

1-1-2011

Aging And Emotional Effects On Working Memory And Long-Term Memory For Target And Distracting Information

Linda Truong
Ryerson University

Follow this and additional works at: <http://digitalcommons.ryerson.ca/dissertations>



Part of the [Psychology Commons](#)

Recommended Citation

Truong, Linda, "Aging And Emotional Effects On Working Memory And Long-Term Memory For Target And Distracting Information" (2011). *Theses and dissertations*. Paper 1645.

AGING AND EMOTIONAL EFFECTS ON WORKING MEMORY AND LONG-TERM
MEMORY FOR TARGET AND DISTRACTING INFORMATION

by

Linda Truong

B.Sc. (Hons) Specialist in Psychology, University of Toronto, 2008

A thesis

presented to Ryerson University

in partial fulfillment of the

requirements for the degree of

Master of Arts

in the Program of

Psychology

Toronto, Ontario, Canada, 2011

©Linda Truong 2011

Author's Declaration

I hereby declare that I am the sole author of this thesis or dissertation.

I authorize Ryerson University to lend this thesis or dissertation to other institutions or individuals for the purpose of scholarly research.

Linda Truong

I further authorize Ryerson University to reproduce this thesis or dissertation by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research.

Linda Truong

Aging and Emotional Effects on Working Memory and Long-Term Memory for Target and Distracting Information

Linda Truong, B.Sc. (Hons), Master of Arts, 2011
Psychology, Ryerson University

Abstract

To resolve discrepancies between studies on the effects of emotional content on working memory, and to examine changes with age, this study examined the effects of emotional content on working memory and subsequent long-term memory for targets and distracters. Thirty-six younger (ages 18-29) and 36 older adults (ages 65-87) participated in a working memory task in which they viewed two target words intermixed with two distracters followed by a probe word, and responded to whether the probe was a target word. The emotional content (valence and arousal) of targets and distracters was manipulated. Subsequent long-term memory was tested with a free recall task. Results indicated that emotional content of targets facilitated working memory. Emotional valence of distracters disrupted working memory accuracy, with younger adults experiencing disruption from positive and neutral distracters, and older adults experiencing interference from negative distracters. Emotional effects in long-term memory were only seen for younger adults.

Acknowledgements

I would like to thank my supervisor, Dr. Lixia Yang, for her guidance throughout my thesis. Without her continuous support and belief in me, I would not have accomplished the many milestones I have achieved to date. I would also like to thank Dr. Julia Spaniol for her comments as part of my supervisory committee along the way. Many thanks to all the research assistants involved in data collection and entry for this project: Sasha Mallya, Dana Greenbaum, and Gina Polsinelli.

I'm also very grateful for having the opportunity to work alongside fellow graduate students, Andrea Wilkinson and Karen Lau; they made this entire process much more enjoyable. Last but not least, I would like to thank my family and Michael Wu for giving me the opportunity to pursue my goals of educational success and for supporting and encouraging me along the way.

This work was supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant (CCI-102930) awarded to Dr. Lixia Yang in 2009.

Table of Contents

Introduction.....	1
Method	12
Participants	12
Working Memory Task	14
Stimuli	14
Memoranda	14
Probes.....	16
Practice, buffer, and filler trials	17
Working memory task procedure	17
Long-term memory task	19
Procedure.....	19
Statistical Analyses	20
Results.....	23
Effects of Emotional Content on Target Identification in Working Memory.....	23
RT analysis.	23
Accuracy analysis.....	25
Effects of Emotional Content on Interference Resolution in Working Memory	27
RT analysis	27
Accuracy analysis.....	28
Long-term Memory: Free Recall	31
Discussion.....	37
Emotional Effects on Working Memory.....	37
Working memory for target information.....	37
Rejection responses in working memory.	38
Emotional Effects on Long-term Memory of Target and Distracting Information	39
Age Differences in Memory and Emotional Effects.....	40
Memory performance	40
Age differences in emotional target identification in working memory	40
Age differences in rejecting emotional distracters in working memory	41
Age differences in long-term memory of emotional stimuli	43
Limitations and Future Directions	44
Conclusions and Implications	46
References.....	48

List of Tables

Table 1 - Sample Characteristics	14
Table 2 - Memoranda and New Control Probe Stimuli Statistics.....	15
Table 3 - Response Times (ms) to Target Probes	23
Table 4 - Accuracy to Target Probes	25
Table 5 - Response Time (ms) to Distracter and Control Probes	27
Table 6 - Accuracy to Distracter and Control Probes	29
Table 7 - Percentage Recall (%) in the Free Recall Task	31

List of Figures

Figure 1. Working memory task procedure	19
Figure 2. The Age by Arousal interaction in RTs for correct target identification responses	24
Figure 3. The Valence by Arousal interaction in RTs for correct target identification responses	25
Figure 4. Accuracy for target identification responses	26
Figure 5. RTs for accurate rejection responses to distracter and control probes	28
Figure 6. Accuracy for rejection responses to distracter and control probes	30
Figure 7. The Age by Item Type Interaction in percentage recall (%) of incidentally encoded items during the working memory task	32
Figure 8. The Age by Valence Interaction in percentage recall (%) of incidentally encoded items during the working memory task	33
Figure 9. The Item Type by Valence Interaction in percentage recall (%) of incidentally encoded items during the working memory task	34
Figure 10. The Item Type by Valence by Age Interaction in percentage recall (%) of incidentally encoded items during the working memory task	35

Aging and Emotional Effects on Working Memory and Long-Term Memory for Target and Distracting Information

Extensive cognitive aging research has demonstrated that older adults experience deficits in working memory performance (e.g., Borella, Carretti, & de Beni, 2008; Paxton, Barch, & Racine, 2008) and long-term memory (for review, see Craik & Jennings, 1992). Various theoretical accounts of basic cognitive mechanisms underlying these age-related memory changes have been proposed, including general slowing in processing speed (Salthouse, 1996), reduced cognitive capacity or lower working memory span (Craik, 1986 book chapter; also see Conway et al., 2008 for a review), and inhibitory deficits (Hasher & Zacks, 1988). Inhibitory deficit theory assumes that deficits in inhibition, the ability to stop distracting or irrelevant information from entering working memory, underlie most age-related cognitive declines (Hasher & Zacks, 1988). This theory has been used to explain age-associated declines in working memory performance. According to this theory, one function of inhibition is to maximize information processing efficiency by constraining attention such that only goal-relevant information enters the system (Hasher, Lustig, & Zacks, 2007). This is typically termed the access function of inhibition (Hasher, 2007). Any information that is goal-irrelevant (e.g., distraction) but manages to gain access to working space reduces the efficiency of information processing. A second function of inhibition, termed deletion (Hasher, 2007), suppresses and removes competing information from consciousness and allows interference to be resolved. From this framework, older adults' deficits in working memory may be due to ineffective inhibitory functioning, which makes it more difficult to resolve interference from distracting or competing information and consequently impairs performance (e.g., Hedden and Park, 2001). This interference may also have implications for subsequent long-term memory performance.

For example, Gerard, Zacks, Hasher, and Radvansky (1991) found a “fan effect”, where recognition of target information declined as the amount of competing information associated with the target increased (i.e., a larger “fan”). This fan effect was larger for older adults relative to younger adults. They proposed that older adults’ poorer performance was due to age-related decline in the ability to initially inhibit irrelevant or competing information from working memory (during encoding), which caused greater interference during subsequent retrieval. Thus, deficits in inhibitory functioning may explain age-related declines in both working memory and long-term memory. This perspective provides the theoretical framework for the current study, which aimed to examine the effects of aging and emotional content on working memory and long-term memory for target and distracting information.

Research on inhibition has demonstrated that older adults are more susceptible to distraction than younger adults (e.g., Carlson, Hasher, Zacks, & Connelly, 1995; Rowe, Valderrama, Hasher, & Lenartowicz, 2006). This susceptibility causes older adults to attend to task-irrelevant items, which may subsequently interfere with their processing of task-relevant items (Hasher, Quig, & May, 1997). It is this difficulty with inhibiting and ignoring distracters that makes it more difficult for older adults to resolve interference (e.g., Darowski et al., 2008; Ikier, Yang, & Hasher, 2008; Lustig, May, & Hasher, 2001; Yang & Hasher, 2007). Indeed, a lack of suppression does appear to impair working memory performance, as was demonstrated in a study by Gazzaley, Cooney, Rissman, & D’Esposito (2005). This study adopted a working memory paradigm that placed targets and distracters in competition. Younger and older adults were asked to remember two face stimuli and ignore two scene stimuli, or vice versa (i.e., to remember two scene stimuli and ignore two face stimuli), or passively view faces and scenes. All stimuli were presented sequentially on a computer screen. After a delay period, a probe face or

scene appeared and participants indicated whether this was a target in the current stimulus set (i.e., to-be-remembered face or scene stimuli). In the passive view condition, participants only had to indicate the direction of a presented arrow (not a memory task). Because this paradigm was coupled with fMRI scanning, Gazzaley et al. (2005) were able to compare cortical activity during these three conditions to calculate physiological measures of enhancement and suppression. They found that older adults, compared to younger adults, experienced a deficit with suppressing cortical activity associated with irrelevant information that had entered working memory. This deficit correlated with behavioural measures, such as lower accuracy scores and slower response times.

Research has also been conducted on the effects of inhibitory deficits on long-term memory. Zacks, Radvansky, and Hasher (1996) examined age differences in four directed forgetting experiments. Of particular interest are the results from recall tests, in which older adults recalled a greater proportion of the to-be-forgotten words (i.e., intrusions of distracters) than did younger adults, despite explicit instructions to only recall to-be-remembered words (i.e., targets). The authors attributed these differences in recall to age-related deficits in inhibition, with older adults demonstrating less efficient suppression of irrelevant information. This effect is not limited to explicit memory; studies have also demonstrated that older adults have better implicit memory for distracters incidentally encoded previously (e.g., Campbell, Hasher, & Thomas, 2009; Kim, Hasher, & Zacks, 2007; Rowe, Valderrama, Hasher, & Lenartowicz, 2006). In a more recent study, Gopie, Craik, and Hasher (2011) compared younger and older adults' implicit and explicit memory for irrelevant information (i.e., distracter words) incidentally encoded during a colour judgement task. Memory for distracter words was measured with either an explicit or an implicit word fragment completion task. In the explicit condition, participants

were instructed to complete fragments using words from the colour judgement task; no such instructions were given in the implicit condition. The results revealed a double dissociation between age effects and the type of memory task: Younger adults remembered more distracters than older adults on the explicit memory task but the results were reversed for the implicit task. Taken together, these studies demonstrate how age-related deficits in inhibitory functioning may contribute to age differences observed in long-term memory for target and/or distracting information.

