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Working Memory and the Strategic Control of Attention in Older and Younger Adults

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Objective. The objective of this study was to investigate the effects of aging on the strategic control of attention and the extent to which this relationship is mediated by working memory capacity (WMC). This study also sought to investigate boundary conditions wherein age differences in selectivity may occur.

Method. Across 2 studies, the value-directed remembering task used by Castel and colleagues (Castel, A. D., Balota, D. A., & McCabe, D. P. (2009). Memory efficiency and the strategic control of attention at encoding: Impairments of value-directed remembering in Alzheimer's Disease. *Neuropsychology, 23*, 297–306) was modified to include value-directed forgetting. Study 2 incorporated valence as an additional task demand, and age differences were predicted in both studies due to increased demands of controlled processing. Automated operation span and Stroop span were included as working memory measures, and working memory was predicted to mediate performance.

Results. Results confirmed these predictions, as older adults were less efficient in maximizing selectivity scores when high demands were placed on selectivity processes, and working memory was found to mediate performance on this task.

Discussion. When list length was increased from previous studies and participants were required to actively forget negative-value words, older adults were not able to selectively encode high-value information to the same degree as younger adults. Furthermore, WMC appears to support the ability to selectively encode information.

Key Words: Attention—Memory—Working memory.

As proposed by Baddeley and Hitch (1974), working memory is a multicomponent, limited-capacity workspace capable of monitoring and transforming information while executing complex cognitive tasks. A crucial function of the working memory system is distinguishing between relevant and irrelevant information while maintaining task goals, often in the face of competing or distracting information (Engle, 1999). Because environmental demands are constantly changing, it is important that the contents of working memory be monitored and updated efficiently.

Hasher and Zacks (1988) argue that older adults have deficits in attentional selection, thereby allowing more irrelevant information to enter working memory and occupy working memory resources requisite for efficient processing. Impaired selection can be a hindrance in everyday situations, for it is often necessary to attend to important information while directing attention away from less relevant information. This relates to the strategic control of attention, or the ability to optimally direct attentional resources and selectively encode high-value information (Castel, Balota, & McCabe, 2009).

Given limited cognitive resources and an abundance of information in the environment, it is critical that individuals selectively attend to high priority or high-value information at the expense of low priority or low-value information. Consider, for example, wanting to remember the birthdays of loved ones. Although it is rare to remember the birthdays of every person one has known, being able to remember the birthdays of parents or grandchildren, for example, could be considered an efficient use of cognitive resources. Further, the capacity to inhibit irrelevant information is essential to using memory resources and attention in an efficient, goal-directed manner. It is often necessary to disregard certain information, for it may no longer be relevant to current task demands. Consider a change in dosage of medication. Alongside this change, it may be necessary to disregard previous instructions to take one pill every 4 hr and now remember to take one pill twice a day. This requires forgetting of the previously relevant information along with maintenance of newly relevant information.

To investigate age-related differences in the strategic control of attention, Castel and colleagues (2009) used a value-directed remembering task, wherein selective encoding was operationalized as encoding high-value stimuli in alignment with task goals. Participants were presented with a list of words, and each word was paired with a distinct point value ranging from +1 to +12. Participants were instructed to remember as many words as possible, with the goal being to selectively encode high-value words in order to maximize their total score. At the end of each word list, participants were provided feedback in the form of a summed score for words recalled. A selectivity index was later calculated for each participant by dividing their

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actual score by an ideal score based upon the number of words recalled (Castel, Benjamin, Craik, & Watkins, 2002).

Across numerous variants of the value-directed remembering task, Castel and colleagues (2002, 2009) and Castel, Farb, and Craik (2007) found that older adults were equally as selective as younger adults when encoding high-value information, albeit at a cost of being able to recall fewer lower-value items. Castel and colleagues (2002, 2007) further claimed that older adults were exercising control in limiting attention to lower-value items while maintaining activation of the highest value items. Given that age differences are typically found on tasks requiring controlled processing (Park et al., 1996), the finding that older adults exercised control in maintaining selectivity is particularly surprising. In order to suggest that there are no age-related differences in the ability to strategically control attention, it is imperative that the task poses sufficient attentional demands to measure age-related differences in controlled processing.

