Effects of Emotion and Age on Cognitive Control in a Stroop Task

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Abstract

Research indicates that cognitive control is affected by aging and by emotion. However, no studies have addressed whether performance in an emotional Stroop task varies in older relative to younger adults. We examined the effect of aging in a classic Stroop color-naming task (Experiment 1) and in an emotional Stroop task using faces (Experiment 2). Results suggest that aging is associated with changes in cognitive control but that older adults benefit more than younger adults from positive information in an emotional Stroop paradigm.

Keywords: cognitive control; emotion; aging; Stroop task

Background and Motivation

The ability to exert cognitive control in the presence of task-irrelevant information is crucial for adaptive cognitive functioning in everyday life and has been studied extensively in experimental research. A commonly used task to examine cognitive control is the classic Stroop color-naming paradigm (Stroop, 1935). In this task, color words are printed in congruent or incongruent ink (e.g., "red" printed in red vs green ink) and participants have to name the color of the ink while ignoring the color word. While congruent items require the same response for both word reading and color naming, word reading interferes with the correct color-naming response for incongruent trials. Thus, incongruent trials are typically associated with slower, less accurate responses than congruent trials (MacLeod, 1991).

Although the exact mechanisms that enable cognitive control are still debated, there is reason to believe that cognitive control is not a unitary process. According to the dual mechanisms of control (DMC) theory (Braver, Gray, & Burgess, 2007), cognitive control operates in two distinct control modes, 'proactive control' and 'reactive control'. In their theory, Braver et al. conceptualize proactive control as an actively sustained control mode, which is initiated before the occurrence of conflict. Thus, proactive control is thought to bias attention and action systems in a goal-directed way. In contrast, reactive control is activated by the occurrence of conflicting events and thus, is only mobilized when needed. As both control modes are thought to be associated with advantages and limitations (e.g., resource-demanding but fast mode of proactive control vs. parsimonious but slow mode of reactive control), it is suggested that both systems are needed for successful cognitive performance.

The Stroop task has also been used to induce shifts in control modes. For instance, increasing the amount of congruent and incongruent trials relative to 'neutral' trials (non-words such as XXXX printed in different ink colors) is thought to facilitate a shift to proactive control due to high expectancy of conflict (e.g., Entel, Tzelgov, Bereby-Meyer, & Shahar, 2014). In contrast, reducing the amount of congruent and incongruent trials relative to neutral trials is thought to facilitate a shift away from proactive to reactive control due to low expectancy of conflict. Similarly, trial-by-trial changes in control modes can be introduced in cuing paradigms (e.g., Goldfarb & Henik, 2013). Incongruent trials that are cued are thought to induce shifts to proactive control in contrast to non-cued items. Studies using the Stroop task to test cognitive control usually report longer RTs for congruent than neutral trials (reversed facilitation) and relatively increased RTs for incongruent compared to neutral trials (interference) when proactive control is low (e.g., Goldfarb & Henik, 2007).

Despite a large body of research examining cognitive control, studies investigating the effect of aging on different control modes are relatively sparse to date. In studies using the AX-CPT task, which requires participants to maintain goal-related information and to make target responses on cued trials and non-target responses on all other trials, older adults were found to show significantly impaired goal maintenance relative to younger adults (e.g., Haarmann, Ashling, Davelaar, & Usher, 2005). These results are usually interpreted as evidence for a reduction in proactive control among older adults. However, such results have not been replicated in other experiments (e.g., Paxton, Barch, Racine, & Braver, 2008, Exp. 2) suggesting that age-related changes in proactive control are still poorly understood. Reactive control seems relatively preserved in aging (Braver, 2012), but brain-imaging data suggest that reactive control is associated with an increase in transient activation in older relative to younger adults (Paxton et al., 2008). This pattern of results was interpreted as evidence that older adults might perform similar to younger adults by resorting to compensatory mechanisms. However, more research is needed to understand age-related changes in control modes. As the results reported above have been found using the AX-CPT paradigm, other tasks may help to shed light on age-related changes in cognitive control.