In contrast to widely reported cognitive deficits in older adults, research has demonstrated that various abilities remain stable with age. Of particular relevance to this study are the findings that emotional processing remains stable, or even improves, with age (Charles & Carstensen, 2004; Kensinger, 2008). A positivity shift with advanced age, noted by better memory for positive versus negative content has further been observed (Charles, Mather, & Carstensen, 2003). Socioemotional selectivity theory has been outlined to explain why emotional stimuli (conceptualized as stimuli that are high in arousal and valence; see Russell, 1980, and Lang, Bradley, & Cuthbert, 1990, on the Circumplex Model of Affect), or rather positive stimuli specifically, predominantly capture the attention of older adults (Carstensen, Isaacowitz, & Charles, 1999). This theory explains that as older adults approach end of life and perceive their time as limited, more resources are devoted towards regulating emotion in order to achieve emotional goals. This motivation drives older adults to prioritize emotional information that is relevant to their goals. Thus, emotional regulation to maintain satisfactory mood and processing of emotionally gratifying information (e.g., positivity effect) remains stable, or even improves, with age. However, this shift towards positive emotion does not occur effortlessly. A considerable body of studies have demonstrated that this age-related positivity shift occurs in

explicit controlled processing or for high executive functioning older adults only (Kensinger, 2008; Mather & Knight, 2005; Petrican, Moscovitch, & Schimmack, 2008; Talmi, Schimmack, Paterson, & Moscovitch, 2007; Thomas & Hasher, 2006; Yang & Hasher, 2011). Thus, it appears that older adults intentionally and selectively invest more effort to enhance their emotional regulation and processing.

Thus far, I have reviewed literature that demonstrates how older adults' inhibitory deficits may affect working memory and long-term memory, coupled with literature on older adults' stable, or enhanced, emotional processing abilities. However, to our knowledge, there is no research that has addressed whether maintained emotional processing in older adults helps them with activating and inhibiting emotional information in working memory, and whether these effects influence subsequent long-term memory. To this end, the current study addressed the following questions: 1) does emotional content *facilitate* or *hinder* working memory? 2) do the effects of emotional content for incidentally encoded information extend to subsequent long-term memory? and 3) how do these effects change with age? Insights into these questions have been obtained from some recent studies (Borg, Leroy, Favre, Laurent, & Thomas-Antérion, 2011; Dolcos & McCarthy, 2006; Levens & Phelps, 2008).

Borg et al. (2011) examined how emotional content can facilitate working memory, and how these effects vary with age by comparing younger and older adults (comparisons with Alzheimer's disease patients were also conducted, but are not of relevance to this paper). Participants were presented with 2 negative and 2 neutral pictures, presented sequentially for 850 ms each. The task was to maintain these 4 targets during a 4500 ms delay, after which a probe picture appeared. Participants had to indicate whether this probe was from the target set or if it was a new picture they had not seen before. For both age groups, accuracy on this task was better

when stimuli were negative versus neutral. Thus, it appeared that the emotional content of target information facilitated working memory performance in both younger and older adults.

These results conflict with those from Dolcos and McCarthy's 2006 study that used a delayed-response working memory task to examine the effect of emotional distracters on recognition of target stimuli. On each trial, participants were presented with three memoranda (pictures of neutral faces), followed by a delay of 6000 ms during which distracter stimuli were presented. The distracter stimuli were either emotional scenes (negative and high-arousing), neutral scenes (neutral and low-arousing), or digitally scrambled versions of these pictures (which served as a perceptual control). Participants had to inhibit the distracters in order to maintain memoranda in working memory. Following this delay, a probe face appeared and participants indicated whether or not this probe belonged to the current memoranda set. The results showed that correct identification of probes was best when scrambled pictures were presented as distracters, declined when neutral scenes were presented, and was the worst when emotional scenes were presented. Thus, the emotional content of distracters disrupted working memory.

A comparable study was conducted by Levens and Phelps (2008) to examine emotional effects on proactive interference resolution in younger adults. This study modified a recency-probes paradigm to include emotional and neutral stimuli and it required participants to successfully resolve proactive interference produced by previous trials. For each trial, participants encoded three target stimuli. After a 3000 ms delay, a probe appeared and participants had to indicate "yes" if this probe belonged to the current target set. There were four different probe types: (1) from the current target set only (nonrecent yes-response); (2) from the target sets in the preceding two trials only (recent no-response); (3) from neither the current set

or preceding target sets (nonrecent no-response); and (4) from both the current and preceding target sets (recent yes-response). In this paradigm, interference is only present in the recent no-response trials. In order to examine how emotional content of stimuli affects interference resolution, trials were split into two conditions: a neutral condition, where only neutral stimuli were used as targets and probes, and an emotion condition, where target sets contained one to three emotional stimuli. The trials in the emotion condition were further classified into a condition where the probes were emotional or a condition where probes were neutral and targets were emotional. Results demonstrated a sizable proactive interference (i.e., response times to recent no-response trials were significantly longer than nonrecent no-response trials). This interference effect differed across conditions; response times to reject a distracter from a previous trial were shorter when the probe was emotional versus when it was neutral. These results indicate that emotional content reduces proactive interference and facilitates working memory performance.

These studies provide some insights into how emotional content can affect working memory performance. However, Borg et al. (2011) and Dolcos and McCarthy (2006) used negative distracters only, so it is unknown whether positive content would produce the same effects. In addition, distracters differed between studies, ranging from no distracters (Borg et al., 2011), distracters that were presented following all targets (Dolcos & McCarthy, 2006), and distracters that had previously served as targets in earlier trials (Levens & Phelps, 2008). Thus no information was offered on how emotion affects interference resolution when distracters are intermixed with targets, a situation most commonly experienced in the context of everyday life. Furthermore, only one of these studies tested both younger and older adults (Borg et al., 2011) but it did not include distracters, so little is known about how these emotional effects influence

older adults' ability to resolve interference in working memory. Finally, none of these studies examined subsequent long-term memory for information that was incidentally encoded during the working memory task. This final issue has been addressed in another study with younger adults (Kensinger & Corkin, 2003). Using five working memory tasks with a variety of negative and neutral stimuli (e.g., words, pictures), Kensinger and Corkin (2003) found that task accuracy did not vary by emotional content. However, on one of the tasks (an *n*-back task using fearful and neutral faces), participants had slower response times to fearful compared to neutral faces. Thus, for at least one task, the emotional content of information hindered working memory performance. In contrast, results from their tests of long-term memory, a surprise free recall task, revealed an emotional enhancement effect, with more emotional stimuli from the working memory task being recalled than neutral stimuli. However, this study did not include positive stimuli and it did not examine age differences.

Results from the research reviewed thus far on the effects of emotional content on working memory and long-term memory performance remain unclear. Borg et al. (2011) demonstrated better working memory performance for emotional targets, whereas Dolcos and McCarthy (2006) demonstrated that emotional distracting stimuli presented following targets disrupted working memory performance. Levens and Phelps (2008) demonstrated that emotional stimuli previously presented as targets facilitated working memory and Kensinger and Corkin (2003) found emotional disruption in only one out of five working memory tasks, but a robust emotional enhancement in long-term memory. These seemingly discrepant results may be resolved through manipulation of the source of emotional content (contained in either relevant targets or irrelevant distracters) in a working memory paradigm. To this end, the current study modified the delayed-response working memory paradigm used by Gazzaley et al. (2005), which

presented both targets and distracters within a memoranda set, to address the effects of emotional content (contained either in targets or distracters) in working memory for both target and distracting information.

Specifically in the current study, younger and older participants viewed a memorandum set that consisted of four sequentially presented words: two were cued as targets and two were cued as distracters. After a delay, a probe word would appear that was a target, a distracter, or a new control probe. Participants' task was to indicate whether this probe was a target word from the current memorandum set. The critical manipulation was the emotional content, as indexed by both the arousal (high vs. low) and valence (positive, negative, neutral) levels of targets and distracters. For some trials, targets were emotional words and distracters were neutral words; for others, targets were neutral and distracters were emotional. These trials were compared to trials where *both* targets and distracters were neutral words. Given that the arousal level of stimuli was not systematically controlled for in the aforementioned studies (except in Levens & Phelps, 2008 study with younger adults), as well as the available evidence that arousal does moderate age differences in emotional memory (Kensinger, 2008), the arousal level of stimuli (high vs. low) was systematically manipulated in the current study, so that half of the words were high arousal and half were low arousal within each of three valence categories: positive, negative, and neutral. Long-term memory for words incidentally encoded during the working memory task was subsequently tested in a surprise free recall task.

This paradigm allowed us to assess whether working memory and subsequent long-term memory performance was affected by the emotional content of targets and distracters. In addition, it addressed the question of whether older adults' preserved emotional processing facilitates or hinders working memory and long-term memory of targets and distracters presented

in an intermixed format. Based on the literature reviewed above, several hypotheses were proposed: (1) younger adults would outperform older adults in overall working memory and long term memory performance, consistent with the vast literature on age-related declines in these cognitive domains; (2) older adults may specifically have trouble with rejecting distracters from working memory versus identifying targets, in line with results from Gazzaley et al. (2005) who found age-related suppression deficits for task-irrelevant information, but preserved activation of task-relevant information; (3) emotional content would affect working memory: emotional content of targets would be facilitative to target identification (e.g., Borg et al., 2011), whereas the emotional content of distracters would be disruptive for the interference resolution of distracting information (e.g., Dolcos & McCarthy, 2006; Levens & Phelps, 2008); (4) emotional content would enhance long-term recall (e.g., Kensinger & Corkin, 2003); and (5) the emotional effects for older adults may manifest in two different ways: Older adults may show a differentially larger emotional effect than younger adults, as predicted by the socioemotional selectivity theory. However, given the evidence that older adults need to recruit controlled process to enhance emotional regulation and processing (e.g., Kensinger, 2008; Mather & Knight, 2005), it is also possible that older adults may show less emotional enhancement in such a highly resource-demanding working memory task in the face of distraction, which may consequently constrain controlled emotional processing.