To increase task demands and investigate boundary conditions wherein age differences in selectivity may occur, the value-directed remembering task used by Castel and colleagues (2009) was modified in the current studies to include negatively valued items. Specifically, word lists were lengthened such that participants must limit the processing of negative-value words while selectively encoding high-value words. Point values were extended to range from −6 to +12. In this manner, the current studies most closely resemble Castel and colleagues (2007, Experiment 2), wherein 16 items were assigned point values ranging from −16 to +16, spaced in increments of four. Castel and colleagues (2007, Experiment 2) found that both age groups were able to maintain selectivity (with only two participants recalling negative-value words), although older adults displayed greater recognition of negative-value words.

The inclusion of negative-value items bears semblance to directed forgetting tasks, such that negative-value words could be considered to-be-forgotten (TBF) items. Alternatively, positive-value words could be considered to-be-remembered (TBR) items. By including negative-value items, participants must now inhibit the processing of these items while maintaining activation of task-relevant (i.e., positive-value) items. Zacks, Radvansky, and Hasher (1996) found that older adults were more likely to recall TBF items, relative to younger adults, and this may reflect diminished efficiency of inhibitory control. This diminished efficiency may result in greater intrusion of task-irrelevant items, thereby cluttering the working memory space and limiting resources available for processing goal-relevant stimuli.

It was predicted that younger adults would outperform older adults in the modified value-directed remembering task, and working memory capacity (WMC) was expected to support performance. Research suggests that individuals with greater WMC are better able to maintain activation of task-relevant information while inhibiting distracting interference, relative to individuals with lesser WMC, and a relationship between WMC and selectivity performance was expected (Kane & Engle, 2003; McCabe, Robertson, & Smith, 2005).

STUDY 1

Method

Participants. The sample included 24 younger adults ranging in age from 19 to 23 (M = 20.29, SD = 1.33) and 24 older adults ranging in age from 65 to 79 (M = 71.96, SD = 3.88). Younger adults were recruited from the undergraduate population at Georgia Tech and received 1.5 hr of course credit for their participation. Older adults (all of whom lived independently in metropolitan Atlanta and were capable of making their own way to campus) were recruited from the laboratory database and were compensated $15 for their time. All participants were native English speakers and reported themselves to be in good health. Information about the sample is included in Table 1.

Materials and design. Stimuli included 162 items and all words were selected to have neutral-valence means, as measured by the Affective Norms for English Words (ANEW) database (Bradley & Lang, 1999). Each word list contained 18 items, and point values ranged from −6 to +12. Words valued −6 to −1 were considered TBF items, whereas words valued +1 to +12 were considered TBR items. The value-directed remembering task consisted of nine word lists: one practice list and eight test lists.

Procedure. All participants were tested in a single session lasting approximately 90 min. Participants were invited into

Table 1. Demographic, Working Memory, and Processing Speed Variables

	Younger adults	Older adults	p value
Study 1			
n	24	24	
Age	20.29 (1.33)	71.96 (3.88)	$p < .001$
Education	13.79 (1.29)	15.92 (2.13)	$p < .001$
Health	4.33 (0.76)	3.92 (0.83)	$p = .076$
AOSPAN	59.04 (13.78)	38.33 (17.85)	$p < .001$
Stroop span	43.67 (7.11)	29.92 (8.28)	$p < .001$
Processing speed	35.58 (4.59)	25.11 (3.71)	$p < .001$
Study 2			
n	48	48	
Age	19.81 (1.44)	69.69 (5.15)	$p < .001$
Education	13.79 (1.29)	16.00 (2.87)	$p < .001$
Health	4.23 (0.66)	3.98 (0.98)	$p = .146$
AOSPAN	59.12 (12.59)	35.15 (21.91)	$p < .001$
Stroop span	43.46 (7.41)	30.40 (8.87)	$p < .001$
Processing speed	32.96 (4.87)	23.52 (5.54)	$p < .001$

Note. Standard deviations are enclosed within parentheses. Stroop span and AOSPAN reflect total number of correct items. Processing speed reflects mean total number of correct items in 30 s.

the testing room, gave informed consent, and completed a demographic questionnaire. Task ordering was as follows: (a) value-directed remembering task; (b) recognition task; (c) working memory task (i.e., automated operation span); (d) processing speed task (i.e., letter, pattern, and number comparison worksheets); and (e) working memory task (i.e., Stroop span).

