AN ABSTRACT OF THE THESIS OF

Jamie Naylor for the degree of Master of Arts in Interdisciplinary Studies in Psychology, Psychology and Gerontology presented on June 1, 2016

Title: An Investigation of Age-Related Differences in Value-Driven Attentional Capture

Abstract approved:

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Previous research on age-related differences in attentional capture has indicated that older adults are more susceptible to distraction than younger adults and this has been interpreted as a reduced capacity to inhibit distraction in late life. Recently, however, there have been discrepancies in the literature about in what circumstances older adults are more susceptible to distraction than younger adults. Additionally, theoretical work has emerged in the attentional capture literature which indicates that more sophisticated theory is needed to fully understand attention capture. The present study was conducted in order to provide some clarification about attentional capture across the lifespan. We used a recently developed paradigm to examine the effects of reward and motivation on attentional capture in younger adults who were paid, younger adults who received course credit, and older adults who were paid. Our results indicated that older adults were no more susceptible to distraction than younger adults in the task even when both groups were paid. Additionally, compensation did not affect the magnitude of attentional capture by stimuli that had previously been associated with gain or loss, had a neutral association, or when no distractor was present. We replicated previous research which has demonstrated enhanced attentional capture by previously rewarding, but irrelevant stimuli and extend these findings to gain-associated stimuli. Results are interpreted within the context of several major theories of cognitive aging, the inhibitory deficit and the generalized slowing views.

An Investigation of Age-Related Differences in Value-Driven Attentional Capture

by
Jamie Naylor

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Arts in Interdisciplinary Studies

Presented June 1 2016

Commencement June 2016

Master of Arts in Interdisciplinary Studies thesis of Jamie Naylor presented on June 1, 2016

APPROVED:

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Jamie Naylor, Author

ACKNOWLEDGEMENTS

The author would like to express sincere appreciation to his mentor and primary advisor, Dr. Mei-Ching Lien for her advice, patience, and guidance through the years.

The author also extends his gratitude towards Dr. Kathryn Becker-Blease, secondary advisor, Dr. Robert Stawski, tertiary advisor, and Steven Kunert, graduate council representative for their guidance throughout this process.

The author also extends his gratitude toward the School of Psychological Science for the Graduate Teaching Assistantship granted to him, which made it possible to pursue graduate education.

Additionally, the author would like to thank his parents, Rick Naylor and Kerry Naylor for their financial and emotional support throughout his education. The author also thanks his fiancée, Alison Burros, for her love and support throughout this process.

Finally, the author thanks his fellow graduate students, both former and current, Alyssa Raymond, Shana Needham, Amy Bonnett, Keiko Bostwick, Birken Noesen, Christian Sinnott, Katy Krieger, Ameer Almuaybid, and Nicole Martin for their friendship, support, and for sharing in this experience with him.

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Attention capture plays a vital role in everyday life. Capture is often thought of as being detrimental, such as when attention is drawn to irrelevant information (e.g., a cell phone going off while driving). However, capture is also incredibly beneficial in cases where attention is drawn to irrelevant information in the environment (e.g., while driving, noticing brake lights on the car ahead). Due to the potential consequences, it is of interest of researchers to further understand the conditions necessary for attention to be captured so that steps can be taken to maximize capture when necessary and minimize capture when harmful.

There are two major theoretical accounts of how attention is captured involuntarily: by properties of a stimulus, known as bottom-up salience capture (Theeuwes, 1992), or in a goal-driven manner, known as top-down contingent capture (Folk, Remington, & Johnston, 1992). Bottom-up theorists have suggested that attention is captured regardless of a person's task goals and that characteristics of a stimulus (e.g., loudness, brightness, uniqueness) cause attention to be captured. Top-down theorists, however, have suggested that people are generally relatively good at ignoring irrelevant stimuli and that only stimuli relevant to a given task capture attention (e.g., stop sign captures attention while driving). While much evidence for top-down and bottom-up theories have been demonstrated, researchers have recently conceded that these two theories may not be dichotomous (Awh, Belapolsky, & Theeuwes, 2012). This is highlighted by recent evidence demonstrating that the attentional system is highly flexible (Lien, Ruthruff, & Johnston, 2010) and that resistance to bottom-up capture is strong but can be weakened (Lien, Ruthruff, & Naylor, 2014). Additionally, a recent study (Anderson, Laurent, & Yantis, 2011) found that attention can be captured irrespective of task goals and stimulus characteristics (outside of the top-down/bottom-up dichotomy). Anderson and colleagues found that attention was captured by the irrelevant colors that were previously associated with a monetary reward (e.g., a blue circle = 5¢). Anderson and colleagues labeled the phenomenon of attention capture by previously rewarding stimuli Value-Driven Attentional Capture (VDAC) and argue that their findings cannot be easily accounted by top-down or bottom-up theories, suggesting that a more comprehensive theory is needed.

Attention Capture across the Lifespan

A concern with attention capture research is that the majority of studies only include young adult samples (usually 18-25 year olds). This is somewhat concerning from a developmental perspective because humans are viewed as being in a constant state of development and a complete understanding of attention capture may not be possible without inclusion of varying age ranges. For this reason, attention theorists need to study not only what captures attention but also how susceptibility to capture changes throughout the lifespan. For instance, an informal poll may reveal that they people believe that older adults are more susceptible to distraction while driving and these beliefs may have bearing on how long older adults can maintain independence by driving themselves.

Recent evidence has also shown that young children lack top-down control of their own attention and are thus more susceptible to distraction (Gaspelin, Margett-Jordan, & Ruthruff, 2015). Similarly, Roper, Vecera, and Vaidya (2014) applied Anderson and colleagues' (2011) methodology to the study of lifespan attention capture by conducting a cross-sectional study on adolescents (13-16 year olds) and young adults (20-35 year olds). They also found evidence that adolescents were much more susceptible to distraction than younger adults and that value-driven attentional capture weakens as age increases.