In summary, this study aims to examine emotional effects on working memory and long-term memory for targets and distracters and how these effects might vary by age. Through examining the complex interactions between aging, emotion, and cognition, this study will make novel contributions to the existing literature in each of these domains. Specifically, it will provide insightful information into how and when emotional content helps or hinders memory

performance of younger and older adults. In doing so, it will resolve discrepancies between previous studies by manipulating the emotional content of both target and distracting information within the same task. This study also manipulates arousal in addition to valence. Arousal has frequently been ignored in the literature, despite research demonstrating the unique contributions of arousal (e.g., Kensinger, 2008). Finally, this study examines subsequent long-term memory for target and distracting information incidentally encoded during working memory, and examines how this varies by emotional valence and age. This avenue of research is particularly important given that older adults experience declines in memory, but usually spared emotional processing.

Method

Participants

Thirty-six healthy younger adults (ages 18-29, $M = 19.69$, $SD = 2.84$; 3 males) and 36 healthy older adults (ages 65-87, $M = 73.25$, $SD = 6.37$; 6 males) were recruited for this study. Three older adults were replaced due to accuracy (see Results). One older adult was replaced due to computer malfunctions and one older adult was replaced due to a high Short Blessed Test score. Younger adults were recruited from the undergraduate participant pool at Ryerson University. They received course credit as compensation. Older adults were recruited from the older adult participant pool at The Psychology Research and Training Centre at Ryerson University and received \$10 per hour of participation. All participants were tested at the Cognitive Aging Laboratory of Ryerson University and provided informed consent before commencing the study.

Exclusion criteria for all participants in this study included: (a) English learned after the age of 6; (b) scores less than 20 on the Shipley Institute of Living Vocabulary (Shipley, 1946); (c) scores greater than 26 on the Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988), suggesting severe anxiety symptoms; (d) scores greater than 29 on the Beck Depression Inventory (BDI; Beck, Rush, Shaw, & Emery, 1979), suggesting severe depressive symptoms; (e) previous neurological disorders (e.g., stroke, dementia, prolonged periods of unconsciousness, and head injury); (f) uncontrolled medical conditions (e.g., diabetes, cholesterol, and cardiovascular diseases). Older adults were screened with the Short Blessed Test (SBT; Katzman et al., 1983) for dementia-related cognitive impairments, with all of them in the final sample scoring above the cut-off score of 6 ($M = 0.78$, $SD = 1.35$). All demographic and

health information was collected through a background information questionnaire and a telephone prescreening for older adults.

There were age differences in several demographic and cognitive measures (see Table 1). Older adults had more years of education than younger adults and also learned English at a younger age. Younger adults were faster on the Digit-Symbol Substitution Task (DSST; Wechsler, 1981) and had lower positive affect scores on the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). Older adults scored higher on the Shipley Institute of Vocabulary Test (Shipley, 1946) than younger adults but scored lower than younger adults on the BAI (Beck, Epstein, Brown, & Steer, 1988) and the BDI (Beck, Rush, Shaw, & Emery, 1979).

Table 1

Sample Characteristics

Measure	Younger adults		Older adults	
	<i>M (SD)</i>		<i>M (SD)</i>	
Age	19.69	(2.84)	73.25	(6.37)
Years of education	13.00	(1.74)	17.53	(4.11)
Age learned English	1.13	(1.92)	0.14	(0.83)
DSST ^a	82.86	(15.37)	68.78	(14.97)
PANAS-Positive affect ^b	27.22	(7.91)	33.83	(6.40)
PANAS-Negative affect ^b	15.19	(5.48)	13.61	(4.14)
2-back number task: accuracy ^c	0.87	(0.09)	0.85	(0.08)
2-back number task: d' ^c	2.47	(0.90)	2.20	(0.83)
Shipley ^d	27.50	(3.00)	37.36	(1.93)
BAI ^e	12.67	(7.61)	6.19	(5.67)
BDI ^e	10.83	(6.67)	5.06	(4.65)
Health rating ^f	7.79	(1.13)	8.25	(1.27)
SBT			0.78	(1.35)

Note. Detailed descriptions of the measures were provided in the Procedure section. ^aDSST scores are based on the number of correct solutions, with a maximal range of 0-133; ^bPANAS scores have a maximal range of 10-50; ^c2-back accuracy is the proportional accuracy (hits and correct rejections); d' is a measure of sensitivity to target detection, calculated as $z(\text{hit rate}) - z(\text{false alarm rate})$; One older adult did not complete the 2-back task and thus was excluded from these analyses; ^dShipley scores have a maximal range of 0-40; ^eBAI and BDI scores have a maximal range of 0-63; ^fHealth ratings were self-reported on a 1 (“poor”) to 10 (“excellent”) Likert-Type scale.

Working Memory Task

Stimuli. All stimuli for the working memory (WM) task in this experiment were programmed with E-prime 1.0 and presented on a computer screen. The stimuli consisted of a total of 329 words selected from the Affective Norms of English Words (ANEW) database (Bradley & Lang, 1999). The ANEW database contains ratings of both arousal (1 for low arousal to 9 for high arousal) and valence (1 for negative valence to 9 for positive valence).

Memoranda. Each trial consisted of a set of four memoranda: two target words and two distracter words. A total of 240 words were selected to be targets ($N = 120$) and distracters ($N =$

120) and consisted of 48 positive words ($M = 7.44$, range: 6.59-8.39), 48 negative words ($M = 2.86$, range: 1.57-3.50), and 144 neutral words ($M = 4.98$, range: 4.00-6.00). Half of the words for each valence category were high in arousal (HA; $M = 5.89$, range: 4.51-7.45) and the other half were low in arousal (LA; $M = 3.86$, range: 2.39-4.48), resulting in a total of 6 word lists (one HA and one LA list for each of the three valence categories; see Table 2 for the descriptive statistics of valence and arousal).

Table 2

Memoranda and New Control Probe Stimuli Statistics

	Valence		Arousal		<i>N</i>
	<i>M (SD)</i>	Range	<i>M (SD)</i>	Range	
Memoranda					
Positive HA	7.55 (0.49)	6.84-8.39	6.14 (0.83)	4.60-7.22	24
Positive LA	7.34 (0.34)	6.59-7.92	3.73 (0.58)	2.39-4.45	24
Negative HA	2.84 (0.40)	2.09-3.50	6.17 (0.82)	4.61-7.45	24
Negative LA	2.88 (0.59)	1.57-3.43	3.93 (0.48)	2.64-4.39	24
Neutral HA	4.92 (0.66)	4.00-6.00	5.37 (0.70)	4.51-7.00	72
Neutral LA	5.04 (0.53)	4.02-5.98	3.91 (0.42)	2.65-4.48	72
New Control Probes					
Positive HA	7.61 (0.08)	7.55-7.66	5.96 (0.08)	5.90-6.02	2
Positive LA	7.20 (0.18)	7.07-7.33	4.05 (0.16)	3.93-4.16	2
Negative HA	2.85 (0.08)	2.79-2.90	6.19 (0.32)	5.96-6.41	2
Negative LA	2.75 (0.02)	2.73-2.76	4.08 (0.30)	3.87-4.29	2
Neutral HA	5.26 (0.57)	4.32-5.85	4.94 (0.25)	4.66-5.28	6
Neutral LA	4.89 (0.35)	4.39-5.33	3.60 (0.33)	3.18-3.98	6

All valence categories in the LA list were matched for arousal ($ps > .10$); positive and negative lists in the HA list were matched for arousal ($p = .90$) and both were higher in arousal than the neutral list ($ps < .001$). These six lists were then divided into two lists: targets and distracters. These two lists were matched on word frequency (Kucera & Francis, 1967) ($M = 42.21$; range 1-294) and word length (i.e., the number of letters) ($M = 6.26$; range: 3-11) ($ps > .21$).

The combination of words used in each trial varied according to trial type: (1) positive targets paired with neutral distracters (posT/neuD); (2) negative targets paired with neutral distracters (negT/neuD); (3) neutral targets paired with neutral distracters (neuT/neuD); (4) neutral targets paired with positive distracters (neuT/posD); and (5) neutral targets paired with negative distracters (neuT/negD). In each trial, one target/distracter was HA and the other target/distracter was LA. Within each trial, targets and distracters were roughly matched on arousal, frequency, and word length. For example, a neuT/negD trial consisted of one neutral HA target, one neutral LA target, one negative HA distracter, and one negative LA distracter. There were 12 trials for each trial type, resulting in a total of 60 trials. The trials in the WM task were presented in a pseudorandomized order such that no more than three trials of the same trial type occurred consecutively.

The sequencing of memoranda within a set on each trial was pseudorandomized such that there were eight possible presenting sequences. Of these combinations, four combined either two targets or two distracters in a row (e.g., distracter-distracter-target-target), and four interweaved targets and distracters (e.g., distracter-target-distracter-target). Within each condition, the sequence of the items was counterbalanced and rotated in a Latin-Square design based on emotional valence and arousal of targets and distracters.

Probes. After a brief delay following presentation of the memoranda, a probe was presented. Probes belonged to one of six categories: (1) HA targets; (2) LA targets; (3) HA distracters; (4) LA distracters; (5) HA new control probes; and (6) LA new control probes. Target and distracter probes were from the current trial memoranda set. New control probes were one of 20 additional words: 4 positive words ($M = 7.41$, range: 7.07-7.66), 4 negative words ($M = 2.80$, range: 2.73-2.90), and 12 neutral words ($M = 5.08$, range: 4.32-5.85), selected from

ANew (Bradley & Lang, 1999); half of the words in each valence category were HA ($M = 5.70$, range: 4.66-6.41) and half were LA ($M = 3.91$, range: 3.18-4.29) (see Table 2 for valence and arousal means, *SDs*, and ranges). The new control probes matched those of the distracters on valence within a trial set (i.e., a neuT/negD trial had a new control probe that was also negative).

The six probe categories occurred equally often for each trial type. The selection of probes (e.g., which target word served as the target probe for a particular trial) was counterbalanced with a Latin Square design, resulting in six counterbalance conditions. In addition, the position in which targets and distracter probes appeared in the ordering of memoranda was also counterbalanced such that each appeared equally often at each of the four possible positions (e.g., a HA target cue appeared in the first to fourth position equally).

