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Cognitive Resources, Valence, and Memory Retrieval of Emotional Events in Older Adults

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In 2 studies with older adults, the authors investigated the effect of executive attention resources on the retrieval of emotional public events. Participants completed a battery of working memory tasks, as a measure of executive attention, and a battery of tasks assessing memory, as well as subjective experiences associated with the retrieval of remote public events. Participants also rated the valence of each public event story. The group-rated valence of the public event stories predicted retrieval and the quality of experiences associated with them, such that emotionally arousing events elicited the highest memory rates and the richest experiences. Furthermore, positive public events elicited the highest memory rates. Executive attention moderated only the relationship between event valence and how participants' associated memories are experienced at retrieval, such that superior executive attention resources predicted richer experiences associated with positive relative to neutral and negative stories. The current results extend previous findings on the effects of aging on emotion regulation, suggesting that cognitive control resources modulate subjective experiences associated with retrieved memories for remote real life events, but not memory retrieval itself.

Keywords: executive attention, retrieval, long-term memory, personality, older adults

Time perspective has been proposed to be an essential determinant of emotional experience (Carstensen, Isaacowitz, & Charles, 1999; Charles, Mather, & Carstensen, 2003). As such, one of the most prominent theories of motivational dynamics across the lifespan, socioemotional selectivity theory, advanced by Carstensen and her colleagues (Carstensen et al., 1999; Charles et al., 2003), posits that humans have an intuitive awareness of the time left in their life. Perceptions of unlimited time left in life, characteristic of the young age, are hypothesized to foster information acquisition goals, which would support optimal future performance (Charles et al., 2003). Complementarily, perceptions of limited time left in life, characteristic of older age, are assumed to enhance focus on emotion regulation goals, namely the goal of maintaining positive affect and decreasing negative affect (Charles, Reynolds, & Gatz, 2001).

Consistent with the aforementioned proposals of an age-related increase in the motivation to maximize well-being (Carstensen et al., 1999; Carstensen & Mikels, 2005; Mather & Carstensen, 2005), attention and memory studies have documented that, relative to younger adults, older adults tend to focus away from negative information (i.e., *antinegativity* bias) and toward positive information (i.e., *positivity* bias; for a review, see Mather & Carstensen, 2005). Specifically, relative to younger adults, older adults spend less time attending to negative (relative to neutral) images (Isaacowitz, Wadlinger, Goren, & Wilson, 2006; Knight et al., 2007) and their memory is worse for negative information (Charles et al., 2003; Mather & Knight, 2005). Complementarily, relative to younger adults, older adults have been reported to recall more positive pictures (Mather & Knight, 2005) and to be most proficient at discriminating among positive relative to negative or neutral stimuli (e.g., facial expressions; Mather & Carstensen, 2003).

A recent study by Mather and Knight (2005, Experiment 2) suggests that enhancement of positive affect in old age is not a ubiquitous phenomenon. In this study, the researchers measured participants' memory for positive and negative pictorial stimuli, as well as their cognitive control abilities. The results showed that only older participants with superior cognitive control abilities recalled a higher proportion of positive relative to negative pictures (43% vs. 40%), whereas older participants with low cognitive control resources recalled more negative than positive pictures (46% vs. 35%). The performance of the low cognitive control older group closely resembled the performance of the younger adult group (irrespective of their cognitive control abilities), who recalled a higher proportion of negative relative to positive pictures (47% vs. 32%). A third experiment in Mather and Knight's (2005) article demonstrated that manipulating participants' ability to attend to the emotional pictures during encoding eliminated the positivity bias across all participants. This finding seems to suggest that cognitive control abilities influence memory primarily during encoding. However, due to the small sample size and the use of a between-subjects design, it would be premature to conclude from this finding that age and cognitive control abilities do not influence retrieval processes.

In short, Mather and Knight's (2005) article suggests that an assessment of cognitive control abilities is necessary for a richer understanding of emotion regulation and well-being in old age. Drawing on their findings, we investigated in our present research

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the more specific cognitive control abilities, which are necessary to implement cognitive strategies that maximize well-being. Our current studies extend Mather and Knight's (2005) seminal work in several ways: (a) We provide a more detailed account and focused assessment of the underlying cognitive control abilities involved; (b) we examine the generalizability of the findings from laboratory stimuli to memory for real-life events; (c) we focused on participants' emotional engagement with the public event stories, which may be more important for well-being than the mere ability to recall objective story details; and (d) we used real remote public events, encoded when the participants were in their youth or middle age, in order to investigate whether retrieval processes also contribute to the information processing biases, previously reported in older adults.

CURRENT STUDIES

Mather and Knight's (2005) article made an important contribution by acknowledging the cognitively controlled nature of the information processing biases in old age. However, in all the analyses, cognitive control was operationalized as the participants' composite score across three cognitive control tasks, whose scores were uncorrelated (Mather & Knight, 2005, Experiment 2). Consequently, it remains unclear to what extent each of these tasks on its own, and the underlying neurocognitive processes, contributed to the positivity effect observed in older adults.