The Stroop task has also been adapted to investigate the effects of emotion on cognitive control, often in the context of anxiety or mood disorders. For instance, negative words (e.g., 'death' printed in red) vs neutral words (e.g., 'desk' printed in red) have been used to investigate interference caused by emotional content. Generally, participants were found to be slower in naming the color of emotional relative to neutral words (Williams, Mathews, & MacLeod, 1996). A common interpretation is that the affective nature of the emotional words interferes with color-naming by capturing attentional resources (Williams et al., 1996). Similar results were observed for studies using pictures or faces as emotional stimuli (Kindt & Brosschot, 1997). Although some findings suggest that this effect is restricted to negative items (McKenna & Sharma, 1995), other studies have shown that both positive and negative pictures interfered stronger with color-naming than neutral pictures as evidenced in longer RTs (Constantine, McNally, & Hornig, 2001). In a more recent study, Krug and Carter (2012) reported higher interference by irrelevant emotional relative to irrelevant neutral information in a Stroop task. This effect was marginally more pronounced under low than under high expectancy conditions and thus, when proactive control was low. However, as in previous studies emotional information was task-irrelevant, it is less clear how task-relevant emotion would affect performance in a Stroop task. As suggested by the dual-competition model (DCM; Pessoa, 2009), emotion can improve cognitive performance through enhanced target processing. Thus, it is possible that in a Stroop paradigm, the processing of target emotional information can be more resilient against distraction.

More importantly, no previous study has investigated how aging affects cognitive control in an emotional Stroop task. It is important to consider age-related changes when investigating the interaction between emotion and cognitive control, as aging is associated with preserved or even improved emotional functioning (Charles & Carstensen, 2010). Older adults seem to place greater importance on emotional information compared to younger adults (Fung & Carstensen, 2003). It was argued that an increased striving for emotional well-being might underlie age-related changes in emotional functioning. For instance, socioemotional selectivity theory (SST; Carstensen, 1993) suggests that perceiving time as limited promotes a prioritization of emotional well-being. Consequently, older adults are thought to focus more on emotional and particularly on positive information, resulting in a 'positivity bias' in attention and episodic memory (for a review, see Reed & Carstensen, 2012). For instance, it was found that older adults showed gaze preferences towards positive and away from negative stimuli (e.g., Isaacowitz, Wadlinger, Goren, & Wilson, 2006) and that they remembered positive information better than negative information (Charles, Mather, & Carstensen, 2003).

Other studies from the domain of working memory (WM) have shown that older adults can benefit from task-relevant emotional rather than neutral information in cognitive tasks. For instance, Mammarella and colleagues (2013a; 2013b) found that older adults showed poorer performance than younger adults in an operation WM span task with neutral but not emotional words. In an n-back task with emotional information, older adults were even more accurate than younger adults when updating positive information (Mikels, Larkin, Reuter-Lorenz, & Carstensen, 2005).

Despite evidence of age-related changes in the effects of emotion on attention, episodic memory and WM, to date, no study has examined cognitive control of emotional material in older as compared to younger adults.

Present studies

We report results of two behavioral studies investigating proactive and reactive control in aging. The first experiment focused on neutral material in the classic Stroop color-naming paradigm. In the second experiment, we extended the task to include emotional material by using facial stimuli. Cognitive control was manipulated by varying the amount and thus, expectancy of congruent and incongruent trials relative to neutral trials as in the study of Tzelgov, Henik, and Berger (1992). High-expectancy (HE) blocks were thought to be associated with increased proactive control, whilst low-expectancy (LE) blocks were thought to be associated with reduced proactive control.

Based on previous research, we expected to find reduced cognitive control in older adults in Experiment 1. In Experiment 2, we expected that task-relevant emotion would facilitate Stroop performance and reduce age-related differences. It was an open question, whether task-relevant emotion would interact with expectancy of conflict.

Experiment 1

Methods

Subjects. Twenty younger (ages 20–40) and 20 older (ages 60–85) participated in the experiment. Younger adults were students at Birkbeck, University of London, and received either course credits or £7.50/hour for their participation. Older adults were high-functioning volunteers, who were recruited from the University of Third Age in London and were paid £7.50/hour. Participants were community-dwelling, pre-screened for psychiatric disorders and a history of neurological disorders and had normal or corrected-to-normal vision. Subjects were tested individually.

Stimuli. Three color words were used in this experiment: red, green, yellow. Congruent items were created by printing each of the color names in their own color (e.g., 'red' printed in red ink). Incongruent items were created by printing each of the color names in one of the two other colors (e.g., 'red' printed in green or yellow ink). Neutral items were created by printing a string of 'XXXX' in the three different colors. The stimuli were presented centrally on black background in 42-point Courier New font.