On the other end of the spectrum, a similar concern comes from studies suggesting that older adults (age 60-80) may have reduced ability to filter out irrelevant information and therefore suffer from increased attention capture (Juola, Koshino, Warner, McMickell, & Peterson, 2000; Pratt & Bellomo, 1999). However, Lien, Gemperle, and Ruthruff (2011) found no evidence for age-related differences in bottom-up capture. These discrepancies could have far-reaching implications. For example, if it is erroneously concluded that attention capture worsens with age, this could have broader social implications as it has been demonstrated that negative beliefs about aging can induce stereotype threat in older adults (Barber & Mather, 2013) and negative self-perceptions of aging have been linked to decreased longevity (Levy, Slade, Kunkel, & Kasl, 2003). Further research is needed to clarify the true nature of attention capture and aging in order to comprehensively understand attention capture in the context of cognitive aging.

While controversy exists about whether older adults are more susceptible to attention capture by irrelevant objects in general, there is compelling evidence that there are age-related differences in the processing of emotional stimuli. An established age-related difference manifests in capture by emotional information, whereby attention is more susceptible to capture by negative information in younger adults (a negativity bias; Murphy & Isaacowitz, 2008) and positive stimuli in older adults (a positivity bias; Isaacowitz, Wadlinger, Goren & Wilson, 2006; Mather & Carstensen, 2005). Mather and Carstensen have described age-related bias as the result of age differences in motivated cognition and goal activation, arguing that older adults' are motivated to engage in information processing strategies that maximize emotional well-being. They cited Charles, Mather, and Carstensen's (2003) study, where older and younger adults were presented with three types of images (positive, negative and neutral) and then quizzed them later on whether they had seen the images before. Their results for the negative and neutral images were pretty straightforward – sharp declines in memory performance for older adults. However, older adults remembered significantly more positive images than neutral or negative, and their performance was comparable with younger adults. These results suggest that motivation to attend to or remember an image plays a vital role in cognitive aging.

Inhibition and Aging

One prevalent theory of cognitive aging is the inhibitory deficit view, which posits that deficits in cognitive performance in normal healthy aging are largely explained by reduced ability to inhibit distracting information in older adulthood (Hasher & Zacks, 1988). This theory has received considerable support throughout the cognitive aging literature with studies demonstrating that older adults show considerable performance deficits on tasks where irrelevant distractions are present (Connelly, Hasher, & Zacks, 1991; Duchek, Balota, & Thessing, 1998; Gazzaley, Cooney, Rissman, & D'Esposito, 2005; Jost, Bryck, Vogel, & Mayr, 2011). These results are interpreted as a general deficit in older adult's ability to suppress competing information and prevent it from entering working memory which has deleterious effects on task performance.

An interesting finding from studies of inhibition is that older adults often implicitly encode distracting information and can carry this information over into later tasks. In Biss, Ngo, Hasher, Campbell, and Rowe's (2013) study, distracting words that appeared as irrelevant distractors in an initial task were better remembered by older adults in a later surprise memory test. Similarly, Kim, Hasher, and Zacks (2007) found that older adults were able to remember distracting words presented in an initial reading task that later served as answers to word problems. These studies seem to suggest that older adults naturally encode distractors implicitly, likely because of an inability to inhibit them from entering working memory. Campbell, Hasher, and Thomas (2012) also found that, not only are older adults less able to filter out irrelevant distractors, they also attempt to implicitly link co-occurring relevant and irrelevant information together in meaningful ways. Taken together, all of these findings suggest that older adults allow more distracting information to enter attention and working memory, save this information implicitly in memory, and associate irrelevant and relevant information together.

Within the context of attentional capture, this view predicts that older adults are more susceptible to attentional capture by salient but irrelevant information. However, an important distinction for the inhibitory deficit hypothesis is that inhibition of competing distractors and facilitation of relevant information are separable. In tasks where competing information does not need to be inhibited, older adults show equivalent performance to younger adults. Lien et al. (2011), for example, suggested that older adults may be able to use a search strategy that helped them select relevant information as opposed to suppressing irrelevant information, indicating preserved top-down control with advanced age.

As mentioned previously, there has recently been concern that top-down and bottom-up theories of attentional capture may not be sufficient to explain all instances of capture, with Anderson's value-driven capture framework providing evidence that capture can occur outside of this dichotomy. Interestingly, the value-driven capture paradigm relies on two tasks, an implicit learning task followed by the attentional capture task. In the first task, participants must learn to associate certain stimuli with various reward types. Since within the inhibitory deficit literature, older adults tend to rely on implicit associations with distracting information more readily that younger adults, then we should predict that older adults would have more exacerbated attentional capture by these implicit associations in the second task. The value-driven capture paradigm then may be an appropriate tool to study attention capture in older adulthood. A second advantage of the value-driven capture paradigm is that it directly pits a new target against a totally irrelevant but previously rewarding distractor. If we observe larger capture effects in older adults by irrelevant stimuli, then this would support the inhibitory deficit hypothesis. However, since the target and distractor do not share similar features (i.e. a shape-based target and color-based distractors) it is also entirely possible that older adults can utilize preserved top-down control to facilitate target identification such as in Lien et al. (2011).

Value-Driven Attentional Capture

The idea that motivation can impact attention and memory is corroborated by studies of attention capture by non-emotional but rewarding stimuli. Recent research on value-driven capture has revealed that stimuli which are associated with a previously rewarding outcome receive attentional processing priority (Della Libera & Chelazzi, 2009; Kiss, Driver, & Eimer, 2009; Raymond & O'Brien, 2009) that may persist even in later tasks where there is no longer incentive to attend to such stimuli (Anderson, Laurent, & Yantis, 2011; Anderson & Yantis, 2012; Hickey, Chelazzi, & Theeuwes, 2010; Theeuwes & Belopolsky, 2012).