Our present research investigates the effect of one type of cognitive control abilities in old age, executive attention resources, on retrieval and the associated subjective experiences elicited at the time of retrieval of emotional memories. The two studies presented in this article build upon Mather and Knight's (2005) research, where executive attention resources, assessed with the executive attention component of the Attentional Network Test (Fan, McCandliss, Sommer, Raz, & Posner, 2002) as part of the composite cognitive control variable, had been found to contribute to the information processing biases in older adults. In the cognitive literature, executive attention has been conceptualized as the cognitive mechanism underlying the active maintenance of action plans, goal states, or task demands under conditions of interference from immediate environmental stimuli (Cohen et al., 1997; Kane et al., 2004). In the neuroscience literature, executive attention abilities had been reported to depend upon a network of anterior and posterior attentional control areas (Engle & Kane, 2004), centered on the dorsolateral prefrontal cortex (DLPFC; i.e., Brodmann's areas [BA] 9, 46; Fan et al., 2002). In the affective neuroscience literature, the same neural network has been found to support the reinterpretation of the meaning of a stimulus to increase or decrease one's emotional response to it (for a review, see Ochsner & Gross, 2005).

Drawing upon previous literature that suggested that executive attention abilities may be involved in emotion regulation processes, broadly, and the age-related processing biases, in particular (e.g., Mather & Knight, 2005; Ochsner & Gross, 2005), we examined whether executive attention abilities made differential contributions to the antinegativity and positivity biases in older adults' memory for real life stimuli (i.e., emotional remote public events). This question has become particularly relevant in light of recent findings of experimental manipulations with a unique effect on the positivity, but not the antinegativity, bias in older adults (e.g., divided attention; Knight et al., 2007; Mather & Knight, 2005, Experiment 3), thereby raising the possibility that the distinct cognitive control systems exert differential effects on the age-related processing biases.

The public events used in our study were preselected to be relevant to our participants' age group (see Method below). As such, although our stimuli were nonautobiographical in nature, their associated memory representations were likely to have some autobiographical significance (Westmacott & Moscovitch, 2003). We focused on autobiographically significant stimuli, since they had been found to be the most reliable in eliciting the positivity and negativity biases in older adults (see Mather & Carstensen, 2005), probably because they are most likely to have an impact on well-being.

Unlike previous studies (e.g., Charles et al., 2003; Mather & Knight, 2005), the focus of our present research was not objective memory performance but the participants' subjective recollective experiences, more specifically the current absorption in their memories associated with the public event stories. We chose to focus on participants' current recollective experiences due to previous proposals that the age-related positivity and antinegativity biases reflect older adults' increased motivation to maximize their emotional well-being (Mather & Carstensen, 2005). As such, we reasoned that the level of absorption in emotional public event stories at the moment of retrieving them, rather than the ability to retrieve the specific story details themselves, is likely to exert a stronger effect on individuals' emotional states. Our hypothesis is consistent with previous findings that the level of absorption in a public story is the best predictor of the emotional and motivational impact of the respective story (Green & Brock, 2000).

STUDY 1

In Study 1, we examined the effect of individual differences in executive attention abilities on older adults' experiences associated with the retrieval of emotional remote public events. We assessed the participants' current experiences associated with public event retrieval using an adapted version of Green and Brock's (2000) Narrative Transportation Scale. The original scale was intended to assess readers' absorption in fictional public narratives (Green & Brock, 2000). In our study, the fictional narratives were the participants' memories of each public event presented to them. Consequently, the narrative transportation scale assessed the participants' immersion in their memories of the public event stories at the moment of retrieving them.

Performance on a complex spatial working memory task was used as the sole measure of executive attention (Kane et al., 2004). Similar to the other complex working memory span tasks, the spatial working memory span task is assumed to measure a domain-general executive control ability (Kane et al., 2004), along with domain-specific (i.e., spatial) processing and storage capacities (Kane & Engle, 2002; Kane et al., 2004). Given the heavily verbal nature of the public event task used in our study, we assumed that any relationships between scores on the spatial working memory task and performance on the public event task in Study 1 would reflect the contribution of the domain-general executive attention component.

Method

Participants

Study 1 included 54 (27 men) neurologically intact older adults between the ages of 69 and 79 (M = 74.07 years, SD = 2.98 years). They had completed between 8 and 25 years of education (M = 15.40 years, SD = 3.44 years).

All participants were native English speakers, had been living in North America for the past 50 years, and had not traveled outside North America for more than 2 months at a time. The participants were recruited via an older adult volunteer pool at the University of Toronto and were paid $10/hr. They were screened for the presence of depression, and they did not take medication that would influence cognitive functioning. Informed consent was obtained from all participants in accordance with the guidelines of the Social Sciences and Humanities Research Ethics Board at the University of Toronto.

Procedure

The study involved a single 2-hr long experimental session, during which participants completed the following tasks in fixed order:[1] a spatial working memory task, a narrative transportation task, assessing participants' current experience associated with the retrieval of each public event, as well as a valence rating task, where participants rated the valence of each of the public events presented to them. The narrative transportation and the valence rating tasks were presented as self-paced computer-administered surveys, where the event order was randomized for each participant. Prior to the beginning of the narrative transportation task, participants were only informed that they would be presented with a set of public event headlines. At the beginning of each task, participants were informed that the same events would be used in the narrative transportation and the valence rating task, respectively.

