentage error rates across conditions are shown in Table 3.

PoP Effect

A mixed analysis of variance (ANOVA) with age group as the between factor and condition (RR vs. SS) as the within factor revealed PoP effect in older and younger adults, $F(1,38) = 194.46$, $p < .001$, $\eta^2 = 0.84$, with older adults responding faster on RR trials ($M = 850$, $SD = 89$) than on SS trials ($M = 981$, $SD = 114$) and younger adults responding faster on RR trials ($M = 597$, $SD = 65$) than on SS trials ($M = 670$, $SD = 66$). The analysis confirmed the main effect of age group, $F(1,38) = 115.78$, $p < .001$, $\eta^2 = 0.75$, and a significant age by condition interaction, $F(1,38) = 15.34$, $p < .001$, $\eta^2 = 0.29$. Table 2 reveals that the difference in RT between RR and SS trials was larger for older than younger adults. After controlling for general slowing by logarithmic transformation of data, the PoP effect, $F(1,38) = 252.22$, $\eta^2 = 0.87$, and age effect, $F(1,38) = 124.15$, $\eta^2 = 0.77$, persisted (both $p < .001$), but the interaction between PoP and age group was no longer significant, $F(1,38) = 1.61$, $p > .20$, $\eta^2 = 0.04$.

Distractor Inhibition

Two distractor inhibition effects were examined: (a) distractor repetition (NN vs. NR) and (b) target switch (NN vs. SN).

A mixed ANOVA with condition (NN vs. NR) as the within factor and age group as the between factor revealed a significant effect of distractor repetition, $F(1,38) = 13.70$, $p = .001$, $\eta^2 = 0.27$, with older adults responding faster on NR trials ($M = 893$, $SD = 101$) than on NN trials ($M = 917$, $SD = 98$) and younger adults responding faster on NR trials ($M = 624$, $SD = 72$) than on NN trials ($M = 643$, $SD = 73$). The analysis further revealed a significant age group effect, $F(1,38) = 101.68$, $p < .001$, $\eta^2 = 0.73$. There was no significant condition by age group interaction, $F < 1$.

Another mixed ANOVA with condition (NN vs. SN) as the within factor and age group as the between factor revealed a significant effect of target switch, $F(1,38) = 19.55$, $p < .001$, $\eta^2 = 0.34$, with older adults responding faster on NN trials ($M = 917$, $SD = 98$) than on SN trials ($M = 955$, $SD = 95$) and younger adults responding faster on NN trials ($M = 643$, $SD = 73$) than on SN trials (M = 660, $SD = 76$). Further, the analysis revealed a significant effect of age group, $F(1,38) = 115.30$, $p < .001$, $\eta^2 = 0.75$, and a near-significant interaction between condition and age group, $F(1,38) = 3.14$, $p = .085$, $\eta^2 = 0.08$. After controlling for general slowing, the effects of target switch, $F(1,38) = 23.88$, $\eta^2 = 0.39$, and age group, $F(1,38) = 117.55$, $\eta^2 = 0.76$, persisted (both $p < .001$), with no significant interaction between condition and age group, $F(1,38) = 0.89$, $p = .35$, $\eta^2 = 0.02$.

Target Activation

Two target activation effects included target repetition (NN vs. RN) and distractor switch (NN vs. NS).

A mixed ANOVA with condition (NN vs. RN) as the within factor and age group as the between factor revealed a significant effect of target repetition, $F(1,38) = 5.31$, $p = .03$, $\eta^2 = 0.12$, with older adults responding faster on RN trials ($M = 900$, $SD = 104$) than on NN trials ($M = 917$, $SD = 98$) and younger adults responding faster on RN trials ($M = 629$, $SD = 64$) than on NN trials ($M = 643$, $SD = 73$). The analysis further revealed a significant effect of age group, $F(1,38) = 106.09$, $p < .001$, $\eta^2 = 0.74$, and no interaction between condition and age group, $F(1,38) = 0.03$, $p > .80$, $\eta^2 = 0.001$.