There is evidence that reward-associated stimuli can influence established attentional biases. For example, studies on object-based attention have revealed that people are more likely to search for a target within an object (e.g., searching for a specific button on a single control panel) than to search outside of it. Shomstein and Johnson (2014) found that this attentional bias was eliminated when participants were given monetary incentive to search outside of the object, suggesting that motivation can override how attention is deployed. Similarly, Wentura, Müller, and Rothermund (2014) found that reward-associated distractors captured attention even when they were irrelevant and harmed task performance. These findings suggest that stimulus value, rather than physical properties, may take precedence in attentional allocation and that motivation can influence attention allocation. If this is the case, then how is value assigned to a stimulus? Surprisingly, Wentura et al. found that distractors associated with a monetary gain and loss captured attention equally, slowing target responses than neutral distractors. It is possible that any stimuli that are assigned value (either positive or negative) may capture attention regardless of monetary outcome. While their study only included younger adults, they suggested that capture by stimulus value (regardless of positive or negative valence) may be context specific, since it is certainly beneficial to alert a person whether positive or negative information is present.

According to studies on age-related difference in processing emotional information (e.g., Isaacowitz, Wadlinger, Goren, & Wilson, 2006; Mather & Carstensen, 2005), one would expect age-related differences in gain and loss capture. That is, a positivity bias for gain-associated stimuli should have observed for older adults but a negativity bias for loss-associated stimuli should have observed for younger adults. Samanez-Larkin, Gibbs, Khanna, Nielsen, Carstensen, and Knutson (2007) observed neural activity in younger and older adults while they were anticipating monetary gain or loss and found no differences between age groups in gain processing. Interestingly, they found that older adults did not show activation during loss anticipation, suggesting that gain processing remains intact in advanced age, but loss processing is diminished. This is somewhat at odds with emotional attention capture literature which would predict that older adults show increased reward sensitivity as compared to younger adults. This suggests that emotional capture and reward capture may indeed be different.

In one of the few studies on aging and value-driven capture, Roper et al. (2014) replicated Anderson et al.'s (2011) findings using a sample of adolescents and adults. Their study showed much larger capture effects for adolescents than adults but also found that as age of adult increased, reward capture decreased. This finding seems to contradict those of Samanez-Larkin and colleagues (2007) and suggest that older adults may have decreased reward sensitivity in attentional capture. Importantly, Roper et al. did not examine loss-related capture, a limitation that cannot fully account for the discrepant findings in the literature. Taken together, the contradictory findings of these studies leave a gap in the literature and discrepant predictions for gain and loss capture.

The Present Study

The main motivation for the present study was to reconcile the stark differences in attention capture between older and younger adults with the value-driven attentional capture literature. Since transitioning into older adulthood is generally characterized with increased emotional positivity reflected by the deployment of attention to positive information (Mather & Carstensen, 2005), it is currently unknown whether value-driven attention operates similarly. While there has been some suggestion that susceptibility to reward capture decreases with age (Roper et al., 2014) and that older adults show less neural activation toward loss-associated stimuli (Samanez-Larkin et al., 2007), the role of aging in the value-driven capture paradigm has not been directly tested in older adulthood.

Another consideration for the study of value-driven capture is whether it is an artifact of monetary incentive. In Anderson and colleagues' (2011) study, participants were provided monetary feedback. However, drawing conclusions about value-driven phenomena based solely on monetary incentive may not tell the whole story. An example of this comes from Wang, Yu, and Zhou (2013) who replicated Anderson and colleagues' (2011) findings and provided point-based feedback that later led to monetary incentive. These results may suggest that non-monetary reward feedback may be just as powerful to capture attention.

The present study tested the effects of gain against loss association to see if they are processed differently in the value-driven capture paradigm. Additionally, we examined whether value-driven capture is an artifact of monetary incentive or if the same results could be achieved through awarding non-monetary rewards (in the form of points) to participants. Finally, we examined whether there are age-related differences in value-driven capture. We hypothesized that A) loss-related stimuli would capture attention in younger but not older adults, B) older adults would show a bias for gain-associated capture and an insensitivity to loss-associated capture and C) non-monetary feedback would produce capture effects similar to monetary incentive.

Method

Participants

A total of 72 participants were in this study. Forty-eight were undergraduate students from Oregon State University. Their mean age was 21 years (range: 18-29; 32 females and 16 males). Twenty-four of them received extra course credit for their 2-hour participation (Younger–extra credit group) whereas the remaining 24 participants received $20 for their participation (Younger–monetary payment group). The remaining 24 were older adults recruited from the Corvallis community. Their average age was 70 years (range 60-80; 14 females and 10 males). They received $20 for their participation (Older–monetary payment group). Half of the participants in each group randomly assigned to the red-gain, green-loss condition and the other half to the green-gain, red-loss condition. All participants received the training phase followed by the test phase. All reported having normal or corrected-to-normal acuity. They also demonstrated normal color vision using the Ishihara Test for color deficiency.

Apparatus and Stimuli

Stimuli were presented on IBM-compatible micro-computers equipped with E-Prime software. The viewing distance was approximately 55 cm. During the training phase, three visual displays were presented in succession within each trial (see Figure 1, Panel A). The fixation display consisted of a centrally located white cross (0.94° width × 0.94° length) against a black background. The target display consisted of the fixation cross surrounded by six circles placed at an imaginary circle with a 5.61° radius (one circle on the top and the bottom, and two circles on each hemifield). Each circle was equidistant from the center cross and from adjacent circle (4.37°, center to center). Each circle was 2.50° in diameter, drawn with thin (0.21°) lines that were colored differently in either cyan (CIE [Yxy]: 23.62, 0.27, 0.15), orange (CIE [Yxy]: 22.38, 0.55, .40), green (CIE [Yxy]: 24.45, 0.30, 0.60), yellow (CIE [Yxy]: 22.90, 0.43, 0.50), blue (CIE [Yxy]: 25.00, 0.18, 0.17), red (CIE [Yxy]: 23.56, .62, .34), or pink (CIE [Yxy]: 23.23, .34, 0.18). Those colors were equal in luminance. The targets were defined as a red or green circle, with the restriction that the red and green circles never appeared in the same trial. Each circle (both target and nontarget) contained a line segment (1.35° in length and 0.21° thick) that was either oriented vertically or horizontally, randomly determined. The visual feedback display consisted of the target display except that the fixation cross was replaced with the gain or loss points earned on the current trial, as well as the total points accumulated thus far.