Materials

Working Memory Tasks

We downloaded the automated e-prime version of the Symmetry Span task (Unsworth, Heitz, Schrock, & Engle, 2005) from Randall Engle's Web site (Engle, 2006). These automated versions of the standard complex working memory span tasks have demonstrated good internal consistency (α = .78) and have been reported to be equally reliable as the standard experimenter-controlled versions (rs = .80s over 2 weeks; Unsworth et al., 2005).

As in all complex working memory span tasks, in the symmetry span task, presentation of the to-be-remembered stimuli is embedded within a processing task. In the symmetry span task, participants are required to judge the symmetry of abstract designs, while also attempting to remember the location of colored squares that appear on the computer screen. The number of memory items ranges from two to five (Unsworth et al., 2005). There are three trials at each memory level for a total of 12 recall trials.

The participants' working memory span scores are automatically reported at the end of the tasks. In order to ensure enough variability for performing correlational analyses, we used the more lenient total score, which represents the total number of memory items recalled in the correct position[2] (Unsworth et al., 2005).

Public Event Task

Public event selection. Based on a previous study with older adults (Petrican & Moscovitch, 2008), we selected 20 events from an initial pool of 180 public events, ranging from 1942 to 2001. The initial pool consisted of three events per year, two that had occurred in North America and one that had occurred outside North America. Canadian events were included in the initial public event pool if they had appeared in all of the following sources for the year in which they had occurred: *Chronicle of Canada* (1990), *Facts on File* (1950–1999), and CBC Digital Archives (only for the most recent decade; http://archives.cbc.ca/). Non-Canadian events were included in the test set if they appeared in all of the following sources for the year in which they occurred: *American Chronicle: Year by Year Through the Twentieth Century* (Gordon & Gordon, 1999), *The World Almanac and Book of Facts* (Joyce, Lazzarra, & Janssen, 1950–1999) and *Britannica, Calendar of Events* (1950–1999).

Based on the participants' responses in our previous study (Petrican & Moscovitch, 2008), for the present research we selected 20 events with the following constraints: (a) the most recent event occurred more than 15 years before the present study sessions (i.e., it could be considered as part of the very remote memory store); (b) the events selected did not span over more than 25 years (to minimize the effect of time-related memory decay processes); (c) according to experimenter ratings, the event set included a roughly equal number of positive, negative, and neutral events. The final set of public events ranged from 1967 to 1989. Information regarding the period during which a public event was present in the press was available for 15 of the 20 events selected for our study. The length of time the events were available in press ranged from 3 days (i.e., for "The strangled body of Pierre Laporte is found in the trunk of a car") to 6 months (i.e., for "The space shuttle Challenger explodes shortly after launching"), with a median value of 14 days of in-press availability.

Narrative transportation task. In order to assess their experience associated with the retrieval of each public event, participants responded on a 7-point scale (1 = *strongly disagree* to 7 = *strongly agree*) to seven statements that were adapted from the original narrative transportation measure (Green & Brock, 2000), such that they would be meaningful in the context of our public event task. Our adapted transportation scale assessed three components of the participants' transportation in the experience associated with memory retrieval of each public event. The first component assessed was the vividness of the participants' memories associated with the public events (i.e., "While I was reading the

[1] We chose to have the participants complete the working memory battery always prior to the public event task, due to previous findings that situational variables may affect availability of working memory resources (e.g., Klein & Boals, 2001).

[2] This choice is understandable, given that the working memory span tasks used in our present studies have been developed and validated with young undergraduate students (Unsworth et al., 2005), which tend to perform better on these tasks as a group than older participants (Lustig, May, & Hasher, 2001).

news headline, I could easily picture the events in it taking place," "While reading the headline, I had a vivid image of [name of the main character involved in the event]").

The second component measured their cognitive and emotional involvement in the event described (i.e., "I was mentally involved in the event while and/or after reading the headline," "After reading the headline, I found myself thinking of ways the event could have turned out differently," "After I finished reading the headline, I found it easy to put the event out of my mind," "I found my mind wandering while reading the headline"; the last two were reverse scored). The final aspect of transportation assessed by our measure was the participants' lack of awareness of their surroundings—as a result of their immersion in the public event described by each headline (i.e., "While reading the headline, activity going on in the room around me was on my mind"; reverse scored). Our 7-item scale of narrative transportation demonstrated reasonable internal consistencies for each story (median alpha value of .68; alphas ranged from .57 to .82). Participants' responses to the seven scale items were averaged in order to obtain indices of transportation in each public event.

Valence rating. Following the narrative transportation task, participants rated on a 7-point scale (1 = *highly negative* to 7 = *highly positive*) the valence of each of the 20 public events used in the study.

Results and Discussion

Preliminary Analyses

Table 1 presents the means and standard deviations for Study 1's measures.