Another mixed ANOVA with condition (NN vs. NS) as the within factor and age group as the between factor revealed a significant effect of distractor switch, $F(1,38) = 18.24$, $p < .001$, $\eta^2 = 0.32$, with older adults responding faster on NN trials ($M = 917$, $SD = 98$) than on NS trials ($M = 950$, $SD = 109$) and younger adults responding faster on NN trials ($M = 643$, $SD = 73$) than on NS trials ($M = 664$, $SD = 76$). The analysis further revealed a significant effect of age group, $F(1,38) = 100.88$, $p < .001$, $\eta^2 = 0.73$. There was no significant interaction between condition and age group, $F < 1$.

Accuracy

Table 3 suggests that older adults committed more errors than younger adults in each condition, but their accuracy was relatively the same when compared with the baseline. Indeed, older and younger adults did not differ significantly in accuracy on distractor inhibition measures of NN versus NR, $F(1,38) = 1.0$, $p > .30$ and NN versus SN, $F < 1$, or on target activation measures of NN versus NS, $F = 2.59$, $p > .10$ and NN versus RN, $F = 1.58$, $p > .20$. Further, there were no significant differences in accuracy between NN and NR trials, $F(1,38) = 1.36$, $p = .25$, or NN and SN trials, $F(1,38) = 1.52$, $p > .20$, and no significant interactions between distractor inhibition effects and age, all $F < 1$. Similarly, there were no significant differences in accuracy between NN and RN trials, $F(1,38) = 0.19$, $p > .60$, or between NN and NS trials, $F(1,38) = 0.20$, $p > .60$, and no significant interactions between age and target activation measures of NN versus RN, $F < 1$, and NN versus NS, $F(1,38) = 1.23$, $p > .20$.

Discussion

The PoP effect and all of its components were present in older and younger adults, indicating that the inhibition of distracting information in PoP remains intact with age. More specifically, the effects of distractor repetition and target switch were the same for older and younger adults. Consistent with previous research (McCarley et al., 2004; Yoshida et al., 2003), we also found preserved target activation effects of target repetition and distractor switch. Overall, older adults responded slower than younger adults, and this effect persisted after the log transformation of data. The PoP effect and its components were of similar magnitudes in older and younger adults after controlling for general slowing.

The presence of distractor inhibition effects of comparable magnitudes in both age groups indicates that inhibitory processes of older adults seem to operate as efficiently as the inhibitory processes of younger adults. The results are consistent with the argument that age-related deficits do not necessarily extend to basic perceptual attributes of objects such as color. The results of our study contrast with NP findings that suggest age-related deficits in inhibition. The contrasting results could be due to the different levels of processing underlying PoP and NP. According to Becker (2008), priming can occur at the stage of visual selection, before the response is selected, or at the stage of response selection. Although both types of processing are implicated in PoP and NP, PoP seems to operate primarily at the early stage of visual selection (Eimer, Kiss, & Cheung, 2010; Lamy, Yasher, & Ruderman, 2010). Priming of response-related features, in turn, is characteristic of NP (Lamy et al., 2008). It is possible that inhibition at the stage of response selection is more prone to age-related decline than inhibition at the stage of target selection.

Further, evidence for age-related reduction in inhibitory efficiency on priming tasks, such as NP, is mostly derived from studies that use target-distractor letter arrays (Connelly & Hasher, 1993; Hasher et al., 1991, Experiment 1) and semantic stimuli, such as word fragments (e.g., Ikier & Hasher, 2006). In the study by Hasher and colleagues, younger adults, but not older adults, were slower to react (e.g., name a letter) when colors of distractor and target letters switched than when they repeated. Unlike the singleton displays in PoP tasks, the target-distractor letter arrays often consist of a single distractor per target item. Although distractors are distinguished from targets based on color, it is the repetition of a letter itself that primes attention to the target. This contrasts with our PoP study, where attentional biases were facilitated or inhibited through the repetition of color alone.