Procedure. After giving consent and completing a short visual acuity test, participants were instructed to perform the computerized Stroop task. The task consisted of two blocks, and the order of the blocks was counterbalanced across participants. In the HE block, 75% of the trials were either congruent or incongruent (37.5%, respectively), while 25%

of the trials were neutral. In the LE block, 25% of the trials were either congruent or incongruent (12,5%, respectively) and 75% of the trials were neutral. Each block consisted of 192 randomly ordered items and the task was preceded by a practice block of 24 items with an equal amount of congruent, incongruent and neutral items. Participants were instructed to indicate the color of the ink as quickly and accurately as possible by pressing one of three color-labeled buttons. Button presses initiated the next trials and the assignment of color labels to buttons was counterbalanced across participants. Median RTs for correct responses were analyzed as the main dependent variable in this experiment.

Results and Conclusions

Older adults were generally slower than younger adults, $F(1, 38) = 21.49$, $MSE = 15280$, $p < .001$. There was also a main effect of congruency, $F(2, 76) = 74.52$, $MSE = 10480$, $p < .001$, with significantly longer RTs for incongruent than congruent or neutral trials. No significant difference was observed between neutral and congruent trials across both conditions ($p = .880$). This main effect was qualified by a significant congruency × age interaction, $F(2, 76) = 8.83$, $MSE = 10480$, $p = .004$, as older adults showed a more pronounced RT difference between incongruent and congruent or neutral trials than younger adults.

Although there was no main effect of condition ($p = .178$), there was a significant condition × age interaction, $F(1, 38) = 8.47$, $MSE = 5091$, $p = .006$, as older adults were significantly slower under LE conditions than under HE conditions. No such effect was observed for younger adults. Both younger and older adults showed marginally significant reversed facilitation (RT-congruent vs RT-neutral) and significantly increased interference under LE to HE conditions, as revealed by a significant condition × congruency interaction, $F(2, 76) = 12.66$, $MSE = 1759$, $p < .001$. This interaction was qualified by a significant condition × congruency × age interaction, $F(2, 76) = 8.85$, $MSE = 1759$, $p < .001$. This interaction was driven by higher Stroop interference (RT-incongruent vs RT-neutral) in older adults, $t(19) = 7.01$, $p < .001$, relative to younger adults, $p < .001$, $t(19) = 3.96$, $p = .001$, in the LE condition (Figure 1). Age-related effects were present but less pronounced in the HE condition, where again higher interference was shown by older adults, $t(19) = 6.39$, $p < .001$, than by younger adults, $t(19) = 4.41$, $p < .001$.

This pattern of results suggests that similarly to young adults, older adults exhibited proactive control under HE conditions, as evidenced by facilitation and reduced interference in both age groups. Notwithstanding, aging was associated with changes in cognitive control as evidenced by an age-related increase in interference. Moreover, age-effects were more pronounced under LE conditions und thus, when proactive control was low. Incongruent trials caused disproportionately longer RTs relative to neutral trials in older than in younger adults. This indicates that Stroop-interference is affected by aging and interacts with available levels of control.

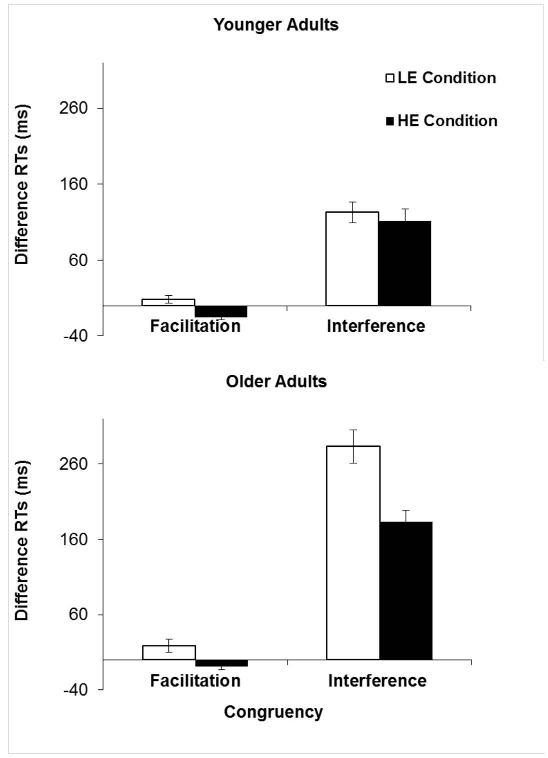

Figure 1: RT facilitation and interference in two age groups under low-expectancy (LE) and high-expectancy (HE) conditions. Error bars represent standard errors.