Composite Event Valence

In order to create a more objective index of an event valence, we computed a standard aggregate valence for each public event, based on the evaluations provided by our participants.[3] First, the 7-point valence ratings were converted to categorical variables, such that an event, which was assigned a rating of 1, 2, or 3 belonged to the negative event category, a rating of 4 belonged to the neutral event category, and a rating of 5, 6 or 7 belonged to the positive event category. Second, we deducted the number of participants who rated the event as negative or neutral from the number of participants who rated the event as positive. For example, if an event was considered neutral by 18 participants, negative by 5 participants, and positive by 31 participants, the event would be assigned a composite valence value of (+8). Third, each event was assigned to one of the three categories: (a) positive, if it had received a composite valence value of (+32) or higher; (b) negative, if it had received a composite valence value of (–32) or lower; (c) neutral, if it had received a composite valence value of between (–31) and (+31). We chose these criteria with two considerations in mind: First, the positive and negative valence (lower and upper, respectively) boundary values would be equidistant from zero; second, a roughly equal number of events belonged to each of the three valence categories. Based on these criteria, nine events were rated as negative, six events were rated as positive, and five events were rated as neutral.

In order to compare the recollective experiences associated with positive and negative events relative to neutral events, we created two dummy variables, positivity and negativity. The positivity variable was created by assigning a code of 1 to all the events identified as positive by the two samples and by assigning a code of 0 to the events identified as negative or neutral. In contrast, the negativity variable was created by assigning a code of 1 to all the events identified as negative by the two samples and by assigning a code of 0 to the events identified as positive or neutral.

Table 1
Means and Standard Deviations for the Measures Collected in Studies 1 and 2

	Study 1		Study 2	
Scale	*M*	*SD*	*M*	*SD*
Spatial Working Memory	.35	.16	.38	.15
Verbal Working Memory			.51	.22
Remember/Know (across all events)			2.36	.61
Transportation (across all events)	5.00	1.19	4.77	1.11

Note. $N_{\text{Study 1}} = 54$ individuals; $N_{\text{Study 2}} = 74$ individuals.

Hierarchical Linear Modeling Analyses

Due to the dependency in our repeated measures data, as well as the unequal number of cases in each group (i.e., unequal number of positive, negative, and neutral events), we used hierarchical linear regression models to test our hypotheses (HLM 6.03; Raudenbush, Bryk, & Congdon, 2005). Hierarchical linear regression produces essentially the same parameter estimates as simple linear regression but uses more appropriate estimates of standard errors to test statistical significance. In the model, transportation ratings for each public event (Level 1) were nested within individuals (Level 2). Our statistical hypotheses concerned both the relationship between Level 1 variables (i.e., transportation ratings and event valence) and the effect of the Level 2 variable, working memory capacity, on the Level 1 outcome variable, transportation ratings. In all the analyses reported below, the Level 1 predictor variables were left uncentered because they were already effect coded, while the Level 2 predictor variable (i.e., spatial working memory capacity) was grand-mean centered (Nezlek, 2001; Paccagnella, 2006). As in simple regression, the outcome variable, transportation ratings, was uncentered. Because most data departed from normality and violated the heterogeneity of variance assumptions, we calculated parameter estimates using robust standard errors (Hox, 2002; Kane et al., 2007).

Event Valence

In order to test the hypothesis regarding the effect of emotional arousal (irrespective of valence) on transportation ratings, we ran a random-effects regression model predicting transportation ratings from public event positivity and negativity. Results of these analyses suggested that the random effect of valence is nonsignif-

[3] To ensure consistency across the two studies and to increase the age group-based objectivity of the valence ratings, we computed the valence assigned to each event based on the ratings given by our participants across the two samples included in the current article.

icant. Consequently, following Nezlek's (2001) recommendations, in all the analyses reported next, only the intercept for transportation ratings was modeled as random, while negativity and positivity were modeled as fixed effects.

Transportation. Emotional events elicited higher transportation levels relative to neutral events; the effect was significant for negative events, $b = .56$, $SE = .07$, $t(1077) = 7.77$, $p < .0001$, and for positive events, $b = .46$, $SE = .08$, $t(1077) = 5.49$, $p < .0001$.

Spatial Working Memory Capacity

Spatial working memory capacity was entered as a Level 2 moderator of the effect of positivity on transportation in retrieved memories. As presented in Table 2, results of this regression analysis confirmed our hypothesis that participants with higher spatial working memory capacity gave higher transportation ratings for positive events relative to negative or neutral ones, $b = 1.10$, $SE = .41$, $t(1076) = 2.68$, $p < .01$. In contrast, we found no evidence that spatial working memory capacity moderates the effect of event negativity on transportation or that it influences baseline transportation levels.

In sum, as presented in Figure 1, the results of Study 1 revealed that executive attention resources, as measured by a complex spatial working memory task, uniquely enhanced older adults' transportation in retrieved memories associated with positive public events. In contrast, we found no evidence that executive attention resources exerted any effect on older adults' transportation in their memories of remote negative or neutral public events.