Practice, buffer, and filler trials. An additional 69 words were selected for five practice trials that occurred before the experimental block plus six buffer and six filler trials that occurred during the experimental block. All buffer and filler trials consisted of target probes, requiring “yes” responses. Three buffer trials occurred at the beginning and the other three at the end of the block to reduce primacy and recency effects. Filler trials were randomly intermixed with experimental trials. These trials were included to balance the number of “yes” responses with those of “no” responses, so that approximately half of all the trials required “yes” responses and half required “no” responses, in order to minimize response bias.

Working memory task procedure. The WM task in this study consisted of a practice block followed by an experimental block. The practice block consisted of five trials, one of each trial type (i.e., posTneuD, negTneuD, neuTneuD, neuTposD, neuTnegD). The experimental block consisted of 72 trials, including six buffers (three at the beginning and three at the end of

the block) and six filler trials randomly intermixed with the 60 experimental trials (10 for each probe type).

Participants were asked to read instructions on a computer screen, indicating which words participants should remember (i.e., targets) and which they should ignore (i.e., distracters), as cued by blue and red font colour, or vice versa, respectively. The two colour coding combinations were counterbalanced across participants. Participants were then instructed that another word (the probe word), printed in black font, would appear. The task was to indicate “yes” if the probe word was one of the target words from the current memoranda set. Otherwise, participants responded “no”. No more than three “yes” or “no” responses occurred in a row. Participants were encouraged to respond as quickly and accurately as possible.

The trial procedure used in this task was adapted from the paradigm used by Gazzaley et al. (2005). Each trial began with a fixation cross presented for 500 ms; then four words appeared sequentially, each for 800 ms with an inter-trial interval of 200 ms. After a delay period of 500 ms, a probe word was presented. If the probe was a target word from the current set, participants were expected to press the “/” key (labeled as “YES”). If the probe was a distracter or a new control word, participants were expected to press the “z” key (labeled as “NO”). The probe word remained on the screen for 2000 ms. Participants then received an accuracy feedback screen indicating “Correct”, “Incorrect” or “No response detected” that was presented for 800 ms (see Figure 1).

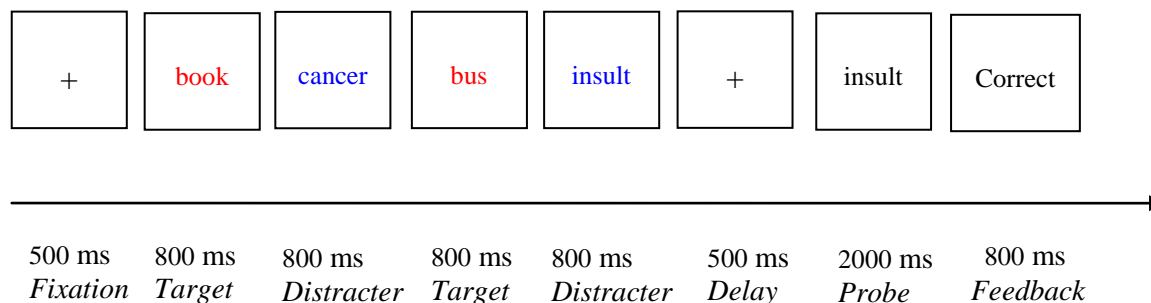


Figure 1. Working memory task procedure (a neuTnegD trial with a negative distracter probe).

Long-term memory task

Long-term memory in this study was defined as memory for words occurring after the brief time frame (within 18 s; Peterson & Peterson, 1959) of working memory. It was assessed on a surprise free recall task that occurred approximately 2 minutes after completion of the WM task. In this 7-minute free recall task, participants were required to recall all the words that they could remember from the WM task, regardless of the font colour it was presented in (i.e., regardless of item type: a target, distracter, or control). Responses on the free recall task were coded for its valence (i.e., positive, negative, or neutral) and item type (i.e., target, distracter, or control). Given the overall low recall performance, the arousal level was not coded to ensure statistical power.

Procedure

Upon arrival at the laboratory, participants read and signed an informed consent. Younger and older adults then performed the WM task on a computer, which lasted approximately 10 minutes (not including practice trials). After the WM task, participants completed the Digit-Symbol Substitution Task (DSST; Wechsler, 1981) for 2 minutes. This is a measure of perceptual-motor speed and requires participants to substitute digits with corresponding symbols, as quickly as possible within a 2-minute time limit. This test was used as a measure of perceptual

speed and also served as a filler task prior to the free recall task. Participants then completed a surprise free recall task for 7 minutes to test their long-term memory. Upon completion of the long-term memory task, the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) was administered. The PANAS measures positive and negative affect at the moment of assessment. After the PANAS, participants completed a computerized 2-back number task, a common measure of working memory ability. The 2-back number task was used as a construct validity check for the working memory task. Next, participants completed a variety of measures to determine the eligibility of their results for data analysis. Participants needed to meet the criteria outlined earlier (see “Participants” section on page 12) for these measures. The first of these measures was the Shipley Institute of Vocabulary Test (Shipley, 1946) which assesses level of English proficiency. Following this, participants completed the BAI (Beck et al., 1988) and the BDI (Beck et al., 1979). Older adults then completed the Short Blessed Test (SBT; Katzman et al., 1983). Finally, a background information questionnaire and debriefing concluded the session for all participants.

Statistical Analyses

All statistical analyses were conducted using SPSS 18.0, with a significance level set at .05 for main effects and .10 for interactions, unless specified otherwise.

The dependent variables of response times (RTs) and accuracy in the working memory task were analyzed with mixed analyses of variance (ANOVAs). To examine the facilitation effects of emotional content (i.e., arousal and valence) on target probe, a 2 x 2 x 3 mixed ANOVA with Age (younger, older) as a between-subjects variable, Arousal (high, low) and Valence (positive, negative, neutral) as within-subjects variables, was conducted on target identification (“yes” responses to target probes) RTs and accuracy. To examine emotional effects

on interference resolution, as indexed by rejection responses (i.e., “no” responses) to distracter versus control probes, a 2 x 2 x 2 x 3 mixed ANOVA with Age (younger, older) as a between-subjects variable, Probe (distracters, controls), Arousal (high, low) and Valence (positive, negative, neutral) as within-subjects variables, was also conducted on the RT and accuracy of rejection responses to distracter and control probes. Only RTs for correct responses were included in all RT analyses. RTs were also trimmed by excluding those that were beyond 2.5 *SDs* away from the mean in each condition for each participant; 6% of data points were excluded as a result. Accuracy was high in this paradigm, as has been reported in previous studies using similar paradigms (e.g., Gazzaley et al., 2005). Following typical practice with this paradigm, three older adults (ages 77-78, $M = 77$, $SD = 0.58$; 0 males) who scored lower than 80% in accuracy were replaced.

The dependent variable in the long-term memory task was the percentage recall, which was calculated as the percentage of correctly recalled items in each condition out of the total number of items encoded for that condition. The low overall percentage recall (younger: $M = 2.19$, $SD = 1.11$; older: $M = 1.37$, $SD = 1.14$) made it difficult to code the arousal level of responses separately. Driven by the specific interests in age differences in memory for items encoded differentially (as targets, distracters, or controls) and in memory for items of different valence (positive, negative, or neutral), a 2 (Age: younger, older) x 3 (Item Type: target, distracter, control) x 3 (Valence: positive, negative, neutral) mixed ANOVA was conducted on the percentage recall data.

In addition, a correlational analysis of accuracy on the 2-back task with accuracy in the working memory task revealed a significant correlation, $r = .24$, $p = .04$. This suggests that the

working memory task used in the study is a valid task that assesses some overlapping component of functioning with the 2-back task, which is a commonly used working memory task.

Results

The results for working memory and long-term memory are presented in three sections. The first section presents the facilitation effects of emotional content on target probe identification (“yes” responses to target probes) in the working memory task. The second section reports emotional effects on interference resolution (i.e., comparing “no” responses to distracter and control probes) in the working memory task. The third section of results presents long-term memory performance as measured with the free recall task.

Effects of Emotional Content on Target Identification in Working Memory

RT analysis. The RTs to target probes are displayed in Table 3.

Table 3

Response Times (ms) to Target Probes

	Younger adults		Older adults	
	<i>M (SD)</i>		<i>M (SD)</i>	
High arousal				
Positive	693.07	(187.55)	809.94	(196.51)
Negative	726.07	(181.87)	898.67	(214.2)
Neutral	697.67	(192.01)	890.49	(220.98)
Low arousal				
Positive	773.75	(214.86)	916.36	(236.53)
Negative	751.28	(197.93)	880.75	(211.63)
Neutral	753.19	(191.54)	861.51	(245.63)

The mixed ANOVA revealed a main effect of Age, $F(1, 65) = 11.13, p < .01, \eta_p^2 = .15$. Overall, younger adults ($M = 731.17, SD = 156.82$) were faster in correctly identifying target probes than were older adults ($M = 876.36, SD = 177.11$). The main effect of Arousal was significant, $F(1, 65) = 5.01, p = .03, \eta_p^2 = .07$, with faster RTs to high-arousal targets ($M = 785.64, SD = 191.12$) than to low-arousal targets ($M = 819.93, SD = 192.68$). This arousal effect, however, was qualified by an Age by Arousal interaction, $F(1, 65) = 4.32, p = .04, \eta_p^2 = .06$.

Follow-up analyses suggested that the arousal effect was only significant for younger adults, $t(35) = -2.50, p = .02$, but not significant for older adults ($p = .38$). This interaction is illustrated in Figure 2.