Experiment 2

Methods

Subjects. Twenty-four younger (ages 20–40) and 24 older (ages 60–85) participated in the experiment. Both younger and older adults were recruited from the same pool of volunteers as in Experiment 1 and met the same criteria. They were compensated in the same way and none of the subjects, who participated in Experiment 1, were included in Experiment 2. Subjects were tested individually.

Stimuli. Stimuli consisted of 36 images of faces from the FACES database (Ebner, Riediger, & Lindenberger, 2010), a validated set of photographs of naturalistic faces of different ages in front view. Faces showed angry, neutral or happy expressions (12 items per emotion). Faces were selected in a way that age group (young, middle-aged, older) and sex (male, female) of the face models were balanced equally in each emotion category. The faces had been rated in a preliminary evaluation study and were selected based on high agreement ratings between younger and older raters.

Angry, neutral and happy faces varied significantly in their valence and angry and happy faces were matched for arousal. Congruent items were created by printing matching emotion labels across the emotional faces (e.g., happy face with 'happy' label). Incongruent items were created by printing non-matching emotion labels across the faces (e.g., happy face with 'angry' label). Neutral items were created by printing a string of ‘XXXX’ across the faces. Face pictures were turned to grey-scale, whilst labels were printed in red, 38-point Courier New font, and placed between eyes and mouths of the faces. To facilitate label reading, labels appeared 100 ms before the face.

Procedure. After giving consent and completing a short visual acuity test, participants were instructed to perform the computerized emotional Stroop task. The task consisted of two blocks and the proportion of congruent, incongruent and neutral in the HE block and in the LE was identical as in Experiment 1. Each block consisted of 288 randomly ordered items and the task was preceded by a practice block of 24 items with an equal amount of congruent, incongruent and neutral items. Participants were instructed to indicate the emotion of the face irrespective of the label as quickly and accurately as possible by pressing one of three labeled buttons (‘A’ for angry, ‘N’ for neutral, and ‘H’ for happy). A button press initiated the next trial and the assignment of labels to buttons was counterbalanced across participants. Median RTs for correct responses were analyzed as the main dependent variable in this experiment.

Results and Conclusions

Older adults were generally slower than younger adults, $F(1, 46) = 20.03$, $MSE = 472052$, $p < .001$. A main effect of congruency, $F(2, 92) = 42.24$, $MSE = 21342$, $p < .001$, was observed as RTs were faster for congruent than neutral items and faster for neutral than for incongruent items. Both younger and older adults showed increased interference under LE relative to HE conditions, as evidenced by a significant condition × congruency interaction, $F(2, 92) = 4.73$, $MSE = 6897$, $p = .019$. Facilitation was unaffected by condition. No further effects including the factor condition were observed. Emotion significantly affected RTs, $F(2, 92) = 21.17$, $MSE = 48104$, $p < .001$, as all participants were faster for happy than neutral or angry faces. No significant difference was found between angry and neutral faces ($p > .05$). However, this main effect was qualified by a significant emotion × age interaction, $F(2, 76) = 3.95$, $MSE = 48104$, $p = .04$. This interaction was driven by a more pronounced RT advantage for happy faces relative to neutral and angry faces in older as compared to younger adults (Figure 2).

These findings suggest that emotion modulated RTs irrespective of item congruency or expectancy of conflict. In the presence of emotional material, interference was increased under LE conditions relative to HE conditions in both younger and older adults, with no effects of conflict expectation observed for facilitation. Happy faces were associated with fastest RTs compared with neutral or angry faces in both age groups. However, it was found that this RT advantage for happy faces was more pronounced for older than for younger adults. These results suggest that older adults benefit from positive information as conveyed by smiling faces to a greater extent than younger adults do.