During the test phase, three visual displays were presented in succession within each trial (see Figure 1, Panel B). The fixation display consisted of a white cross surrounded by six white circles placed at an imaginary circle. The target display consisted of the fixation display, except that one of circles was replaced with a diamond (1.87° × 1.87°) drawn with white thin (0.21°) lines, which served as the target. Thus, the target was always a shape singleton. Inside the target diamond, a line segment (1.35° in length and 0.21° thick) was oriented vertically or horizontally.

Inside each circle, however, a line segment was tilted at 45 º to the left or right, randomly determined. For 75% of the trials, one of the circles was colored previously gain-associated color (e.g., red), previously loss-associated color (e.g., green), or neutral color (e.g., blue) equally distributed (25% for each of three color-singleton distractor types). For the remaining 25% of the trials, there was no color distractor. The color singleton distractor and the target diamond always appeared in one of the four peripheral locations (left and right hemifields), with the restriction that they were always located in opposite hemifields. The feedback display consisted of the fixation display with an auditory tone (200 Hz, 100 ms) followed incorrect responses on the current trial but silence (100 ms) followed correct responses.

Design and Procedure

Training Phase. As shown in Panel A of Figure 1, each trial began with the presentation of the fixation display for 400, 500, or 600 ms, randomly determined. The target display then appeared and remained on the screen until a response. Participants searched for the red or green circle and determined the orientation of the line segment inside the target circle. They were instructed to press the "C" key with their left-index finger for the vertical line and the "B" key with their right-index finger for the horizontal line. Auditory spoken feedback ("Correct" vs. "Incorrect") for 500 ms was given immediately after the response. The visual feedback display on gain/loss points then appeared for 2,000 ms, followed by a blank screen for 500 ms before the next trial began.

Two different gain vs. loss schedules were used. For half of the participants, the red target color was associated with gain (5 points for correct response [high gain] and 1 point for incorrect response [low gain]) and the green target color was associated with loss (-1 point for correct response [low loss] and -5 points for incorrect response [high loss]). For the other half of the participants, the assignment of the target colors to the gain vs. loss was reversed (i.e., green for gain and red for loss).

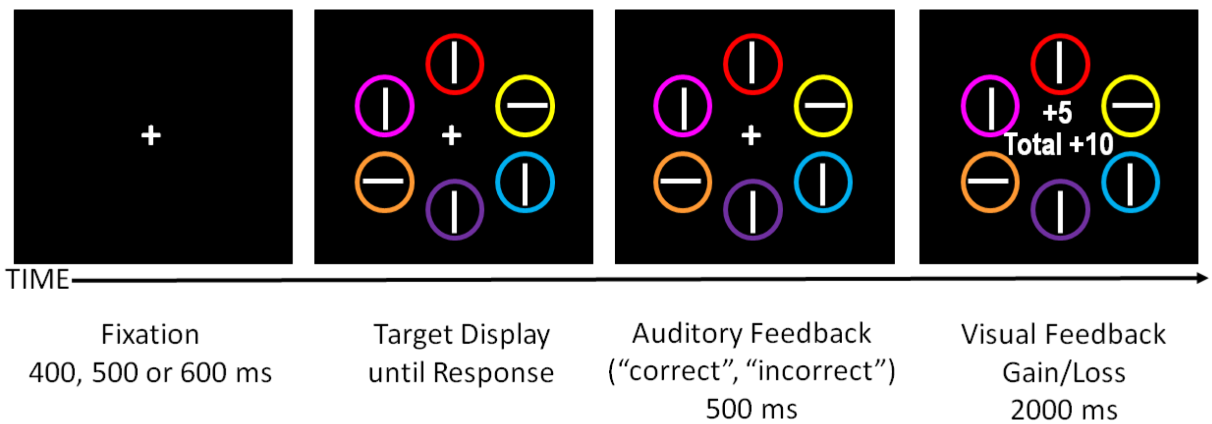
Participants first performed one practice blocks of 24 trials, followed by 9 experimental blocks of 104 trials each. After each block, they were encouraged to take a short break. The next block began only when participants pressed a key to continue. They were asked to respond quickly and accurately. They were also asked to write down the response time and accuracy on the report sheet at the end of each block, as well as the total points earned at the end of the training phase.

Test Phase. As shown in Panel B of Figure 1, each trial began with the presentation of the fixation display for 1,000 to 1,200 ms, randomly determined with a uniform distribution. The target display then appeared for 1,500 ms and was replaced with the fixation display until participants made a response. Participants searched for the target diamond (the shape singleton) and determined the orientation of the line segment inside the diamond. As in the training phase, they were instructed to press the "C" key with their left-index finger for the vertical line and the "B" key with their right-index finger for the horizontal line. An auditory tone feedback for 100 ms was given immediately after an incorrect response or salience after a correct response. The next trial began with the fixation display. There were four types of distractors possible in the test phase: Gain (green or red based on condition), loss (green or red), neutral (a color distractor not associated with gain or loss), and no distractor (no color distractor was present). These distractor types are shown in Figure 2.

All participants received the training phase followed by the test phase within a single 2-hour lab visit. At the end of the experiment, participants were debriefed and given different compensations for their participations. For the younger–extra credit group, participants received course extra credit, whereas for both younger– and older– monetary payment groups, they received $20.

Fig 1.