In the value-directed remembering task, participants were told they would be studying lists of words, and each word would be paired with a point value, ranging from −6 to +12. All words and numbers were presented on the center of a computer screen in black Times New Roman 48-point font against a white background. Each word remained on the screen for 3 s and was immediately followed by its point value (shown separately for 2 s). Participants were informed that the number following each word was its point value, and that the point value indicates how important it was to remember that word (with −6 being the lowest value and +12 being the highest value). Participants were informed that the goal was to try to get as many points as possible, and this could be accomplished by remembering as many of the high-value words as possible.

After each word list, a delay of 10 s was imposed before the word "RECALL" appeared on the screen. At that point, participants were instructed to write down as many words as possible to maximize their total score. Participants were invited to ask questions about the testing procedure and then began a practice list and recall session. After the practice session, participants were again invited to ask questions before continuing with the task. The testing session consisted of eight test trials, and word presentation order was randomized for all participants.

Upon completion of all test blocks, participants were given a computerized recognition test consisting of 96 words. Half of the words (48) were randomly selected from previous test trials, with representative proportions of TBR/TBF items (i.e., 16 TBF items and 32 TBR items). The other half of the recognition words (48) were new, unused words from the ANEW database. The following question appeared on the computer screen above each word: "*Did this word appear in ANY of the previous trials?*" Participants were asked to respond as quickly and accurately as possible by pressing either 'Y' (yes—I've seen this word before) or 'N' (no—I've not seen this word before).

As an index of speed of processing, all participants completed the following timed worksheets: letter comparison, pattern comparison, and number comparison (Salthouse & Babcock, 1991). As measures of WMC, participants completed the automated operation span (AOSPAN) task (Unsworth, Heitz, Schrock, & Engle, 2005) and the Stroop span task (McCabe et al., 2005). The AOSPAN task requires participants to compute math problems (competing against their average computational time and then making true/false decisions regarding the accuracy of the presented solution) while also remembering a string of letters presented individually in between math problems. The participant must then recall letters in their order of presentation. In the Stroop span task, participants judge whether the color and text of Stroop words are congruent (yes or no) and are then asked to recall (in order) the colors that were presented in each trial. Each test block consisted of three test trials, and the number of color-word decisions in each trial increased linearly from one to six as the task progressed. Finally, participants were debriefed, compensated, and thanked for their time.

Results

Selectivity and recall. First, we examined data for the presence of age invariance in selectivity. These data are presented in Table 2. Consistent with previous research (Castel et al., 2002, 2009), the selectivity index (SI) was calculated as follows: (participant's score − chance score)/(ideal score − chance score). The ideal score reflects the greatest point value based upon the number of words recalled. For instance, the ideal score for a participant who recalls three items equals 12 + 11 + 10 = **33**. The chance score reflects the score that would be obtained by chance and equals the average score (which, for a list of 18 words ranging in point value of −6 to +12, equals 3.167) multiplied by the number of words recalled. A one-way ANOVA revealed that younger adults demonstrated superior selectivity indices, relative to older adults, $F(1, 46) = 11.882$, mean-squared error (MSE) = 0.045, $p < .001$. This is in contrast to Castel and colleagues (2002, 2007, 2009), wherein older adults were able to maintain comparable selectivity to younger adults.