STUDY 2

Study 2 was intended to replicate and extend the findings of Study 1. First, we examined whether the effect of executive attention abilities on older adults' experiences associated with the retrieval of positive public events, found in Study 1, was accounted for by the effect of executive attention on older adults' ability to recover detailed memories associated with those public events. Previous research suggested that older adults exhibit superior memory for laboratory-created positive pictorial material (e.g., Charles et al., 2003) and that this effect may be modulated by cognitive control resources (Mather & Knight, 2005, Experiment 2). However, the specific role of executive attention resources, as one type of cognitive control, on older adults' memory for real-life events that they had experienced long time ago is still largely unknown. In order to address these questions, in Study 2 we had participants also complete the Remember/Know paradigm, one of the standard instruments for assessing retrieval from the long-term memory store (Gardiner, 1988; Gardiner & Java, 1991; Gardiner & Parkin, 1990; Knowlton & Squire, 1995; Wheeler & Buckner, 2004). Research on laboratory-acquired memories showed that executive attention had a more noticeable influence on Remember responses than on Know responses at encoding (Gardiner & Richardson-Klavehn, 2000), but it had little effect on either at retrieval (Moscovitch, Yaschyshyn, Ziegler, & Nadel, 2000), with which this study is concerned.

Second, Study 2 was intended to extend the finding of Study 1 on the role of executive attention resources on the age-related positivity effect in transportation in memories of real-life stimuli. As such, participants completed both a spatial and a verbal working memory task. Following current guidelines in the literature, participants' average performance on these two tasks was used as an indicator of their executive attention resources (e.g., Kane et al., 2007).

Method

Participants

Study 2 included 74 (37 men) neurologically intact older adults between the ages of 64 and 79 ($M = 76.59$ years, $SD = 5.51$ years). They had completed between 8 and 25 years of education ($M = 15.40$ years, $SD = 3.44$ years). The sample had the same general characteristics as the sample of Study 1.

Table 2
Unstandardized Regression Coefficients With Standard Errors and Values for the Corresponding Significance Tests From the Regression Analyses Predicting Recollective Experience (i.e., Transportation) Ratings

		Study 1			Study 2		
Outcome	Predictor/Interaction	*b*	*SE*	*t*	*b*	*SE*	*t*
Transportation	Positivity	.46	.08	5.49[a]	.60	.05	12.20[b]
Transportation	Negativity	.56	.07	7.77[a]	.47	.06	8.17[b]
Transportation	Remember/Know				.86	.06	14.53[c]
Transportation	Positivity × Spatial Working Memory	1.1	.41	2.68[d]	.55	.20	2.73[e]
Transportation	Positivity × Verbal Working Memory				.24	.14	1.71[e]
Transportation	Positivity × Executive Attention				.43	.19	2.31[e]
Transportation (after accounting for participants' actual memory of public event details)	Positivity × Spatial Working Memory				.54	.26	2.05[f]
Transportation (after accounting for participants' actual memory of public event details)	Positivity × Verbal Working Memory				.33	.16	2.02[f]
Transportation (after accounting for participants' actual memory of public event details)	Positivity × Executive Attention				.51	.23	2.18[f]

Note. $N_{\text{Study 1}} = 54$ individuals; $N_{\text{Study 2}} = 74$ individuals.
[a] $df = 1077$. [b] $df = 1477$. [c] $df = 1478$. [d] $df = 1076$. [e] $df = 1476$. [f] $df = 1475$.

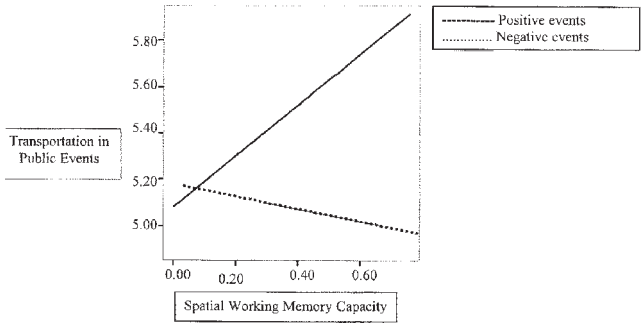

Figure 1. Transportation in positive and negative public events (*y*-axis) as a function of spatial working memory capacity (*x*-axis) in Study 1.

Procedure

The study involved a single 2-hr long experimental session, during which participants completed two batteries of computer-administered tasks in fixed order: a battery of working memory (i.e., spatial and verbal) tasks, as well as a battery of memory tasks involving 20 public events.

The public event battery included the following tasks administered in fixed order: a Remember/Know task assessing memory performance, a narrative transportation task assessing participants' current absorption in their memories associated with each public event, as well as a valence rating task, where participants rated the valence of each of the public events presented to them. The Remember/Know, the narrative transportation, and the valence rating tasks were presented as self-paced computer-administered surveys, where the event order was randomized for each participant. Prior to the beginning of the public event battery, participants were informed that they would be presented with a set of public event headlines. At the beginning of each task, participants were made aware that the same set of public events was used for all three tasks.