A) Training phase event sequence



B) Test phase event sequence

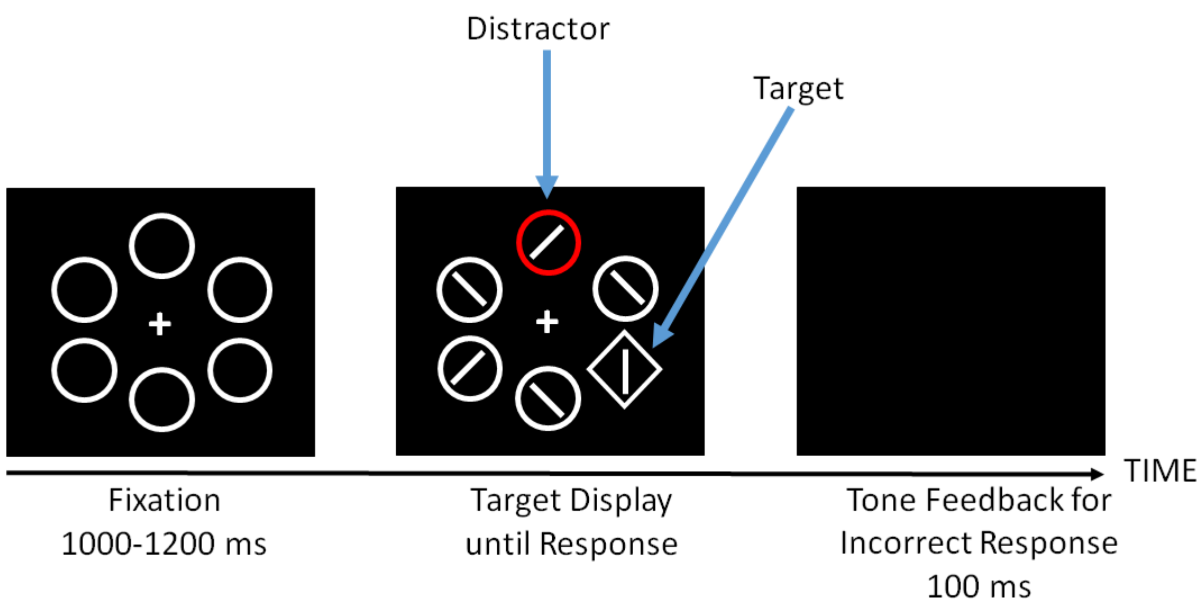
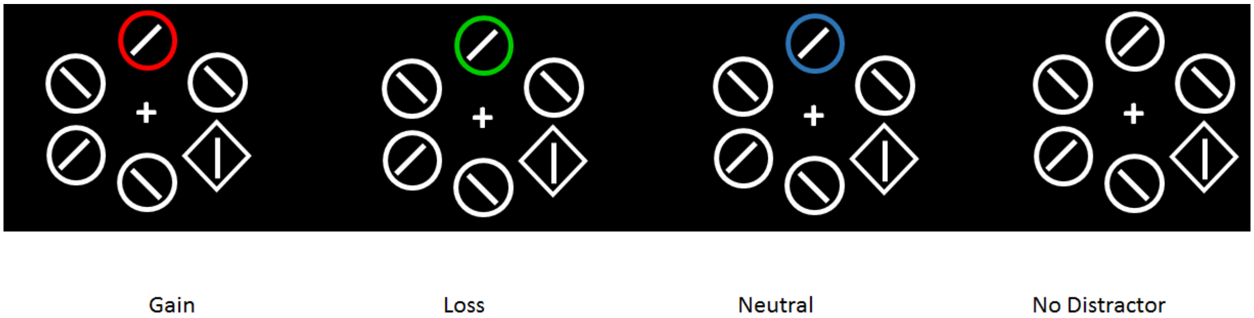


Fig. 2. Types of distractors present in the test phase



Results

Although our main focus was the capture effect in the test phase, we also analyzed data from the training phase to validate learning outcome. Trials in both phases were excluded from analysis if RT was less than 100 ms or greater than 2,000 ms. An analysis of variance (ANOVA) was conducted on RT and proportions of error (PE) with an alpha level of .05 being set for determining statistical significance. Whenever appropriate, *p* values were adjusted using the Greenhouse-Geisser epsilon correction for nonsphericity. Reported confidence intervals were based on a 95% confidence interval, shown as the mean ± the confidence interval half-width.

Training Phase.

RT. Application of the RT cutoffs eliminated 5% of trials. Data were analyzed as a function of group (younger paid, younger extra credit, and older paid), color (red-gain versus green gain), trial type (gain or loss association), and session (Blocks 2-5 vs. Blocks 6-10). The first two variables were between-subject variables, whereas the latter two were within-subject variables. Table 1 shows the mean RT for each of these conditions.

The RT data revealed significant main effects for session with RT decreasing from the first half (1019 ms) to the second half (891 ms), $F(1, 68) = 179.87$, $p<.001$, $\eta^2_p = 0.27$, trial type (gain RT = 938 ms, loss = 972 ms), $F(1, 68) = 7.25$, $p<0.01$, $\eta^2_p = 0.10$, and group (younger paid RT = 847 ms, younger extra credit RT = 799 ms, older paid RT = 1219 ms), $F(2, 68) = 48.70$, $p<.0001$, $\eta^2_p = 0.58$, but not for color (red-gain group RT = 949 ms, green-gain group = 961 ms), $F(1, 68) = 0.10$, $p = 0.75$, $\eta^2_p = 0.00$. There was also a significant interaction of session on trial type, $F(1, 68) = 6.28$, $p=0.0146$, $\eta^2_p = 0.04$, where RT declined more sharply on gain trials than loss trials respectively. No other effect was significant.

PE. Table 2 shows the mean proportion of error for each condition. The PE data for the training phase revealed significant main effects for group, $F(2, 68) = 6.48$, $p<.001$, $\eta^2_p = 0.02$, and session, $F(1, 68) = 24.80$, $p<.001$, $\eta^2_p = 0.27$ but not for color, $F(1, 68) = 0.59$, $p=0.44$, $\eta^2_p = 0.01$, or trial type, $F(1, 68) = 2.95$, $p=0.91$, $\eta^2_p = 0.01$. There was no significant interaction of trial type on color, $F(2, 68) = 4.16$, $p=0.45$, $\eta^2_p = 0.06$. No other effect was significant.

Test Phase.

RT. Application of the RT cutoffs eliminated 0.48% of trials. Data were analyzed as a function of group (younger paid, younger extra credit, and older paid; a between-subject variable), color (red-gain versus green gain; a between-subject variable), and distractor type (gain, loss, neutral, or no distractor). Figure 3 shows overall mean RT for each distractor type in the test phase.

ANOVA analyses revealed significant differences between distractor conditions (gain, loss, neutral, no distractor), $F(3, 204) = 27.78$, $p<.001$, $\eta^2_p = 0.29$, as well as group, $F(2, 68) = 74.95$, $p<.001$, $\eta^2_p = 0.69$. No other effect was significant.