To identify the source of this age-related difference, we conducted a 2 (age: young, old) × 3 (item type: TBF, low-value TBR, high-value TBR) ANOVA. Words valued −6 to −1 were considered TBF, words valued +1 to + 7 were

Table 2. Recall and Selectivity

	Younger adults	Older adults
Study 1		
Selectivity index (SI)	0.75 (0.12)	0.54 (0.28)
Total_Recall	0.47 (0.04)	0.32 (0.08)
Recall_TBR high	0.77 (0.12)	0.60 (0.18)
Recall_TBR low	0.64 (0.19)	0.37 (0.16)
Recall_TBF	0.02 (0.04)	0.06 (0.11)
Study 2		
Selectivity index (SI)	0.73 (0.11)	0.48 (0.31)
Total_Recall	0.44 (0.10)	0.29 (0.09)
Recall_TBR high	0.77 (0.12)	0.53 (0.21)
Recall_TBR low	0.59 (0.19)	0.32 (0.16)
Recall_TBF	0.01 (0.02)	0.06 (0.08)
Recall_Positive	0.10 (0.03)	0.12 (0.06)
Recall_Negative	0.09 (0.03)	0.10 (0.05)

Note. Standard deviations are enclosed within parentheses. Data for Study 2 were collapsed across random and negative conditions. Total_Recall equals the average proportion of words recalled for each word list. Recall_TBF equals the proportion of words recalled valued −6 to −1. Recall_TBR High equals the proportion of words recalled valued +8 to +12. Recall_TBR Low equals the proportion of words recalled valued +1 to +7.

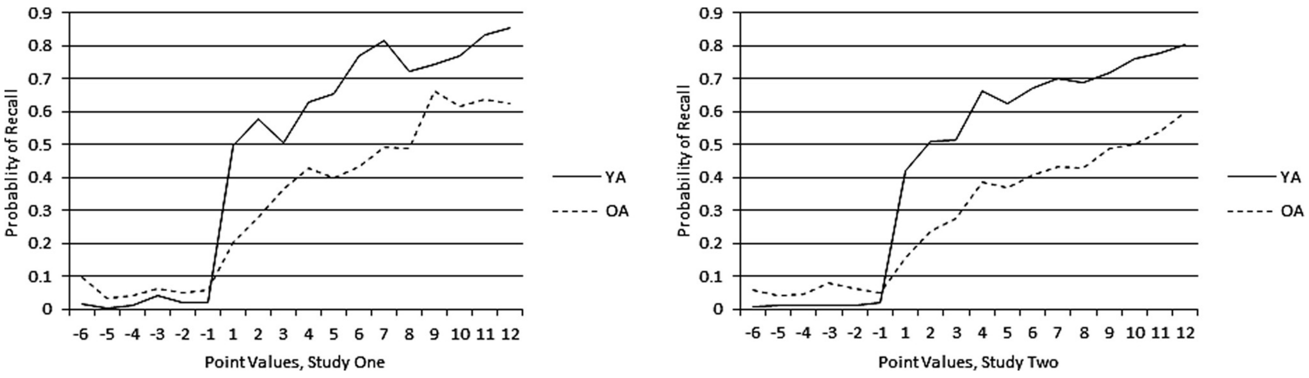

Figure 1. Probablity of recall across point values.

considered low-value TBR, and words valued +8 to +12 were considered high-value TBR. Findings revealed a main effect of age, $F(1, 46) = 26.775$, $MSE = 0.024$, $p < .001$, and a main effect of item type, $F(2, 92) = 304.95$, $MSE = 0.018$, $p < .001$. Importantly, these effects were qualified by a significant Age Item-Type interaction, $F(2, 92) = 16.29$, $MSE = 0.018$, $p < .001$. We decomposed this interaction by conducting independent sample *t*-tests (controlling for familywise error) between older and younger adults for each item type. Relative to older adults, younger adults recalled more high-value TBR items, $t(46) = 3.91$, $p < .001$, and low-value TBR items, $t(46) = 5.27$, $p < .001$. Older adults recalled more TBF items, relative to younger adults, $t(46) = -1.78$, $p = .081$, although this effect fell short of conventional levels of significance. Thus, the interaction stems from younger adults recalling more TBR items than older adults, while both groups were similar in regard to TBF items. A depiction of recall across point values can be found in Figure 1.