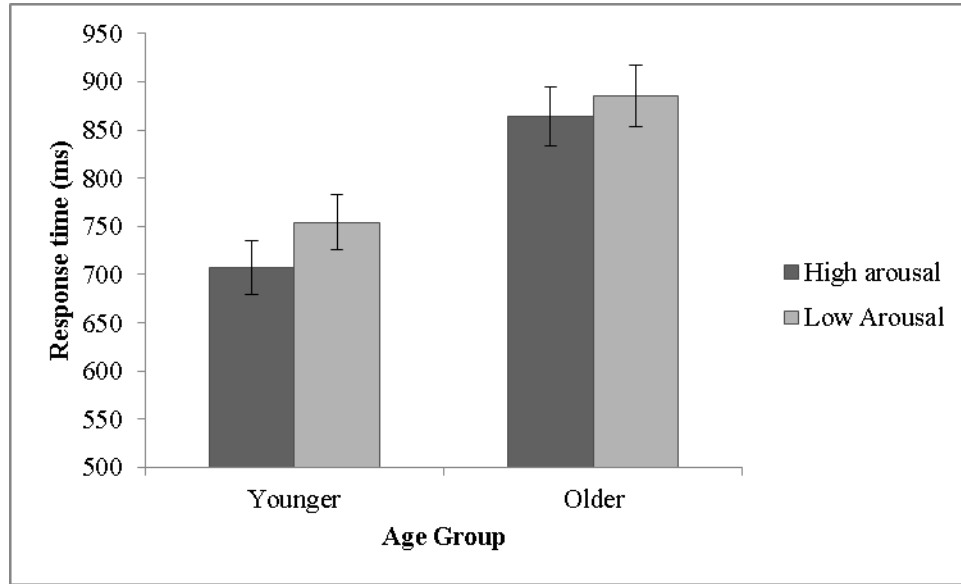


Figure 2. The Age by Arousal interaction in RTs for correct target identification responses. Error bars represent standard errors.

In addition, the Arousal by Valence interaction was also significant, $F(2, 130) = 6.64, p < .01, \eta_p^2 = .09$. Subsequent paired-samples t -tests indicated that the arousal effect was only significant for positive target probes, $t(71) = -4.06, p < .01$, but not for negative ($p = .87$) or neutral probes ($p = .80$). Figure 3 illustrated this interaction. All other effects were not significant ($F_s < 1.30, p_s > .28$).

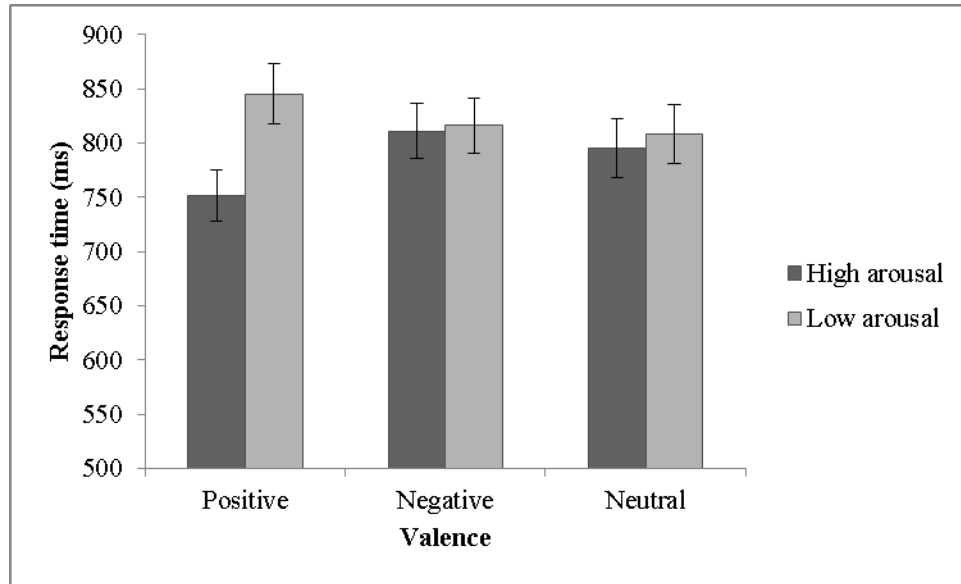


Figure 3. The Valence by Arousal interaction in RTs for correct target identification responses. Error bars represent standard errors.

Accuracy analysis. Accuracy for target identification responses (i.e., proportion of correct target identification) are displayed in Table 4.

Table 4

Accuracy to Target Probes

	Younger adults		Older adults	
	<i>M (SD)</i>		<i>M (SD)</i>	
High arousal				
Positive	0.99	(0.08)	0.99	(0.08)
Negative	0.99	(0.08)	0.97	(0.17)
Neutral	0.92	(0.22)	0.94	(0.16)
Low arousal				
Positive	0.94	(0.16)	0.96	(0.14)
Negative	0.97	(0.12)	0.96	(0.14)
Neutral	0.90	(0.26)	0.90	(0.23)

The accuracy data were submitted to the same mixed ANOVA as conducted in the RT analysis. It revealed a main effect of Valence, $F(2, 140) = 5.79, p < .01, \eta_p^2 = .08$. Follow-up paired t-tests indicated lower accuracy for neutral words ($M = .92, SD = .16$) than for both

positive words, ($M = .97$, $SD = .03$), $t(71) = 2.82$, $p = .01$, and negative words ($M = .97$, $SD = .11$), $t(71) = 2.88$, $p = .01$; the latter two did not differ from each other, $t(71) = -.21$, $p = .84$. This suggested a facilitation effect by emotional valence. In addition, the main effect of Arousal approached significance, $F(1, 70) = 3.15$, $p = .08$, $\eta_p^2 = .04$, with higher accuracy for high-arousal targets ($M = .97$, $SD = .09$) than for low-arousal targets ($M = .94$, $SD = .11$), suggesting a trend towards a facilitation effect by emotional arousal. Figure 4 displays the Valence and Arousal effects. All other effects were not significant ($F_s < .31$, $p_s > .73$).

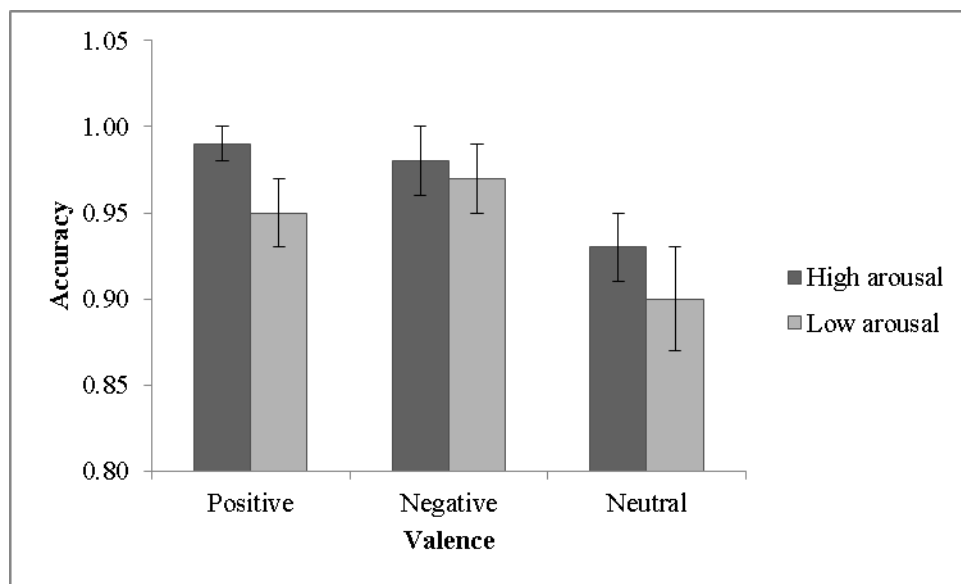


Figure 4. Accuracy for target identification responses for high arousal and low arousal stimuli in each valence category. Error bars represent standard errors.

Overall, these findings indicate an age-related decline in RTs but not in accuracy for target identification in working memory, suggesting that older adults were slower but not less accurate compared to younger adults at detecting targets. The results also revealed that arousal facilitated target identification, primarily in RT (trend in accuracy). However, this arousal facilitation effect in RT only occurred for the detection of positive stimuli. Finally, emotional valence facilitated target identification accuracy. In summary, it appears that emotional content

(both arousal and valence) facilitated target identification by making responses either faster or more accurate.

Effects of Emotional Content on Interference Resolution in Working Memory

The interference effect in working memory was measured by comparing the correct rejection responses to distracter versus control probes. Interference would arise if the distracters were not effectively inhibited and thus entered working memory. Consequently, rejecting distracters would take longer and be less accurate, relative to rejecting new control words.

RT analysis. The RT data for correct “no” responses (to distracter and control probes) are displayed in Table 5.

Table 5

Response Time (ms) to Distracter and Control Probes

	Younger adults		Older adults	
	<i>M (SD)</i>		<i>M (SD)</i>	
Distracters				
Positive HA	802.56	(208.67)	991.90	(256.14)
Negative HA	788.10	(199.52)	951.64	(260.16)
Neutral HA	869.28	(241.53)	985.56	(222.29)
Positive LA	789.79	(241.99)	947.47	(220.95)
Negative LA	788.10	(181.51)	975.61	(263.01)
Neutral LA	803.97	(162.64)	1013.96	(222.08)
Controls				
Positive HA	731.36	(238.79)	915.89	(211.92)
Negative HA	719.14	(197.03)	909.47	(259.13)
Neutral HA	705.96	(181.20)	839.42	(229.49)
Positive LA	709.74	(152.66)	893.39	(265.73)
Negative LA	731.74	(182.52)	872.18	(247.00)
Neutral LA	784.29	(203.65)	895.71	(260.57)

The mixed ANOVA revealed a main effect of Age, $F(1, 65) = 13.77, p < .001, \eta_p^2 = .18$, with overall faster responses for younger ($M = 769.01, SD = 153.21$) than for older adults ($M = 934.03, SD = 177.84$). The main effect of Probe was also significant, $F(1, 65) = 50.29, p < .001$,

$\eta_p^2 = .44$, with longer RTs for distracters ($M = 894.02$, $SD = 190.46$) than for controls ($M = 809.02$, $SD = 192.76$), suggesting an overall interference effect. These effects were clearly depicted in Figure 5. All other effects were not significant, $F_s < 2.09$, $p_s > .13$.