Materials

Working Memory Tasks

In addition to the automated e-prime version of the Symmetry Span task used in Study 1, for Study 2, we downloaded the automated e-prime version of the Reading Span task (Unsworth et al., 2005) from Randall Engle's Web site (Engle, 2006).

The reading span task has the same structure as the symmetry span task, where the presentation of the to-be-remembered stimuli is embedded within the context of a processing task. Specifically, in the reading span task, participants verify the meaningfulness of various sentences presented on the computer screen, while also attempting to keep in mind the letter that follows each sentence. The number of memory items ranges from three to seven items (Unsworth et al., 2005). There are three trials at each memory level for a total of 15 recall trials.

The participants' verbal working memory span scores are automatically reported at the end of the task. In order to ensure sufficient range for performing correlational analyses, for all the analyses reported next, we used the more lenient total correct score for both the spatial and the verbal working memory task.

Following current guidelines in the literature (Kane et al., 2007), we used average performance on the spatial and verbal working memory span tasks as an indicator of executive attention abilities.

Public Event Task

Public event selection. We used the same set of public events from Study 1.

Remember/Know task. Participants were asked to make a Remember/Know judgment for each of the 20 public events included in the test set. The participants were instructed to give a *Remember* response to a public event if they could recollect a particular image from the TV, radio, or newspaper coverage of the respective event or a personal experience associated with it, such as their thoughts, emotions, or the specific circumstances under which they first found out about the event. In contrast, participants were instructed to give a *Know* response to a public event that was only familiar to them but for which they could not recollect any personal experience or any specific event details that would allow them to reexperience the specific event. Finally, the participants were informed that the public event set may also include more obscure events, about which they may not have heard, in which case they should give a *don't know* response. To ensure objective assessment of memory, the experimenter prompted the participants to justify all their responses by providing an oral account of the memories on which they based their decision. The information provided by the participants was verified against published sources on the respective public event. If the information provided was wrong, the response was scored as a "don't know."

Transportation task. Participants' transportation in their memory of each public event was assessed with the same measure used in Study 1. Our adapted seven-item scale of narrative transportation demonstrated reasonable internal consistencies for each story (median alpha value of .66; alphas ranged from .49 to .79). Participants' responses to the seven scale items were averaged to obtain indices of transportation in each public event.

Valence rating. Following the transportation task, participants rated on a 7-point scale (1 = *highly negative* to 7 = *highly positive*) the valence of each of the 20 public events.

Results and Discussion

Preliminary Analyses

Table 1 presents the means and standard deviations for the measures collected in Study 2. Participants' responses in the Remember/Know task were coded as 1 for *don't know*, 2 for *know*, and 3 for *remember*. As presented in Table 1, the majority of the events were known to the participants.

Composite Event Valence

Since the valence assignment was done based on the ratings provided by both samples in order to increase the objectivity of the valence ratings, the public events in Study 2 were assigned the same valence values as in Study 1.

Hierarchical Linear Modeling Analyses

As in Study 1, we used hierarchical linear regression models to test our hypotheses (HLM 6.03, Raudenbush et al., 2005). Because

most data departed from normality and violated the heterogeneity of variance assumptions, we calculated parameter estimates using robust standard errors (Hox, 2002; Kane et al., 2007). The main findings of Study 2 are presented in Figure 2.

Event Valence

In order to test whether arousal increases transportation and Remember/Know rates, we ran a random-effects regression model predicting transportation ratings and Remember/Know responses from public event positivity and negativity. Results of both analyses suggested that the random effect of valence is nonsignificant. Consequently, following Nezlek's (2001) recommendations, in all the analyses reported next, only the intercept for transportation ratings and Remember/Know responses, respectively, was modeled as random, while negativity and positivity were modeled as fixed effects.

Transportation. As in Study 1, emotionally valenced events elicited higher transportation ratings relative to neutral events; the effect was significant for negative events, $b = .47$, $SE = .06$, $t(1477) = 8.17$, $p < .0001$, as well as for positive events, $b = .60$, $SE = .05$, $t(1477) = 12.20$, $p < .0001$.

Remember/Know response rates. We investigated the relationship between participants' memory of public event details and their transportation in their memories of those events. Remembered public events were found to have elicited greater transportation levels relative to known events, which in turn elicited greater transportation levels relative to not known events, $b = .86$, $SE = .06$, $t(1478) = 14.53$, $p < .0001$.

Next, we investigated the effect of valence on Remember/Know response rates. Similarly to the effect of valence on transportation, we found that emotionally valenced events elicited higher Remember/Know response rates relative to neutral events: for positive events, $b = .37$, $SE = .03$, $t(1477) = 12.21$, $p < .0001$, and for negative events, $b = .18$, $SE = .03$, $t(1477) = 7.41$, $p < .0001$. Additionally, following up on Charles et al.'s (2003) and Mather and Knight's (2005) findings, we investigated whether positive public events elicited higher Remember/Know response rates relative to negative and neutral events. In order to address this question, we imposed equality constraints on the effect of positivity and negativity on Remember/Know response rates. Results of this analysis revealed that positive public events elicited the highest memory rates.