Table 3. Corrected Recognition Scores

	Younger adults	Older adults
Study 1		
CR_TBR High	0.82 (0.14)	0.63 (0.21)
CR_TBR Low	0.67 (0.18)	0.51 (0.17)
CR_TBF	0.41 (0.19)	0.43 (0.20)
Hits TBR High	0.94 (0.07)	0.77 (0.21)
Hits TBR Low	0.79 (0.14)	0.66 (0.20)
Hits TBF	0.52 (0.17)	0.56 (0.24)
False alarms	0.12 (0.13)	0.14 (0.11)
Study 2		
CR_TBR	0.70 (0.15)	0.56 (0.16)
CR_TBF	0.37 (0.14)	0.38 (0.19)
Hits TBR	0.82 (0.12)	0.75 (0.15)
Hits TBF	0.50 (0.20)	0.56 (.20)
False alarms	0.12 (0.12)	0.18 (0.14)

Note. Standard deviations are enclosed within parentheses. Corrected recognition (CR) was calculated as follows: (hits–false alarms). CR_TBR High equals corrected recognition of words recalled valued +8 to +12. CR_TBR Low equals corrected recognition of words recalled valued +1 to +7. CR_TBR equals corrected recognition of words valued +1 to +12. CR_TBF equals corrected recognition of words valued −6 to −1.

Corrected recognition. Corrected recognition (hits–false alarms) was examined to ascertain the effects of value on long-term recognition memory. Additionally, analysis of TBF item recognition may provide some indication of whether participants were simply ignoring TBF items during encoding. These data are presented in Table 3. A 2 (young, old) 3 (TBF, low-value TBR, high-value TBR) ANOVA revealed a main effect of item type, $F(2, 45) = 86.483$, $MSE = 0.013$, $p < .001$, which was qualified by a reliable Age Item-Type interaction, $F(1, 46) = 10.471$, $MSE = 0.013$, $p < .001$. The interaction was decomposed as before. Younger adults recognized more high-value TBR items, $t(46) = 3.689$, $p < .001$, and low-value TBR items, $t(46) = 2.945$, $p = .005$, relative to older adults. However, there were no age-related differences in recognition of TBF items, $t(46) = -.264$, $p = .793$. As a final note, inspection of the means for TBF items in recognition suggests that individuals were not simply ignoring TBF items during encoding.

Results from Study 1 suggest age differences in selectivity upon increases in task demands. To further explore age differences and boundary conditions in selectivity, TBF items in a test condition of Study 2 were selected to be particularly distracting (as suggested by prior research). Previous research suggests that emotional items may garner processing priority and disrupt the processing of neighboring, neutral items (Kensinger & Corkin, 2003; Minnema & Knowlton, 2008). Thus creating a negative condition where negative-value TBF items were manipulated to be emotionally salient was used to further examine age differences and boundary conditions in selectivity. Specifically, we varied the valence (i.e., how positive or negative an item is) of these items. Using stimuli with a positive or negative valence also allowed for a post hoc investigation of age-related attentional biases toward items of a particular valence.

STUDY 2

Method

Participants. The sample included 48 younger adults ranging in age from 18 to 23 ($M = 19.81$, $SD = 1.44$) and 48 older adults ranging in age from 60 to 79 ($M = 69.69$, $SD = 5.15$). Recruitment procedures were identical to Study 1, and information about the sample is included in Table 1.

Materials and design. The primary distinctions from Study 1 were that one third of the words utilized in Study 2 were high-valence words with a positive or negative valence, as measured by the ANEW database (Bradley & Lang, 1999). In the ANEW database, words are normatively ranked for arousal (on a scale of calm to stimulating) and valence (on a scale of positive to negative). Of the 234 words utilized as stimuli, 156 were neutral-arousal ($M = 4.20$, $SD = 2.20$), neutral-valence ($M = 5.06$, $SD = 1.58$); 39 were high-arousal ($M = 6.21$, $SD = 2.38$), positive-valence ($M = 7.71$, $SD = 2.38$); and 39 were high-arousal ($M = 6.22$, $SD = 2.55$), negative-valence ($M = 2.37$, $SD = 1.58$). Identical to Study 1, each word list consisted of 18 words ranging in point value from −6 to +12. The total length of the value-directed remembering task was increased from 8 to 12 word lists, and a measure of nonretrieval was included for the final two word lists. Participants were asked whether there were any words they remembered but chose not to write down because they knew it would hurt their score. This was included as a measure of retrieval inhibition and was intended to measure possible age-related differences in selective encoding vs. retrieval inhibition operating within the value-directed remembering task.