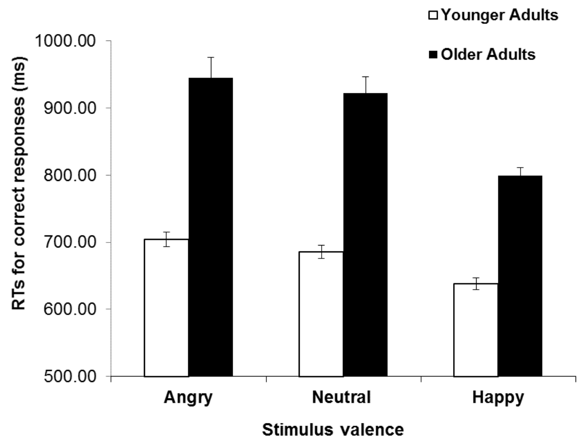

Figure 2: RTs for emotional stimuli in two age groups across items and conditions. Error bars represent standard errors.

General Discussion

The aim of the present research was to investigate how emotion and aging affect cognitive control in a Stroop task. Data from Experiment 1 show that older adults can deploy proactive control in the face of varying task demand. This was evidenced by facilitation and reduced interference in the HE relative to the LE block. However, cognitive control was found to be affected by aging in both conditions: Older adults showed increased interference from incongruent trials relative to younger adults. More pronounced age-related changes were observed when proactive control was low, as interference in older relative to younger adults was more increased under LE compared to HE conditions.

Data from Experiment 2 suggest that emotion affects performance in a Stroop task irrespective of expectancy manipulations and thus, task demands. It was found that both age groups were fastest when responding to happy faces rather than neutral or angry faces. However, this effect was more pronounced for older adults as they showed a higher speed advantage for happy faces than younger adults. This facilitating effect of task-relevant positive emotion was observed across congruent, incongruent and neutral items.

Both experiments shed light on age-related changes in cognitive control in the presence of neutral and emotional material. The findings add to the empirical evidence obtained in studies using the AX-CPT paradigm. Our results are compatible with studies showing impairments in goal maintenance in older adults, which were interpreted as an age-related reduction in proactive control (Haarmann et al., 2005). Under HE conditions, older adults showed increased interference from incongruent trials relative to younger adults. This might indicate that active maintenance of task goals was reduced in older adults, resulting in higher conflict experienced for incongruent stimuli. Moreover, our results extend previous findings by showing that word-reading interfered stronger with color naming in older than in younger adults when proactive control was low: older adults were disproportionately slower than younger adults when responding to incongruent relative to neutral items under LE conditions. Given the implication by the dual mechanisms of control (DMC) theory that a shift away from proactive control facilitates the use of reactive control (Braver et al., 2007), our results suggest that reactive control might also be affected by aging. Previous studies have shown that reactive control is largely preserved in older adults (Braver, 2012), but there is also evidence that older adults' reactive control is less efficient, as compensatory mechanisms might be recruited at neural levels (Paxton et al., 2008). Our results are in line with those pointing at less efficient reactive control in older relative to younger adults. Finally, the finding of increased interference in older adults is consistent with findings of reduced inhibition of irrelevant information with aging (e.g., Hasher, Stoltzfus, Zacks, & Rypma, 1991).

The results from Experiment 2 suggest that emotion affects Stroop performance irrespective of expectancy across all trial types. Both age groups were fastest when responding to happy faces, but this RT advantage was more pronounced in older than in younger adults. The speed-up in responses for happy faces is in line with research showing that happy expressions are processed quicker and more accurately relative to other facial expressions (Becker & Srinivasan, 2014). However, a purely perceptual account of our results would imply that older adults are faster or better in recognizing happy faces than younger adults, which is not supported by research (for a meta-analysis, see Ruffman, Henry, Livingstone, & Phillips, 2008). In contrast, a more pronounced RT advantage for happy faces in older relative to younger adults is more consistent with a conceptual view of emotional changes in aging and findings showing a 'positivity bias' in attention and memory in aging (Reed & Carstensen, 2012). It is possible that the emotion × age interaction in Experiment 2 was driven by motivational changes in aging, with older adults focusing more on positive information and thus, responding faster to happy faces relative to younger adults. However, as both age groups generally showed an RT advantage for happy faces, it is likely that perceptual and conceptual features of happy faces contributed to the observed results. Our stimuli do not allow disentangling these effects and future studies using different stimuli such as words or pictures are needed to investigate this question further.