Finally, we investigated whether the effect of emotional arousal on transportation levels remains significant after accounting for the effect of participants' actual memory of public event details. As presented in Table 2, results of the regression analyses where Remember/Know responses were introduced as Level 1 predictors together with the valence variables brought support to the hypothesis that arousal exerts an effect on transportation levels, even after accounting for memory of story details: for negative events, $b = .32$, $SE = .05$, $t(1476) = 6.00$, $p < .0001$, as well as for positive events, $b = .30$, $SE = .05$, $t(1476) = 5.75$, $p < .0001$. Results of the analysis where we imposed equality constraints on the effect of positivity and negativity on transportation in participants' memories of public events revealed though that, after accounting for the participants' memory, positive and negative public events elicit similar levels of transportation.

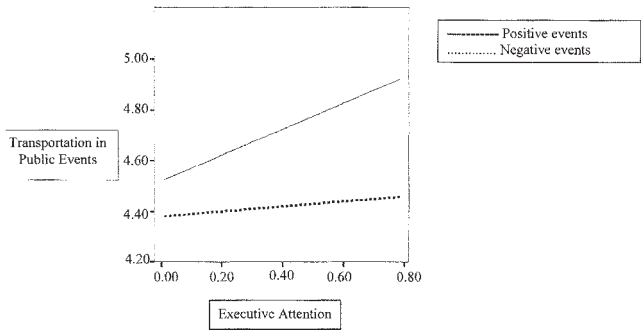

Figure 2. Transportation in positive and negative public events, after accounting for objective memory scores (*y*-axis), as a function of executive attention (*x*-axis) in Study 2.

Executive Attention

Finally, we examined whether executive attention, the shared component of the spatial and verbal working memory systems, moderates the effect of event positivity on recollective experiences. Consistent with this hypothesis, we found that the executive attention score, computed as the average between the spatial and verbal working memory scores (see Kane et al., 2007), moderated the effect of event positivity on transportation, $b = .43$, $SE = .19$, $t(1476) = 2.31$, $p < .05$. As presented in Table 2, this effect remained significant after accounting for the influence of memory on transportation, $b = .51$, $SE = .23$, $t(1475) = 2.18$, $p < .05$. We found no evidence that executive attention would exert any effect on transportation on negative or neutral events or on Remember/Know response rates (irrespective of event valence).[4]

Discussion

Our present research was based upon a growing body of evidence documenting age-specific information processing biases, namely that, relative to younger adults, older adults tend to focus away from negative information and toward positive information (e.g., Isaacowitz et al., 2006; Knight et al., 2007). This age-related shift in processing biases has been proposed to reflect older adults' enhanced motivation to maximize their well-being (Carstensen et al., 1999; Carstensen & Mikels, 2005).

Drawing upon recent evidence that the implementation of older adults' goal of maximizing their well-being is supported by cognitive control resources, our current research focused on one type of cognitive control, previously found to support the age-related processing biases, namely the executive attention resources (Mather & Knight, 2005). Specifically, we examined the differential effect of individual differences in executive attention on the antinegativity and positivity biases, respectively, associated with older adults' recollective experiences of real-life stimuli (i.e., remote public events). Across two studies, our main finding was that, within the older adult group, individual differences in exec-

[4] Preliminary analyses indicated that each individual measure (i.e., verbal and spatial working memory task, respectively) exerted a similar effect on transportation as the combined executive attention measure.

utive attention resources had a unique effect on transportation in retrieved memories of positive public events, but they had no effect on transportation in memories of neutral or negative events. We also extended previous findings regarding the age-related positivity effect in long-term memory (Charles et al., 2003; Mather & Knight, 2005) by showing that, irrespective of executive attention resources, older adults have better memory for positive (relative to negative or neutral) public event stories.

Our present results have several implications for theories of emotion and memory. Broadly, our results suggest that distinct cognitive control mechanisms underlie the memory-related positivity biases in older adults. Furthermore, the unique effect of executive attention resources on transportation in memories associated with positive events suggests the possibility of qualitative differences among recollective experiences associated with positive, negative, and neutral events (at least in the older adult group). Specifically, executive attention processes have been previously found to depend upon the functioning of a DLPFC-centered network (Engle & Kane, 2004). In the affective neuroscience literature, a neurocognitive control system, centered around the DLPFC, has been found to support the reinterpretation of the meaning of a stimulus in order to increase or decrease one's emotional response to it (for a review, see Ochsner & Gross, 2005). Based on our findings that DLPFC-dependent executive attention resources exert a unique effect on recollective experiences associated with positive events, one venue for future research is to examine the recollective accounts of the high versus low executive attention older adults. As such, the question arises whether this group's elevated transportation in their memories associated with positive events can be accounted for by their increased elaboration on the meaning of positive stimuli, which would in turn augment their emotional responses to them. This conjecture of increased elaboration on the meaning of positive stimuli is consistent with previous research showing enhanced elaborative processing of positive stimuli (relative to negative and neutral stimuli) and time-dependent increasing differences in the memory representations associated with positive versus negative stimuli in older adults (Mather & Knight, 2005, Experiment 1).