Pairwise comparisons revealed significant differences between no distractor and neutral distractor, $F(1, 23) = 14.10$, $p<.001$, $\eta^2_p = 0.17$, no distractor and loss distractor, $F(1, 23) = 19.61$, $p<.001$, $\eta^2_p = 0.46$, and no distractor and gain distractor, $F(1,23) = 32.14$, $p<.001$, $\eta^2_p = 0.58$. There were also significant differences between neutral and gain distractor, $F(1,23) = 13.18$, $p<.001$, $\eta^2_p = 0.36$, and neutral and loss distractors, $F(1,23) = 4.41$, $p<.05$, $\eta^2_p = 0.16$. Importantly, there was no significant difference between gain and loss distractor, $F(1,23) = 2.92$, $p=0.10$. The effect of distractor types did not appear to vary by payment group (young paid and young extra credit) or by age group (younger versus older). See Table 3 for mean RT as a function of group and distractor type.

PE. For the PE data there was also a significant main effect of group, $F(2,68) = 10.65$, *p*<.001, η^2_p =.23, but not for color, *F*(1,68) = 0.13, *p*=.72, η^2_p =.00, or distractor type, *F*(3,204) = 1.37, *p*=.25, η^2_p =.02. Pairwise comparisons revealed that the younger adults who were paid had a significantly higher proportion of error (.07) than younger adults who received extra credit (.03), or older adults (.03). There were no other significant differences. See Table 4 for mean PE as a function of group and distractor type.

Table 1. Mean Training Phase Response Time by Trial Type, Group, and Session

	First Half of Training		
	Younger – E.C.	Younger – Paid	Older
Gain	894 (28)	845 (27)	1284 (40)
Loss	907 (29)	870 (45)	1312 (45)
	Second Half of Training		
	Younger – E.C.	Younger – Paid	Older
Gain	777 (27)	720 (26)	1106 (38)
Loss	809 (29)	762 (34)	1172 (43)

Note: The standard error of the mean is shown in parentheses.

Table 2. Mean Training Phase Proportion of Error by Trial Type, Group, and Session

	Younger – E.C.	First Half of Training Younger – Paid	Older
Gain	.05 (.01)	.06 (.01)	.02 (.01)
Loss	.03(.01)	.06 (.01)	.02 (.00)
	Younger – E.C.	**Second Half of Training Younger – Paid**	**Older**
Gain	.02 (.01)	.04 (.01)	.01 (.00)
Loss	.02 (.00)	.04 (.01)	.01 (.01)

Note: The standard error of the mean is shown in parentheses.

Table 3. Mean Test Phase Response Time (in ms) by Distractor Type and Group.

	Younger – E.C.	Younger – Paid	Older – Paid
Gain Dist	644.83 (20)	589.29 (15)	926.42 (27)
Loss Dist	636.50 (19)	590.54 (15)	933.46 (30)
Neutr Dist	627.13 (18	580.88 (14)	906.42 (27)
No Dist	615.37 (17)	571.92 (14)	893.63 (27)

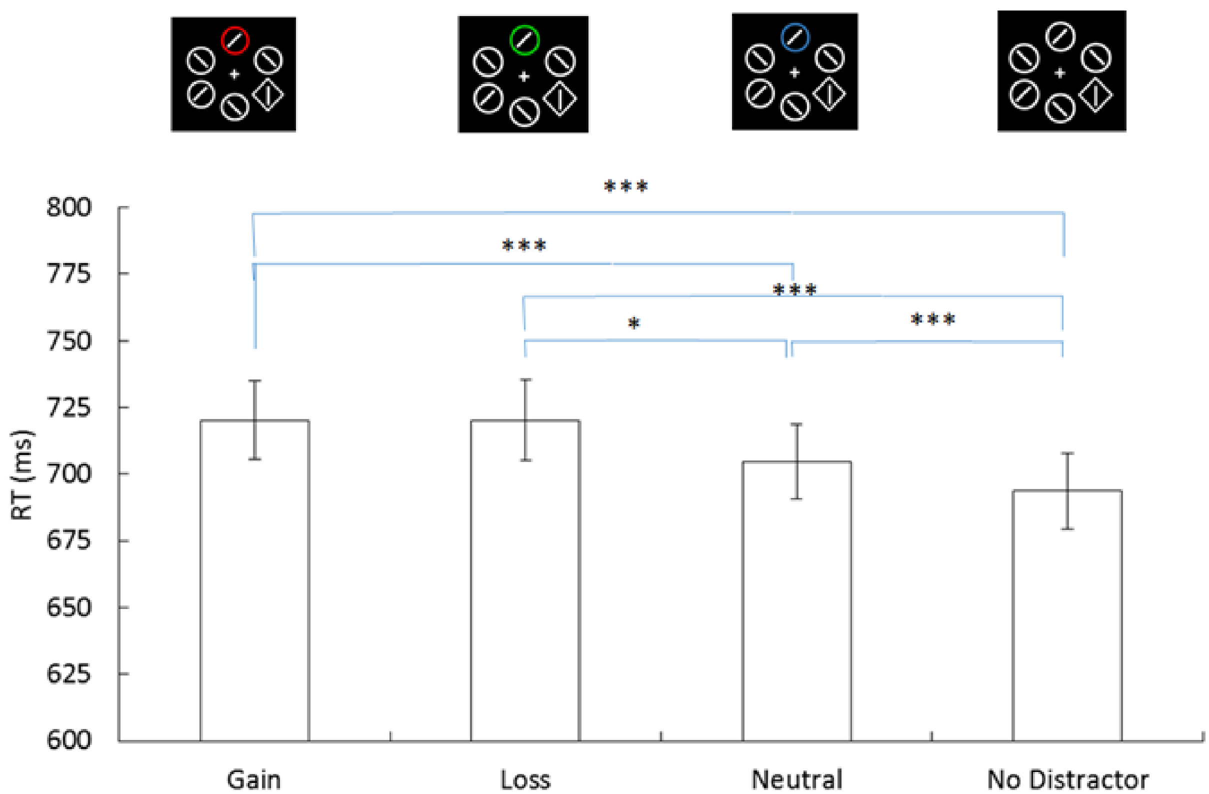
Note: The standard error of the mean is shown in parentheses. “E.C.” refers to extra credit compensation. “Dist” refers to distractor type.