Each word list contained 12 neutral words and 6 high-valence words. Of these six high-valence words, three were positive and three were negative. The random and negative conditions differed solely in their assignment of these items. In the negative condition, all high-arousal items were assigned to values −6 to −1, and thus deemed TBF. All neutral-arousal words were assigned to values +1 to +12 and were considered TBR. In the random condition, all words were randomly assigned to point values, such that high-arousal and neutral-arousal words were equally likely to appear in any of the 18 positions. The random condition was intended to prevent participants from generating a strategy of inhibiting or ignoring any word that seemed arousing or distinct.

Results

Selectivity and recall. Selectivity and recall findings are presented in Table 2. For older and younger adults, SIs did not differ between random and negative conditions, so data from both conditions were collapsed across all 12 word lists. This created a single test condition, where one third of each word list consisted of high-arousal items and two thirds of each word list consisted of neutral-arousal items. As in Study 1, younger adults demonstrated superior selectivity indices, relative to older adults, $F(1, 94) = 29.231$, $MSE = 0.054$, $p < .001$.

A 2 (age: young, old) × 3 (item type: TBF, low-value TBR, high-value TBR) ANOVA revealed a main effect of age, with younger adults recalling a greater number of items, relative to older adults, $F(1, 94) = 64.692$, $MSE = 0.025$, $p < .001$. There was also a main effect of item type, with both age groups recalling more low- and high-value items, relative to TBF items, $F(2, 94) = 496.096$, $MSE = 0.019$, $p < .001$. These main effects were qualified by a significant Age × Item-Type interaction, $F(2, 94) = 36.036$, $MSE = 0.019$, $p < .001$. Post hoc comparisons demonstrated that younger adults, on average, recalled more high-value TBR items, $t(94) = 6.64$, $p < .001$, and low-value TBR items, $t(94) = 7.43$, $p < .001$. However, older adults recalled more TBF items relative to younger adults, $t(94) = -3.58$, $p = .001$. Thus, the reliable interaction stems from older adults' inability to inhibit recalling TBF items, while also not being able to recall as many TBR items as younger adults. A depiction of recall across point values can be found in Figure 1.

Valence. Valence data are presented in Table 2. To assess the role of valence in this effect, we conducted a 2 (young, old) × 2 (positive, negative) ANOVA. Of most importance, the Age × Item-Type interaction was reliable, $F(2, 93) = 4.82$, $MSE = 0.001$, $p = .031$. Using t-tests to decompose this interaction revealed that older adults recalled a greater proportion of positive items, relative to younger adults, $t(94) = -2.83$, $p = .006$. However, there were no age differences in recall of negative items, $t(94) = -.87$, $p = .386$. This suggests that older adults' increased recall of high-arousal items was driven by recall of positive items and aligns with previous literature suggesting a positivity bias in older adults (Carstensen & Mikels, 2005; Mather & Knight, 2005).

Measure of nonretrieval. For the final two word lists, participants were asked whether there were any words they remembered but chose not to write down because they knew it would hurt their score. This measure was included as a measure of retrieval inhibition. No age differences were found, $F < 1$, and both groups were near floor in this measure.