The absence of an effect of individual differences in executive attention on recollective experiences associated with negative events suggests that the previously documented memory-related antinegativity effect in older adults (e.g., Mather & Knight, 2005) draws upon a distinct neurocognitive control system. Based upon Mather and Knight's (2005) study, the neural network centered around the frontal polar area (i.e., BA 10; Johnson, Mitchell, Raye, & Greene, 2004) represents a compelling candidate for the neurocognitive control system underlying the antinegativity bias in older adults' memory. In older adults, specifically, activity in this frontal polar area has been found to support their ability of bringing back to mind recently presented information (i.e., the refresh task; Johnson et al., 2004). In the clinical literature, a network encompassing the frontal polar area (i.e., BA 10) and the anterior cingulate cortex (i.e., BA 32) has been found to underlie posttraumatic stress disorder (PTSD) patients' dampened physiological responses to memories of the traumatic episode and increased vigilance in the present (for dissociative PTSD symptoms, see Lanius et al., 2002). Our conjecture that the aforementioned frontal polar network underlies the antinegativity effect observed in older adults could also account for previous findings that, unlike younger adults, older adults rate negative stimuli as less arousing than positive stimuli (Mather et al., 2004). This phenomenon has been interpreted as reflecting a dampened physiological response to negative stimuli in older adults, supported by cognitive control processes (see Mather et al., 2004). Future research needs to investigate directly the role of the proposed frontal polar network as a candidate for the neurocognitive control system underlying the antinegativity effect in older adults. Future studies could also examine the qualitative characteristics of older adults' recollective experiences associated with negative events as a function of individual differences in the functioning of the aforementioned frontal polar system.

Our current research focused on how older adults currently experience their memories of remote public events, as opposed to how well they recall those events. Nonetheless, results of Study 2 suggested that how successful participants were in retrieving their memories of the public events influenced their current experience of those events. As such, participants were most absorbed by public event stories for which they could recollect specific details (i.e., they gave a *Remember* response). Similarly, events familiar to the participants (i.e., events to which they had given a *Know* response) elicited higher transportation levels relative to unfamiliar events. Study 2 also revealed that older adults exhibited better memory for positive relative to negative or neutral public events, an effect that was of a similar magnitude for *Remember* and *Know* responses. However, executive attention resources modulated only the participants' transportation in their memories associated with positive events, but it exerted no significant effect on either Know or Remember responses for events of either valence. This finding suggests that executive attention resources exert the strongest effect on the elaborative processes, which occur once the memory has been retrieved, but they have a nonsignificant effect on the actual memory for real-life emotional stimuli. The latter result is consistent with previous findings that, under most circumstances, memory retrieval is obligatory, if appropriately cued (Craik et al., 2000; Moscovitch et al., 2000; but see Fernandes, Davidson, Glisky, & Moscovitch, 2004, and Fernandes, Moscovitch, Ziegler, & Grady, 2005).

Our finding that memory was better for the more positive public events suggests that, prior to the study, those positive events may have been elaborated more when they were retrieved in real life, and perhaps rehearsed more often, thus leaving a stronger residue in memory by the time participants entered our study. It is also possible that DLPFC-dependent executive attention resources modulate the consolidation or reencoding of positive public events. As such, it may be the case that older adults with high executive attention abilities bring up positive (autobiographical or autobiographically significant) events more often in conversations, which may result in multiple memory traces associated with positive events (Moscovitch & Nadel, 1998; Moscovitch et al., 2005; Nadel & Moscovitch, 1997), finally leading to richer experiences associated with them, when they are retrieved at a later time. This conjecture is consistent with previous findings that positive stimuli benefit from more elaborative processing relative to negative or neutral stimuli (Mather & Knight, 2005, Experiment 1). However, future research needs to investigate directly the aforementioned hypotheses regarding the impact of age-related processing biases on long-term memory formation processes.

Given recent findings that similar neural mechanisms are implicated in constructing an imagined event as in reconstructing a memory (Hassabis, Kumaran, Vann, & Maguire, 2007; Schacter, Addis, & Buckner, 2007), a project for future research would be to examine the effect of executive attention resources on older adults' construction of positive (relative to negative or neutral) fictional events and their subsequent valence-dependent absorption in the imagined emotional events. Another worthwhile venue for future research would be to examine memory formation processes associated with emotional events. Our current studies presented preliminary evidence that executive attention resources contribute to the older adults' elevated transportation in their memories associated with positive public events. However, the question arises whether executive attention resources also exert an effect on the encoding of positive events, such that older adults with superior executive attention resources are able to create richer memory representations for positive events relative to negative or neutral events.

Though some questions remain, our present research constitutes an important first step in examining the effect of age-related processing biases and executive attention resources, presumably mediated by the DLPFC, on very remote memory for public events. Future studies need to expand our work by investigating the impact of age-related processing biases and cognitive control mechanisms at different stages from memory formation to retrieval, elucidating the distinct neurocognitive control mechanisms modulating the age-related positivity and antinegativity bias, respectively, as well as their distinct effects of the rememberer's subjective experience and well-being.

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