Table 4. Mean Test Phase Proportion of Error by Distractor Type and Group

	Younger – E.C.	Younger – Paid	Older
Gain Dist.	.04 (0.01)	.07 (0.01)	.04 (0.01)
Loss Dist.	.04 (0.01)	.07 (0.01)	.03 (0.01)
Neutral Dist.	.04 (0.01)	.07 (0.01)	.03 (0.01)
No Dist.	.04 (0.01)	.08 (0.01)	.03 (0.01)

Note: The standard error of the mean is shown in parentheses. “E.C.” refers to extra credit payment. “Dist” refers to distractor.

Fig. 3. Mean Response Time Overall for Each Distractor Type. In the example below, red was the gain-associated color, green was the loss-associated color, and blue was the neutral color. * *p*<.05; ** *p*<.01; *** *p*<.001.



Discussion

The present study examined age-related differences in attentional capture by gain and loss associated stimuli. We modified Anderson and colleagues' (2011) value-driven attentional capture paradigm to include loss-associated stimuli and recruited three groups of participants: older adults, younger adults who were paid, and younger adults who were given extra course credit. Our results indicated that there were no significant differences between younger adults who were paid and younger adults who received extra credit in capture by gain, loss, or neutral stimuli. This suggests that course credit is sufficient to produce value-driven capture effects. Additionally, older adults were no more susceptible to value-driven attentional capture than younger adults, suggesting that value-driven capture does not change with age.

While some research has suggested that older adults may be less able to inhibit irrelevant information (Hasher, Lustig, & Zacks, 2007; Kane, Hasher, Stolzfus, Zacks, & Connelly, 1994) and that this may lead to increased attentional capture by salient but irrelevant information (Juola, Koshino, Warner, McMickell, & Peterson, 2000; Pratt & Bellomo, 1999), the current results are in line with other research finding showing no age-related differences in attentional capture (Lien, Ruthruff, & Gemperle, 2011). Additionally, our results indicated that there were no age differences in capture regardless of distractor type. This is an interesting finding since previous research has found age-related differences in emotional attention (Isaacowitz, Wadlinger, Goren & Wilson, 2006; Mather & Carstensen, 2005) and gain and loss processing (Marschner, Mell, Wartenburger, Villringer, Reischies, & Heekeren, 2005; Samanez-Larkin et al., 2007). While we would expect that older adults show a bias toward rewarding stimuli and an insensitivity to loss, we instead found that gain and loss stimuli captured older adult's attention to the same extent. Further, value-associated stimuli captured attention to a greater magnitude than neutral distractors, suggesting an attentional bias toward value-based stimuli over purely salient distractors. These results are at odds with Samanez-Larkin and colleague's (2007) notion of an insensitivity to loss in older adulthood. One possible explanation is that they used a monetary anticipation task and examined neural activity prior to receiving a reward, whereas we assessed gain and loss processing in-situ. It is possible that older adults show less anticipatory neural activity prior to viewing reward-associated stimuli but that this activation does not impact the degree to which attention is allocated to that stimuli. This explanation is purely speculative, however, and future research will be needed to test this notion. Additionally, our study indicates that older adults may show a stronger attentional bias toward emotionally positive information as compared to younger adults but that value-driven attentional capture is unaffected in normal healthy aging.

Another interesting result from the present study is that, regardless of age and payment method group, gain-associated stimuli and loss-associated stimuli captured attention to the same degree and these capture effects were larger than neutral distractors or no distractors. This suggests that value-driven capture effects may be based on a simple assessment of stimulus value and not due to a reward bias. It is possible that simply having a value association with a stimulus, regardless of whether it is gain or loss, it can cause attentional capture. This association clearly must be value-driven, not salience-driven, since the neutral distractor also appeared in the training display but had no apparent value assigned to it. Thus, the present study not only replicates Anderson and colleagues' (2011) finding of capture by gain-associated stimuli but also extends their finding to loss-associated stimuli.

Finally, we found that value-driven attentional capture is not limited to monetary incentive. While all other previous studies on value-driven attentional capture have paid participants for responses in order to form value associations, we found that arbitrary points were equally as effective in making value associations. Interestingly, younger adults who were compensated $20 were overall faster to respond, but they showed similar capture effects to the group who received course credit. This suggests that payment may increase overall motivation to perform, but does not affect attentional capture.

Relations to other aging studies

Some previous research has suggested that older adults are less able to filter out irrelevant information and thus are more susceptible to attentional capture by irrelevant stimuli (Juola, Koshino, Warner, McMickell, & Peterson, 2000; Pratt & Bellomo, 1999). This has been interpreted as a general age deficit in inhibitory mechanisms (Hasher, Lustig, & Zacks, 2007) where older adults are less able to inhibit distractors. Recently, however, Lien et al. (2011) found no age-related differences in attention capture by irrelevant distractors and have suggested that active inhibition of irrelevant distractors is not always necessary in spatial attention capture tasks. They argue that control over top-down attention is preserved in older adults and that declines in performance with age may be explained by other factors such as generalized slowing of cognitive processes (Salthouse & Madden, 2008), fluid intelligence (Rabbitt & Anderson, 2006) or context processing (Braver & Barch, 2002).

While some research has suggested that older adults may show an insensitivity to loss and this may explain attentional biases in emotional attention (Samanez-Larkin et al., 2007) our results indicated that older adults showed equivalent capture effects to younger adults regardless of the type of value association (gain or loss). Samanez-Larkin and colleagues, however only examined neural activity while participants anticipated monetary gain or loss and did not examine in-situ attentional processes. Our results also complement the work of Roper and colleagues (2014) who found increased value-driven attentional capture in adolescents as compared with younger adults. While they hypothesized that value-driven capture decreases with age, our results are inconsistent with this claim. One possibility is that value-driven capture decreases as individual's transition into young adulthood and then levels off into late life. Further longitudinal research is needed to clarify this relationship, however.