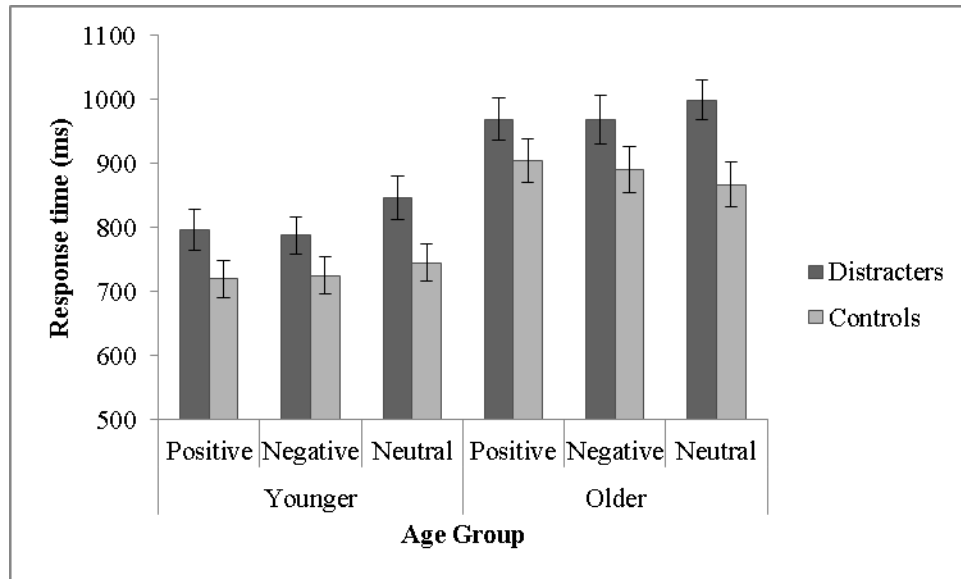


Figure 5. RTs for accurate rejection responses to distracter and control probes of each valence across the two age groups. Error bars represent standard errors.

Accuracy analysis. The proportional accuracy for “no” responses are displayed in Table

6.

Table 6*Accuracy to Distracter and Control Probes*

	Younger adults		Older adults	
	<i>M (SD)</i>		<i>M (SD)</i>	
Distracters				
Positive HA	0.93	(0.18)	0.89	(0.27)
Negative HA	0.96	(0.14)	0.83	(0.27)
Neutral HA	0.97	(0.12)	0.89	(0.21)
Positive LA	0.93	(0.18)	0.92	(0.22)
Negative LA	0.96	(0.14)	0.90	(0.20)
Neutral LA	0.94	(0.20)	0.89	(0.21)
Controls				
Positive HA	0.99	(0.08)	0.94	(0.16)
Negative HA	0.99	(0.08)	0.96	(0.14)
Neutral HA	1.00	(0.00)	0.93	(0.18)
Positive LA	0.99	(0.08)	0.94	(0.16)
Negative LA	0.97	(0.12)	1.00	(0.00)
Neutral LA	1.00	(0.00)	0.93	(0.18)

The same mixed ANOVA as that for the RT analysis was conducted on the accuracy data. There was a main effect of Age, $F(1, 70) = 12.60, p < .01, \eta_p^2 = .15$, and a main effect of Probe, $F(1, 70) = 22.07, p < .001, \eta_p^2 = .24$. Accuracy was higher for younger adults ($M = .97, SD = .05$) than for older adults ($M = .92, SD = .07$). Control probes ($M = .97, SD = .05$) were rejected at a higher accuracy than were distracter probes ($M = .92, SD = .10$). In addition, the Probe x Valence x Age interaction was approaching significance, $F(2,140) = 2.63, p = .09, \eta_p^2 = .04$. Follow-up paired samples t-tests comparing distracter to control probes for each valence and each age group revealed the following patterns: For younger adults, accuracy was lower for positive distracters ($M = .93, SD = .13$) than for positive controls ($M = .99, SD = .06$), $t(35) = -2.75, p = .01$, and lower for neutral distracters ($M = .96, SD = .11$) than for neutral controls ($M = 1.00, SD = 0$), $t(35) = -2.24, p = .03$, but there was no difference between negative distracters ($M = .96, SD = .11$) and negative controls ($M = .98, SD = .07$), $t(35) = -1.14, p = .26$. For older

adults, accuracy was lower for negative distracters ($M = .87$, $SD = .17$) than for negative controls ($M = .98$, $SD = .07$), but the probe effect was not significant for positive or neutral stimuli, $t_s > -1.29$, $p_s > .21$. This three-way interaction is demonstrated in Figure 6. This interaction suggests a trend for differential interference patterns by age: Younger adults showed interference from positive and neutral distracters, whereas older adults showed the opposite pattern, with interference for negative distracters. All other effects were not significant ($F_s < 1.79$, $p_s > .19$).

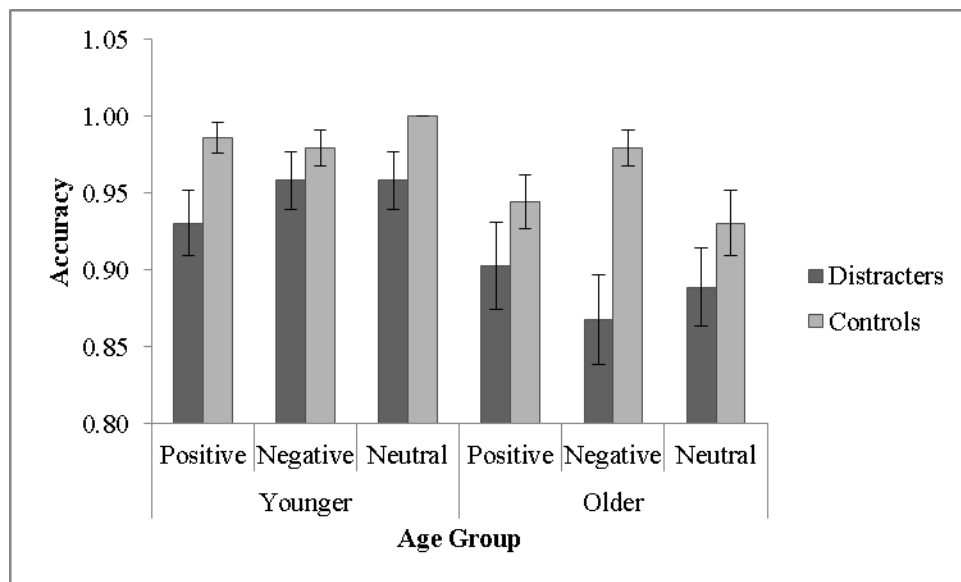


Figure 6. Accuracy for rejection responses to distracter and control probes of each valence across the two age groups. Error bars represent standard errors.

Overall, the results showed a clear interference effect, as indexed by both slower and less accurate responses to distracters relative to control probes. Older adults were differentially slower and less accurate in rejection responses. In addition, there was no overall emotional effect, either facilitation or disruption, on rejection RT. In the accuracy analysis, older adults showed significant interference only from negative distracters whereas younger adults showed interference from both positive and neutral distracters.

Long-term Memory: Free Recall

The percentage recall data are presented in Table 7.

Table 7

Percentage Recall (%) in the Free Recall Task

	Younger adults		Older adults	
	<i>M (SD)</i>		<i>M (SD)</i>	
Targets				
Positive	3.59	(4.00)	2.89	(3.28)
Negative	3.01	(4.41)	1.50	(3.01)
Neutral	2.97	(2.18)	2.24	(2.28)
Distracters				
Positive	1.39	(2.44)	0.46	(1.33)
Negative	1.74	(2.70)	0.81	(1.67)
Neutral	0.89	(1.06)	0.66	(1.02)
Controls				
Positive	4.17	(11.18)	2.08	(7.01)
Negative	7.64	(14.42)	0.00	(0.00)
Neutral	0.93	(2.66)	0.23	(1.39)

The mixed ANOVA revealed a main effect of Age, $F(1, 70) = 13.89, p < .001, \eta_p^2 = .17$; younger adults recalled more items ($M = 2.19, SD = 1.11$) than older adults ($M = 1.37, SD = 1.14$). The main effect of Item Type was also significant, $F(1.30, 91.14) = 5.79, p = .01, \eta_p^2 = .08$. Follow-up analyses suggested a lower recall for distracters ($M = .90, SD = .90$) compared to targets ($M = 2.66, SD = 2.10$), $t(71) = 6.97, p < .001$, and controls ($M = 1.74, SD = 3.58$), $t(71) = 2.04, p < .05$, with a marginally significant difference between the latter two, $t(71) = 1.96, p = .05$. The main effect of Valence was also significant, $F(2, 140) = 4.67, p = .01, \eta_p^2 = .06$. Follow-up analyses revealed that more positive words ($M = 2.16, SD = 2.16$) were recalled than neutral words ($M = 1.60, SD = 1.22$), $t(71) = 2.23, p = .03$, but neither of them differed from negative words ($M = 1.92, SD = 2.19$), $ts < 1.26, ps > .21$.

The Age by Item Type interaction was also significant, $F(2, 140) = 3.85, p = .02, \eta_p^2 = .05$. Follow-up paired t -tests revealed that younger adults recalled more targets ($M = 3.10, SD = 2.17$), $t(35) = 4.78, p < .001$, and controls ($M = 2.92, SD = 4.37$), $t(35) = 2.49, p = .02$, relative to distracters ($M = 1.16, SD = 0.85$); the former two did not differ, $t(35) = .23, p = .82$. However, older adults recalled more targets ($M = 2.22, SD = 1.96$) than controls ($M = 0.56, SD = 1.99$), $t(35) = 3.49, p < .01$, and distracters ($M = 0.65, SD = 0.89$), $t(35) = 5.21, p < .001$; the latter two did not differ, $t(35) = .26, p = .80$. This interaction is displayed in Figure 7.

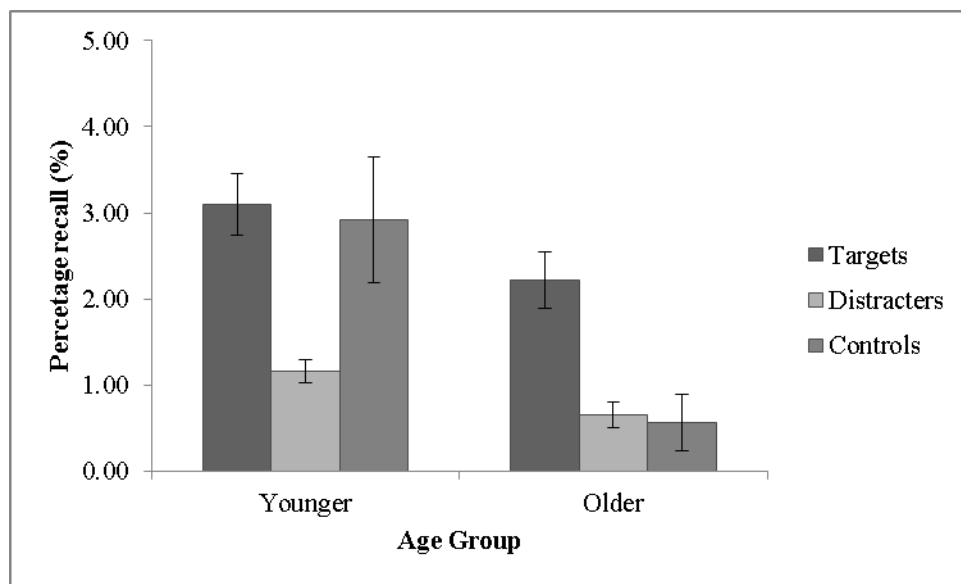


Figure 7. The Age by Item Type Interaction in percentage recall (%) of incidentally encoded items during the working memory task. Error bars represent standard errors.