Corrected recognition. Corrected recognition data are presented in Table 3. Since recognition probes were not evenly distributed between high- and low-value TBR, these two categories were collapsed into a single variable. A repeated-measures ANOVA revealed younger adults correctly recognized more items, relative to older adults, $F(1, 94) = 5.034$, $MSE = 0.039$, $p < .05$. On average, TBR items were recognized with a higher probability, relative to TBF items, $F(1, 94) = 200.452$, $MSE = 0.015$, $p < .001$. These effects were qualified by a significant Age Item-Type interaction, $F(1, 94) = 15.987$, $MSE = 0.015$, $p < .001$. The source of the interaction is similar to Study 1 and can be explained by age differences in corrected recognition of TBR items. Younger adults had greater levels of corrected TBR recognition, $t(94) = 4.33$, $p < .001$, and there were no age differences in corrected recognition of TBF items,

$t(94) = -.21$, $p = .834$. Also, corrected recognition rates for TBF items again suggest that individuals were not simply ignoring negative-value information.

Hierarchical regression analyses. Hierarchical regression analyses were conducted using data from Studies 1 and 2 to examine the proportion of variance in SI accounted for by WMC, processing speed, and age. The *z*-scores for both working memory tasks (i.e., AOSPAN and Stroop span) were combined to create a composite variable reflective of WMC. A measure of processing speed was included for investigative purposes, as speed of processing has been offered as an explanation for age-related performance deficits in complex cognitive tasks (Salthouse, 1996). Similar to the composite measure for WMC, a composite measure of processing speed was created by combining *z*-scores for the letter, pattern, and number comparison worksheets. SI served as the dependent measure.

In Model 1, the predictor of WMC was entered first, followed by processing speed and age. WMC accounted for a significant proportion of variance in SI ($R^2 = .383$), whereas processing speed failed to reach significance ($\Delta R^2 = .009$). In Model 2, the predictor of processing speed was entered first, followed by WMC and age. Processing speed accounted for a significant proportion of variance in selectivity indices ($R^2 = .185$), and the second predictor of WMC additionally accounted for a significant proportion of variance after controlling for the effects of processing speed ($\Delta R^2 = .207$). Importantly, the predictor of age failed to reach significance in either model. Together, these findings suggest that age-related differences in SI are largely mediated by individual differences in WMC.

GENERAL DISCUSSION

The value-directed remembering task used by Castel and colleagues (2009) was modified to increase task demands and more greatly tax individuals' WMC. By expanding the stimulus set to include TBF items, participants must now inhibit these items while maintaining activation of valuable TBR items. The inclusion of an inhibitory task demand required greater controlled attention and was expected to be particularly challenging for older adults, relative to younger adults. In this manner, this study was designed to more closely examine the role of WMC and age-related differences in the strategic control of attention. WMC was expected to support performance, with individuals with greater WMC outperforming individuals with lesser WMC. These expectations were confirmed, as younger adults were more selective than older adults with an increase in task demands, and WMC was found to mediate performance.

The working memory measures were selected to reflect participants' controlled attentional capacities. These measures have been found to reflect executive and attentional control capacities (McCabe et al., 2005; Unsworth et al., 2005), and assuming these capacities are supportive of performance in the value-directed remembering task, one would expect significant correlations between WMC and performance. Castel and colleagues (2009) made similar predictions in expecting WMC to correlate with SI and used computation and reading span measures to create a composite variable reflective of WMC. WMC weakly correlated with SI for older adults ($r = .22$, $p < .05$), and there was no correlation between WMC and SI for younger adults ($r = .00$, $p > .05$). While restriction of range likely played a role in diluting correlations for younger adults, the value-directed remembering task used by Castel and colleagues (2009) may not have adequately challenged controlled processing, thereby limiting the strength of relationships with working memory measures.

By increasing the length of word lists and adding in the TBF requirement, the correlations between WMC and SI increased for both older and younger adults ($r = .408$, $p < .001$; $r = .381$, $p < .001$, respectively). This lends strength to the argument that attentional control (i.e., WMC) is supportive of performance in tasks of selective encoding, and selectivity indices were found to decrease with age alongside declines in the efficiency of WMC. However, it is important to note that the ability to selectively encode information may depend upon several interrelated abilities, such as the ability to inhibit distracting interference, the ability to selectively attend to goal-relevant information, the ability to maintain activation of task goals, the ability to monitor performance across the task, and/or effective binding of words to their respective point values (Castel, 2007; Titz & Verhaeghen, 2010; Zacks et al., 1996). The inhibition deficit hypothesis, however, was not strongly supported. Although there was evidence of age-related differences in inhibition of recall of TBF items, older and younger adults were equally able to recognize TBF items.