Noteworthy are the less common instances of intact NP in older adults. According to Kane, May, Hasher, Rahhal & Stoltzfus (1997), such instances, may be specific to degraded visual conditions, requiring the support of episodic memory. In this context, episodic memories may be less relevant to PoP, because the singleton, by its nature, is salient. Although episodic retrieval has also been implicated in PoP (Hillstrom, 2000), the recent evidence from eye movement (Becker, 2008) and event-related brain potential experiments (Eimer et al., 2010) favors selective inhibition as the principal mechanism.

In non-PoP priming paradigms, attentional biases are created through priming. In PoP, attentional biases exist prior to priming due to the pop-out phenomenon. Attention is automatically directed to the unique item among a number of homogenous distractors. This characteristic renders the distinction between target and distractors more implicit than by a top-down instruction. By contrast, items in two-item arrays do not pop-out. Participants must receive explicit instructions to direct their attention toward one item or another. This suggests that performance on two array tasks fundamentally relies more on higher cognitive processes than PoP. The proposal that lower level inhibitory control is more resilient to aging is further supported by the performance of older and younger adults on singleton visual search tasks (Lawson, Guo, & Jiang, 2008; Madden, Spaniol, Bucur, & Whiting, 2005). Regardless of age, participants detect a singleton item faster when its features and/or features of distractors repeat from one trial to the next. This is in line with our finding that older adults respond faster to the singleton when the target-defining color or the distractor-defining color persists to the next trial.

Funding

The Canadian Institutes of Health Research (184245), National Science and Engineering Research Council (487235) to L.H.

Acknowledgments

We thank our three anonymous reviewers and the handling editor, Dr. Robert West, for their input. We thank Etsuko, T. Harada, Doug Garrett, Shira Zimerman, and our colleagues at Hasher Aging and Cognition Laboratory, Karen Campbell, Karl Healey, Nigel Gopie, Gillian Rowe, Renee Biss, Ruthann Thomas, and Elizabeth Howard for helpful comments and assistance at various stages of the project.

Correspondence

Correspondence should be addressed to Marta Wnuczko, University of Toronto, Scarborough, 1265 Military Trail, Toronto, ON M1C 1A4, Canada. E-mail: m.wnuczko@utoronto.ca.

References

Andres, P., Guerrini, C., Phillips, L. H., & Perfect, T. J. (2008). Differential effects of aging on executive and automatic inhibition. *Developmental Neuropsychology*, *33*, 101–123. doi:10.1080/87565640701884212

Becker, S. I. (2008). The stage of priming: Are intertrial repetition effects attentional or decisional? *Vision Research*, *48*, 664–684. doi:10.1016/j.visres.2007.10.025

Connelly, S. L., & Hasher, L. (1993). Aging and the inhibition of spatial location. *Journal of Experimental Psychology: Human Perception and Performance*, *19*, 1238–1250. doi:10.1037/0096-1523.19.6.1238

Eimer, M., Kiss, M., & Cheung, T. (2010). Priming of pop-out modulates attentional target selection in visual search: Behavioural and electrophysiological evidence. *Vision Research*, *50*, 1353–1361. doi:10.1016/j.visres.2009.11.001

Fox, E. (1995). NP from ignored distractors in visual selection: A review. *Psychonomic Bulletin and Review*, *2*, 145–173. doi:10.3758/BF03210958

Hasher, L., Stoltzfus, E. R., Zacks, R. T., & Rypma, B. (1991). Age and inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*, 163–169. doi:10.1037/0278-7393.17.1.163

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 193–225). New York: Academic Press.

Hillstrom, A. P. (2000). Repetition effects in visual search. *Perception and Psychophysics*, *62*, 800–817. doi:10.3758/BF03206924

Ikier, S., & Hasher, L. (2006). Age differences in implicit interference. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, *61*, 278–284.