The Age by Valence interaction was significant, $F(2, 140) = 5.94, p < .01, \eta_p^2 = .08$. Follow-up analyses revealed an approaching significant main effect of valence for younger adults, $F(1.69, 59.29) = 2.74, p = .08$, who recalled more positive ($M = 2.62, SD = 2.35$) and negative ($M = 2.78, SD = 2.22$) words than neutral words ($M = 1.85, SD = 1.10$), $t_s > 2.08, p_s < .05$; recall for positive and negative words did not differ, $t(35) = -.31, p = .75$. For older adults, there was no valence effect, $p = .15$. This interaction was displayed in Figure 8.

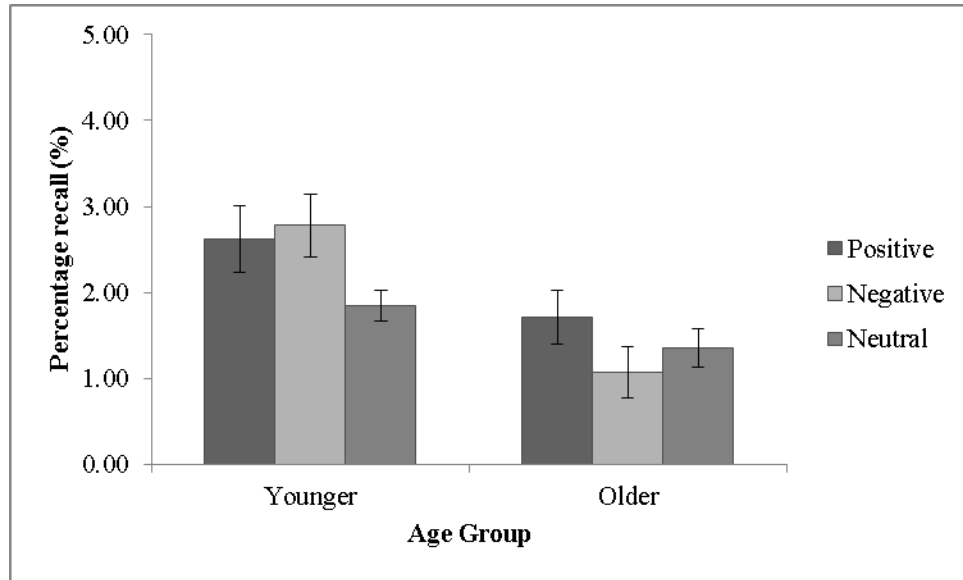


Figure 8. The Age by Valence Interaction in percentage recall (%) of incidentally encoded items during the working memory task. Error bars represent standard errors.

The Item Type by Valence interaction was marginally significant, $F(2.11, 147.90) = 2.85$, $p = .06$, $\eta_p^2 = .04$. Follow-up analyses revealed a valence effect for control items, $F(1.80, 127.85) = 3.48$, $p = .04$, but not for targets or distracters, $F_s < 2.20$, $p_s > .12$. For control items, positive ($M = 3.13$, $SD = 9.32$) and negative ($M = 3.82$, $SD = 10.83$) words were recalled more than neutral words ($M = 0.58$, $SD = 2.13$), $t_s > 2.29$, $p_s < .03$; the former two did not differ, $p = .64$. This interaction is displayed in Figure 9.

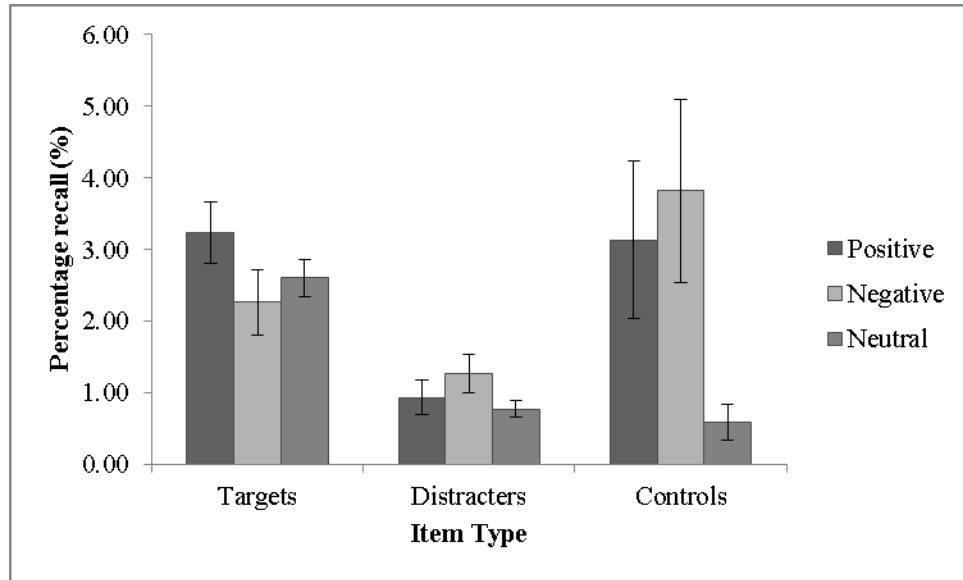


Figure 9. The Item Type by Valence Interaction in percentage recall (%) of incidentally encoded items during the working memory task. Error bars represent standard errors.

Finally, there was an Item Type x Valence x Age interaction, $F(4, 280) = 2.70, p = .03$, $\eta_p^2 = .04$. A 2 (Age) x 3 (Valence) ANOVA for each Item Type revealed an Age x Valence interaction only for control items, $F(1.81, 126.46) = 4.21, p = .02$. Follow-up analyses on control items for each group revealed a valence effect for younger adults, $F(2, 70) = 4.05, p = .02$ but not for older adults, $p = .09$. Paired samples t-tests revealed that younger adults recalled more negative ($M = 7.64, SD = 14.42$) versus neutral ($M = 0.93, SD = 2.66$) control items, $t(35) = 2.81, p < .01$; neither differed from positive control items ($M = 4.17, SD = 11.18$), $ts < 1.64, ps > .11$. This interaction is displayed in Figure 10.

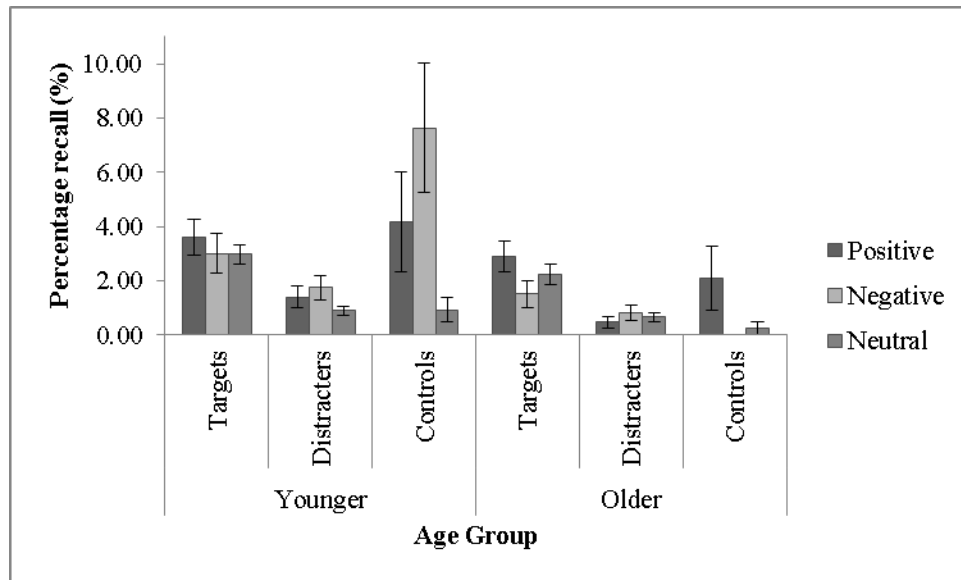


Figure 10. The Item Type by Valence by Age Interaction in percentage recall (%) of incidentally encoded items during the working memory task. Error bars represent standard errors.

In summary, the results from the free recall task replicated the robust age-related decline in explicit memory (Craik & Jennings, 1992). Younger adults recalled more target and control items than distracters, whereas older adults recalled more targets than distracters and controls. This may suggest that younger adults were better able to actively suppress words that were initially encoded as distracters (reflecting an efficient deletion inhibition function), whereas older adults mainly prioritized targets in their recall and did not selectively inhibit distracters over control probes. In addition, younger adults showed an enhancement for both positive and negative over neutral items, whereas older adults did not show any emotional enhancement effect. Furthermore, the emotional enhancement effect was only shown for control items. The 3-way interaction suggested a negativity bias (better recall of negative over neutral items) for control items among younger adults.

Taken together, results from the free recall task demonstrate a similar emotional facilitation effect as that found in the working memory task. Younger adults were able to effectively use emotional content to aid both working memory and long-term memory

performance. Older adults also showed emotional effects but only in working memory accuracy. Also, younger adults demonstrated an efficient and selective deletion inhibition of distracters in subsequent long-term memory whereas older adults only prioritized recall of target items.

Discussion

The current study examined age differences in the effects of emotional content on working memory and long-term memory for target and distracting information. It aimed to address three questions: (1) does emotional content facilitate working memory of target information and/or hinder interference resolution of distracting information in working memory? (2) are the effects of emotional content for incidentally encoded information in working memory evident in long-term memory? and (3) how do these effects change with age? To address these questions, the study manipulated the emotional content (arousal and valence) of target and distracting information in a working memory task and then assessed subsequent long-term memory for this information in a surprise free recall task.