It should be noted that Experiment 2 did not replicate the pattern of results obtained in Experiment 1, particularly with regards to differences in LE and HE conditions. Although increased interference was observed under LE conditions relative to HE conditions, no effect of condition was observed for facilitation. Methodological differences in task design may account for the different results observed. In Experiment 2, we used facial expressions with labels to create incongruent, congruent and neutral stimuli. A 100 ms label preview was also introduced before the face appeared.

These changes to the original Stroop task might have contributed to the discrepancy in results between the two experiments. Faces rather than words were used as they are ecologically valid emotional stimuli, whereas words convey emotional meaning in a symbolic way. A comparison of stimulus types indeed showed stronger effects of valence for pictorial stimuli than for words (Kensinger & Schacter, 2006). Also, it was suggested that even with word stimuli, emotional Stroop tasks differ from the Stroop color-naming task for a number of reasons (Algom, Chajut, & Lev, 2004). For instance, it was argued that the Stroop effect cannot be calculated in an emotional Stroop as no "true" consistency exists for non-color words printed in different colors. Thus, the inclusion of stimuli other than color words comes with major methodological changes, independently of stimulus type.

To conclude, our studies extend previous research by showing that age-related changes were more pronounced in a Stroop task when proactive control was low. Furthermore, it was shown that performance in an emotional Stroop task was affected by aging and by emotion. More specifically, older adults were disproportionately faster when responding to happy rather than angry or neutral faces compared to younger adults. Further research is needed to clarify whether this happy face advantage was driven by perceptual or conceptual features of the stimuli. By furthering our understanding of the effects of emotion on cognitive control in aging, such work can help identifying situations in which older adults' cognitive performance can be facilitated through emotion.

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References

Algom, D., Chajut, E., & Lev, S. (2004). A rational look at the emotional Stroop phenomenon: A generic slowdown, not a Stroop effect. *Journal of Experimental Psychology: General, 133*, 323-338. doi: 10.1037/0096-3445.133.3.323

Becker, D. V., & Srinivasan, N. (2014). The vividness of the happy face. *Current Directions in Psychological Science, 23*, 189-194. doi: 10.1177/0963721414533702

Braver, T. S. (2012). The variable nature of cognitive control: a dual mechanisms framework. *Trends in Cognitive Sciences, 16*, 106-113. doi: 10.1016/j.tics.2011.12.010

Braver, T. S., Gray, J. R., & Burgess, G. C. (2007). Explaining the many varieties of working memory variation: Dual mechanisms of cognitive control. In A. R. A. Conway, C. Jarrold & M. J. Kane (Eds.), *Variation in working memory* (pp. 76-106). New York, NY, US: Oxford University Press.

Carstensen, L. L. (1993). Motivation for social contact across the life span: A theory of socioemotional selectivity. In J. E. Jacobs (Ed.), *Nebraska Symposium on*