Jelicic, M. J., Craik, F. I. M., & Moscovitch, M. (1996). Effects of ageing on different explicit and implicit memory tasks. *European Journal of Cognitive Psychology*, *8*, 225–234. doi:10.1080/095414496383068

Kane, J. M., May, C. P., Hasher, L., Rahhal, T., & Stoltzfus, E. R. (1997). Dual mechanisms of negative priming. *Journal of Experimental Psychology: Human Perception and Performance*, *23*, 632–650. doi:10.1037/0096-1523.23.3.632

Lamy, D., Antebi, C., Aviani, N., & Carmel, T. (2008). Priming of pop-out provides reliable measures of target activation and distractor inhibition in selective attention. *Vision Research*, *48*, 30–41. doi:10.1016/j.visres.2007.10.009

Lamy, D., Yashar, A., & Ruderman, L. (2010). A dual-stage account of inter-trial priming effects. *Vision Research*, *50*, 1396–1401. doi:10.1016/j.visres.2010.01.008

Lawson, A. L., Guo, C., & Jiang, Y. (2008). Age effects on brain activity during repetition priming of targets and distracters. *Neuropsychologia*, *45*, 1223–1231. doi:10.1016/j.neuropsychologia.2006.10.014

Madden, D. J., Spaniol, J., Bucur, B., & Whiting, W. L. (2005). Adult age differences in implicit and explicit components of top-down attentional guidance during visual search. *Psychology and Aging*, *20*, 317–329. doi:10.1037/0882-7974.20.2.317

Maljkovic, V., & Nakayama, K. (1994). Priming of pop-out: I. Role of features. *Memory and Cognition*, *22*, 657–672. doi:10.3758/BF03209251

McCarley, J. S., Kramer, A. F., Colcombe, A. M., & Scialfa, C. T. (2004). Priming of pop-out in visual search: A comparison of young and old adults. *Aging Neuropsychology and Cognition*, *11*, 80–88. doi:10.1076/anec.11.1.80.29362

Meinecke, C., & Donk, M. (2002). Detection performance in pop-out tasks: Nonmonotonic changes with display size and eccentricity. *Perception*, *31*, 591–602. doi:10.1068/p3201

Nigg, J. T. (2000). On inhibition/disinhibition in developmental psychopathology: Views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin*, *126*, 200–246. doi:10.1037/0033-2909.126.2.220

Pratt, J., & Chasteen, A. L. (2007). Examining inhibition of return with multiple sequential cues in younger and older adults. *Psychology and Aging*, *22*, 404–409. doi:10.1037/0882-7974.22.2.404

Radvansky, G. A., Zacks, R. T., & Hasher, L. (2005). Age and inhibition: The retrieval of situation models. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences*, *60*, 276–278. doi:10.1093/geronb/60.5.P276

Sagi, D., & Julesz, B. (1987). Short range limitation on detection of feature difference. *Spatial Vision*, *2*, 39–49. doi:10.1163/156856887X00042

Soldan, A., Hilton, H. J., Cooper, L. A., & Stern, Y. (2009). Priming of familiar and unfamiliar visual objects over delays in young and older adults. *Psychology of Aging*, *24*, 93–104. doi:10.1037/a0014136

Tipper, S. P. (1991). Less attentional sensitivity as a result of declining inhibition in older adults. *Bulletin of the Psychonomic Society*, *29*, 45–47.

Whiting, W. L., Madden, D. J., Pierce, T. W., & Allen, P. A. (2005). Searching from the top down: Ageing and attentional guidance during singleton detection. *Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology*, *58*, 72–97. doi:10.1080/02724980443000205

Wolfe, J. M. (1992). "Effortless" texture segmentation and "parallel" visual search are not the same thing. *Visual Research*, *32*, 757–763. doi:10.1016/0042-6989(92)90190-T

Yoshida, T., Wake, T., & Osaka, N. (2003). Effect of aging on priming of pop-out. *Shinrigaku Kenkyu: The Japanese Journal of Psychology*, *74*, 112–121.