Another approach to understanding our results is through the associative deficit hypothesis (Naveh-Benjamin, 2000; Naveh-Benjamin, Brav, & Levy, 2007). It may be the case that older adults were impaired in their ability to bind words to their associated point values, thereby resulting in source memory confusion and suboptimal recall of high-value items. However, performance in this study requires that participants actively attend to high-value items while reducing attention to negative-value items, and older adults appeared to exhibit effective encoding of high-value items. Thus, performance in this study may not greatly depend upon effective binding. It may also be the case that inhibitory processes support performance by suppressing binding of irrelevant information while concurrently enhancing bindings of more relevant information; thus, the inhibitory deficit hypothesis and associative deficit hypothesis may not be incompatible in this case (Bäuml, Pastötter, & Hanslmayr, 2010).

FUTURE DIRECTIONS

There are several methodological distinctions that limit direct comparability with Castel and colleagues (2002, 2007, 2009). Participants in this study were asked to write their responses using pen and paper, and this may have negatively affected older adults, as handwriting speed and levels of output interference may differ between age groups. Also, a 10-s delay was imposed between presentation of word lists and subsequent recall. This was intended to reduce recency effects, although it might have been useful to fill this time with a distractor task, as age groups may have differentially rehearsed during this delay.

Additionally, Castel and colleagues (2002, 2007, 2009) provided participants with feedback at the end of each word list in the form of a summed score for words recalled. In addition to serving as a monitoring cue, participants may have received positive reinforcement as a result of increasing scores throughout the task. This may have enhanced or extended motivation to actively engage in the task, and this may have also facilitated activation of goal maintenance processes. The lack of feedback in this study may have contributed, in part, to age differences in SI, as older adults might have differentially benefited from the assistance of performance monitoring. However, it is important to note that both age groups were proficient in maintaining selectivity scores and limiting recall of TBF items, despite demanding task conditions. It would be useful for future studies to investigate the direct contribution of block level performance feedback, as this would allow for greater isolation of task modifications from that of Castel and colleagues (2002, 2007, 2009). This would also allow for an investigation of the role feedback plays in monitoring or performance gains for older and younger adults.

This study was also limited in its ability to differentiate between theories of age-related decline, and it would be useful for future studies to incorporate measures of associative binding as well. Perhaps the recognition task could be modified, such that participants are asked whether the word is ‘old’ or ‘new’ and are then asked to enter the point value corresponding to that particular item. In order to investigate extent of binding precision, half of participants could be asked to recall a specific point value, whereas the other half of participants could be asked to select an appropriate point value range (i.e., negative-value, low-value, and high-value). This would help examine the degree to which participants bound each word to a specific or generic point value as well as whether differences in binding exist for words of a particular point value or for participants of differing working memory spans. It may be the case that participants engage in more gist-based encoding strategies, binding items to generic tags (e.g., “high value,” “important,” “to remember,” and “to forget”), rather than engaging resources to bind each word to a specific point value.

CONCLUSIONS

As advanced by Engle and Kane (2004), individual differences in WMC are most predictive of performance in controlled, attention-demanding tasks. The value-directed remembering task used by Castel and colleagues (2009) was modified to include value-directed forgetting, and age differences in selectivity were found across two studies. In considering directed forgetting as an active cognitive process (Fawcett & Taylor, 2008; Paz-Caballero, Menor, & Jiménez, 2004; Wylie, Foxe, & Taylor, 2008), this addition to task requirements was expected to increase reliance upon controlled processing. In accord, performance differences in this study were mediated by WMC, such that individuals with greater WMC were better able to maintain activation of high-value items while limiting activation of TBF items, relative to individuals with lesser WMC.

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