Finally, these results help extend research on the value-driven attentional capture phenomenon by demonstrating that the presence vs. absence of monetary incentives does not alter capture effects. The payment group showed an overall decrease in response time compared to the extra credit group, but these groups showed equivalent capture effects. Importantly all groups showed similar patterns of capture by gain- and loss-associated stimuli. This is consistent with work done by Wentura, Müller, and Rothermund (2014) who found equivalent capture by gain and loss distractors, suggesting that simply associating a stimulus with an arbitrary value may cause attention to be captured by it later.

Top-Down Facilitation?

One possibility for why we did not observe age-related differences in attentional capture is that our task did not require older adults to specifically inhibit the distracting information. It is possible that older adults were able to utilize their preserved top-down attentional control to facilitate search for the diamond target and that this better enabled them to avoid greater distraction. However, the observed difference between gain and loss capture and neutral capture suggests that participants had a harder time suppressing the gain and loss distractors. Another likely possibility is that some inhibition was still required to perform the task but the ability to utilize top-down control processes lessened the burden of inhibition because participants could use the aforementioned strategy of searching for the shape singleton. While speculative, this explanation could be tested in future research by removing the shape singleton target which would eliminate the ability to use top-down control settings to find the target and may then exacerbate bottom-up capture due to inhibitory deficits.

Our results are also in line with previous research arguing for a generalized slowing of cognitive processes in older adulthood (Salthouse, 1996; 2000) where older adults are slower to perform tasks or react as quickly as younger adults. Within the generalized slowing framework, one would expect that older adults may show declines in attentional capture simply because it is generally measured in terms of response time. While it is true that older adults in our sample did perform the task overall more slowly than younger adults, our results do not seem to indicate that there are any differences between older and younger adults on value-driven attentional capture. Salthouse (2012) suggested that, while fluid cognition may decline in advanced age (e.g., processing speed, novel reasoning, etc.) older adults are likely to adopt a compensatory strategy where they rely more on crystallized abilities to guide them. This notion seems to suggest that much of older adult's mental processes and behaviors are based on past experiences. If this is the case then the top-down attentional control that is preserved in older adulthood can be utilized to compensate for any lack of inhibitory processes.

Implicit Learning and Aging

Results from the training phase indicated that participants sufficiently associated one color with gain and one color with loss. We did not expect there would be age-related differences in performance on this task, since implicit learning (Rieckmann & Backman, 2009) and implicit memory (Gopie, Craik, & Hasher, 2011) are often preserved in older adulthood. Some studies have also suggested that older adults perform better on tasks that rely on implicit processes as compared to more effortful and explicit tasks (Campbell, Hasher, & Thomas, 2010; Kim, Hasher, & Zacks, 2007). For example, Biss, Ngo, Hasher, Campbell, and Rowe (2013) had older and younger adults do a simple one-back memory task for pictures, requiring them to judge whether the present image was the same or different from the previous image. Superimposed on these images were words that served as irrelevant distractors that participants were told to ignore. After the one-back task, older and younger adults performed a memory test for the superimposed words. Interestingly, older adults remembered significantly more words than younger adults, suggesting better implicit memory in older adulthood. This is consistent with Lien and colleagues' (2011) assertion that age-related difference may occur in effortful inhibitory processes, but not in attentional capture tasks that do not require active inhibition of distractors.

In the present study, it is possible that the implicit nature of the value-associations could partially explain why we did not observe age differences in attentional capture. If older adults generally do better on these more implicit association tasks, then this could compensate for any age effects that would manifest in more explicit tasks. Rieckmann and Bachman (2009), for instance, argued that neural restructuring may occur in older adulthood as a means to compensate for any losses in implicit learning processes. This restructuring may be an adaptive way to combat stereotype threat, where older adults suffer from performance deficits on some cognitive tasks simply because of beliefs about cognitive aging stereotypes (Barber & Mather, 2013; Mazerolle, Régner, Morisset, Rigalleau, & Huguet, 2012). If this is the case, then implicit learning and implicit memory may play a larger role in older adulthood than once thought, potentially guiding what information is attended to, as our study suggests that implicit value associations may guide attentional processes.

Implications for Cognitive Aging

The finding that older adults were no more susceptible to value-driven attentional capture has many implications for the study of cognitive aging. First, since the majority of studies examining attentional capture and aging have been based on top-down/bottom-up theories, it is necessary to examine age-related differences outside of this dichotomy which has recently been criticized by Awh et al. (2012) and Anderson et al. (2011) who demonstrated attentional capture that could not be currently explained by top-down/bottom up theories. While the present study opts for more internal validity in order to be experimentally rigorous, further work on this topic will need to opt for more external validity by focusing on the importance of attention in older adulthood. Of course there are obvious implications for attention-demanding tasks such as driving. Another possible avenue of future research is the effective design of displays that all users can easily use. In jobs where small cognitive errors have large consequences, such as aviation, future research on attention and cognitive aging can help inform display design. Additionally, in such professions where experience and cognition are highly valued, comprehensive study of attention and aging is necessary. For example, the profession of air traffic control has mandatory retirement policies which require them to retire by age 56 (Heil, 1999). This policy is informed by previous studies on age-related declines in performance on measures of attention and other general cognitive performance. However, some studies have suggested that experienced air traffic controllers may show deficits on laboratory-assessed measures of cognitive ability that are unlike their daily job performance but not on tasks that resemble air traffic control tasks (Nunes & Kramer, 2009). In sum, future research is needed to examine both basic and applied aspects of attention and cognitive aging.

Conclusion

The present study examined attentional capture by gain- and loss-associated stimuli within the context of cognitive aging. We recruited three groups of participants to test for the effects of monetary incentive versus non-monetary incentive on value-driven attentional capture, as well as a cross-sectional design to infer if value-driven attentional capture changes with age. Our results indicated that value-driven attentional capture can occur with non-monetary incentive and arbitrary point-based feedback. Additionally we found no age-related differences in value-driven attentional capture regardless of stimulus type (gain versus loss). We conclude that value-driven attentional capture is a phenomenon that is truly based on stimulus value associations regardless of whether the value is positive or negative or if the participants are paid or not. These results also suggest that there is preserved attentional control in advanced age, consistent with the results of Lien et al. (2011) and that older adults are no more susceptible to value-based attentional biases than younger adults.

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