Motivation: Developmental perspectives on motivation (Vol. 40, pp. 209-254). Lincoln, NE: University of Nebraska Press.
Charles, S. T., & Carstensen, L. L. (2010). Social and emotional aging. *Annual Review of Psychology, 61*, 383-409. doi: 10.1146/annurev.psych.093008.100448
Charles, S. T., Mather, M., & Carstensen, L. L. (2003). Aging and emotional memory: The forgettable nature of negative images for older adults. *Journal of Experimental Psychology: General, 132*, 310-324. doi: 10.1037/0096-3445.132.2.310
Constantine, R., McNally, R. J., & Hornig, C. D. (2001). Snake fear and the pictorial emotional Stroop paradigm. *Cognitive Therapy and Research, 25*(6), 757-764. doi: 10.1023/A:1012923507617
Ebner, N. C., Riediger, M., & Lindenberger, U. (2010). FACES—A database of facial expressions in young, middle-aged, and older women and men: Development and validation. *Behavior Research Methods, 42*, 351-362. doi: 10.3758/BRM.42.1.351
Entel, O., Tzelgov, J., Bereby-Meyer, Y., & Shahar, N. (2014). Exploring relations between task conflict and informational conflict in the Stroop task. *Psychological Research*, 1-15. doi: 10.1007/s00426-014-0630-0
Fung, H. H., & Carstensen, L. L. (2003). Sending memorable messages to the old: Age differences in preferences and memory for advertisements. *Journal of Personality and Social Psychology, 85*, 163-178. doi: 10.1037/0022-3514.85.1.163
Goldfarb, L., & Henik, A. (2007). Evidence for task conflict in the Stroop effect. *Journal of Experimental Psychology: Human Perception and Performance, 33*, 1170-1176. doi: 10.1037/0096-1523.33.5.1170
Goldfarb, L., & Henik, A. (2013). The effect of a preceding cue on the conflict solving mechanism. *Experimental Psychology, 60*, 347-353. doi: 10.1027/1618-3169/a000205
Haarmann, H. J., Ashling, G. E., Davelaar, E. J., & Usher, M. (2005). Age-related declines in context maintenance and semantic short-term memory. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 58A*, 34-53. doi: 10.1080/02724980443000214
Hasher, L., Stoltzfus, E. R., Zacks, R. T., & Rypma, B. (1991). Age and inhibition. *Learning, Memory, and Cognition, 17*, 163-169. doi: 10.1037/0278-7393.17.1.163
Isaacowitz, D. M., Wadlinger, H. A., Goren, D., & Wilson, H. R. (2006). Selective preference in visual fixation away from negative images in old age? An eye-tracking study. *Psychology and Aging, 21*, 40-48. doi: 10.1037/0882-7974.21.1.40
Kensinger, E. A., & Schacter, D. L. (2006). Processing emotional pictures and words: Effects of valence and arousal. *Cognitive, Affective & Behavioral Neuroscience, 6*, 110-126. doi: 10.3758/CABN.6.2.110
Kindt, M., & Brosschot, J. F. (1997). Phobia-related cognitive bias for pictorial and linguistic stimuli. *Journal of Abnormal Psychology, 106*, 644-648. doi: 10.1037/0021-843X.106.4.644
Krug, M. K., & Carter, C. S. (2012). Proactive and reactive control during emotional interference and its relationship to trait anxiety. *Brain Research, 1481*, 13-36. doi: 10.1016/j.brainres.2012.08.045
MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109*, 163-203. doi: 10.1037/0033-2909.109.2.163
Mammarella, N., Borella, E., Carretti, B., Leonardi, G., & Fairfield, B. (2013). Examining an emotion enhancement effect in working memory: Evidence from age-related differences. *Neuropsychological rehabilitation, 23*, 416-428. doi: 10.1080/09602011.2013.775065
Mammarella, N., Fairfield, B., Di Domenico, A., Borella, E., & Carretti, B. (2013). Is working memory affective in dementia of Alzheimer's type? *Neuroscience Discovery, 70*, 1-4. doi: 10.7243/2052-6946-1-4
McKenna, F. P., & Sharma, D. (1995). Intrusive cognitions: An investigation of the emotional Stroop task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 1595-1607. doi: 10.1037/0278-7393.21.6.1595
Mikels, J. A., Larkin, G. R., Reuter-Lorenz, P. A., & Carstensen, L. L. (2005). Divergent trajectories in the aging mind: Changes in working memory for affective versus visual information with age. *Psychology and Aging, 20*, 542-553. doi: 10.1037/0882-7974.20.4.542
Paxton, J. L., Barch, D. M., Racine, C. A., & Braver, T. S. (2008). Cognitive control, goal maintenance, and prefrontal function in healthy aging. *Cerebral Cortex, 18*, 1010-1028. doi: 10.1093/cercor/bhm135
Pessoa, L. (2009). How do emotion and motivation direct executive control? *Trends in Cognitive Sciences, 13*(4), 160-166. doi: 10.1016/j.tics.2009.01.006
Reed, A. E., & Carstensen, L. L. (2012). The theory behind the age-related positivity effect. *Frontiers in Psychology*. doi: 10.3389/fpsyg.2012.00339
Ruffman, T., Henry, J. D., Livingstone, V., & Phillips, L. H. (2008). A meta-analytic review of emotion recognition and aging: Implications for neuropsychological models of aging. *Neuroscience & Biobehavioral Reviews, 32*, 863-881. doi: 10.1016/j.neubiorev.2008.01.001
Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643-662. doi: 10.1037/h0054651
Tzelgov, J., Henik, A., & Berger, J. (1992). Controlling Stroop effects by manipulating expectations for color words. *Memory & Cognition, 20*, 727-735. doi: 10.3758/BF03202722
Williams, J. M. G., Mathews, A., & MacLeod, C. M. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin, 120*, 3-24. doi: 10.1037/0033-2909.120.1.3