Emotional Effects on Working Memory

Working memory for target information. To address the effects of emotional content on working memory, the arousal level and valence of target and distracting information was manipulated in a delayed-response working memory task. The results indicated that emotional content of target information differentially facilitated working memory performance in both RT and accuracy in younger and older adults.

In the RT analysis, there was a facilitation effect of high arousal relative to low arousal target words. This result is consistent with prior studies that demonstrate how arousal aids speed of processing (e.g., Maljkovic, 2005). However, this facilitation effect of arousal was only evident for positive, but not for negative or neutral stimuli. A speculative explanation may be that high arousal positive targets are more accessible and thus more readily identified during retrieval. Support for this hypothesis comes from a study that compared detection times of high and low arousal positive and negative targets and neutral targets in a visual search task (Leclerc

& Kensinger, 2008). They found faster detection times to positive high arousal targets amidst an array of distracters. These results suggest that in the current study, positive high arousal targets in particular may have been more readily identified during retrieval. However, the exact mechanism for this is still unclear. It is unclear, for example, whether faster responses to high arousal positive targets are due to increased elaboration during encoding or whether they are better maintained in working memory during a delay.

Emotional content also facilitated target identification accuracy in working memory. Accuracy was higher for emotionally-valenced (positive and negative) words than for neutral words and there was a tendency for higher accuracy to high arousal words than to low arousal words. The overall emotional enhancement effects are consistent with the study by Borg et al. (2011), who found higher accuracy when identifying negative target pictures compared to neutral pictures in a visual working memory task in which positive pictures were not used. The current study extended the emotional enhancement effect in working memory to positive and verbal stimuli. Together, these results suggest that emotional content, when encoded with target information, facilitates target identification in working memory.

Interference resolution of distracting information. In contrast to the facilitation effects of emotional targets, the effects of emotional distracters on interference resolution in working memory were less straightforward. Overall, both RT and accuracy analyses showed a reliable general interference effect. In the RT analysis, emotional content had no effect; participants were neither faster nor slower at rejecting emotional versus neutral probes. This finding is inconsistent with those of Levens and Phelps (2008) who found faster rejection times to emotional distracters. One major difference between the two studies is that Levens and Phelps (2008) examined distraction resulting from proactive interference, whereas the current study examined distraction

that was arbitrarily and externally assigned by experimenters. Thus, distracters in Levens and Phelps (2008) study once served as relevant target information in prior trials, whereas distracters in the current study only served as distracting information in the current trials. As such, it is plausible that once information is initially encoded as target information, it is differentially processed (perhaps in a deeper manner) that can then facilitate later interference resolution, as found in Levens and Phelps (2008). Consistent with this assumption, the current study found that the emotional content of target items facilitated working memory performance in target identification.

In the analysis on the accuracy data, there appears to be a disruptive effect of emotional content, but the effect interacted with age (a Probe x Valence x Age interaction). A detailed discussion of this result will follow in the last section of the discussion on age differences in memory and emotional effects.

Emotional Effects on Long-term Memory of Target and Distracting Information

To address long-term memory for information incidentally encoded during the working memory task, participants completed a surprise free recall test. Results indicated that overall, positive words were better recalled than neutral words. However, a Valence by Item Type interaction revealed that the emotional enhancement effect (i.e., better recall of positive and negative words than neutral words), was only significant for control items. This emotional enhancement for control items may be consistent with the hypothesis that emotional enhancement, such as the positivity bias, primarily occurs when information is encoded in an ‘open-ended’ manner, such as when passively viewing stimuli (Emery & Hess, 2008). In the current study, the control items were presented as new control probes and were not presented for any oriented encoding (i.e., not to be either remembered or ignored). Thus, it may be that an

absence of oriented encoding for control items promoted emotional processing, which resulted in higher recall of emotional versus neutral control items.

Age Differences in Memory and Emotional Effects

Memory performance. As predicted, younger adults outperformed older adults in most measures of working memory and long-term memory performance, with faster response times and higher accuracy in working memory, as well as greater recall in long-term memory. However, age differences varied for target versus distracter information in both working memory and long-term memory. Older adults, relative to younger adults, were less accurate at rejecting distracters and controls, but not at identifying targets. This is somewhat consistent with the hypothesis that older adults would demonstrate a deficit in suppressing distracting information, but preserved activation of target information (e.g., Gazzaley et al., 2005). In free recall, younger adults recalled fewer distracters relative to target and control items, whereas older adults recalled more target than distracter or control items. This may suggest that younger adults' highly efficient deletion function of inhibition allows them to efficiently deactivate and suppress distracters in long-term memory. However, driven by inhibition deficits and the limited amount of cognitive resource, older adults strategically prioritize target items only in long-term memory over both distracters and control items.

Age differences in emotional target identification in working memory. Emotional arousal of target information facilitated younger adults', but not older adults', response latencies in target identification in working memory. The absence of an emotional arousal effect in older adults might be attributed to age-related declines in speed of processing. Responses to probes had to occur within a 2000-ms time limit, which may be a tight response time window for older adults, given their age-related declines in speed of processing. It is possible that older adults

were already responding at their upper limit, leaving little room for any further benefit from high arousal targets. Thus, this absence of an emotional arousal effect may be driven by age differences in speed of processing rather than emotional processing per se. Indeed, when examining accuracy, older adults showed equivalent emotional enhancement effect (higher accuracy to positive and negative targets versus neutral targets) as younger adults. Thus, it appears that older adults show a speed-accuracy trade-off to prioritize working memory accuracy at the expense of a much slower response speed. Therefore, older adults managed to respond as accurately as younger adults, and they were also able to use their preserved emotional processing to benefit working memory performance accuracy.

Age differences in rejecting emotional distracters in working memory. The emotional content of distracters appeared to have no effect on interference resolution RTs for both age groups, despite the age-related decline in overall rejection responses to distracters and control items. However, the emotional content of distracters appeared to be disruptive to interference resolution accuracy. The emotional effect, however, differed between age groups, as suggested by a 3-way interaction between probe, valence, and age. This interaction suggested that younger adults showed a significant interference effect (i.e., reduced accuracy to distracters than controls) for positive and neutral probes, but not for negative probes. The opposite pattern was found for older adults, who showed interference for negative probes only. The results may suggest different emotional biases for each age group. Younger adults, with their dominant negativity bias (e.g., Baumeister, Bratslavsky, Fickener, & Vohs, 2001), may have paid more attention to negative distracters during encoding, which helped them correctly identify negative distracters as non-targets. In contrast, less attention was paid to positive and neutral information, thus resulting in greater interference. Unlike younger adults' negativity bias, research has demonstrated that

older adults may have an anti-negativity bias and allocate less visual attention to negative stimuli as compared to younger adults (e.g., Isaacowitz, Wadlinger, Goren, & Wilson, 2006; Knight et al., 2007). Research has also suggested that younger and older adults may allocate similar levels of attention to negative stimuli initially, but younger adults sustain attention on negative information for a longer time than do older adults (Rosler et al., 2005). This overall anti-negativity bias may have resulted in less attention and a more shallow processing of negative distracters, which diminished older adults' ability and confidence to distinguish whether a negative word was presented as distracting or target information, and thus causing differentially larger interference effect for negative distracting information.

It should be noted that the results on younger adults' interference effects are not entirely consistent with those of Dolcos and McCarthy (2006) who found reduced accuracy in working memory when negative distracter images were presented during a delay. Differences in paradigms may explain why this occurred. Dolcos and McCarthy used pictures of high arousing negative scenes (e.g., a woman being held at gunpoint) as distracters and presented them during a delay period of 6000 ms between target items and the probe. In contrast, the current study presented distracters intermixed with targets during working memory encoding that was followed by a much shorter delay of 500 ms before the probe was presented at each specific trial. These differences may have made the distracters in Dolcos and McCarthy's study particularly distracting, as attention is immediately drawn to the high arousing negative scenes and for a longer amount of time. In contrast, the current study had participants focus on distracters for 800 ms each, with attention being switched between viewing targets and distracters. Additionally, Dolcos and McCarthy's study used picture stimuli but the current study used words. Thus, differences in results may be due to differential emotional effects for nonverbal stimuli (pictures)

versus verbal stimuli (words). Results from Kensinger and Corkin (2003) support this explanation, as they found a disruptive effect of emotion (to response times) in an n-back task with fearful faces, but not with negative words.

Age differences in long-term memory of emotional stimuli. A valence by age interaction revealed emotional enhancement for younger adults, but not for older adults. For younger adults, recall was higher for negative control items relative to neutral control items. This is consistent with younger adults' negativity bias (e.g., Doerksen & Shimamura, 2001; Kensinger, 2008; Kensinger & Corkin, 2003). Driven by their preoccupation with negative affect (Labouvie-Vief, 2003), younger adults recalled more negative items from their long-term memory. In contrast, older adults did not show any enhancement for emotional information in their recall data. The absence of this effect could be attributed to older adults' focus on perceptual (colour) features of the stimuli (because colours cued which words were targets/distracters), which diverted focus away from the semantic content of the words. This limited processing of semantic content may have reduced processing of emotional information, resulting in an absence of emotional effects in long-term memory. This explanation is supported by findings from Emery and Hess (2010) who found equal positivity and negativity biases in recall during open-ended and emotion-oriented encoding in older adults, which disappeared when they were directed to encode perceptual details of the stimuli instead. Thus, it appears that focus on perceptual features, such as those encouraged in the current study, may explain the absence of emotional effects in older adults in long-term memory.

Another related explanation is that the absence of emotional effects may be attributed to older adults' reduced cognitive resources in the context of a free recall task, which requires high amounts of controlled processing (Craik & McDowd, 1987). Older adults' limited resources may

have been primarily devoted to recalling target information, as demonstrated in their greater recall of target items relative to distracter and control items. This may have limited the resources required to elicit emotional enhancement (e.g., Mather & Knight, 2005). As a result, the emotional effect in long-term memory was absent in older adults. Nevertheless, the absence of negativity effects in older adults is consistent with the anti-negativity effect commonly observed and reported with older adults in the literature (e.g., Murphy & Isaacowitz, 2008). In this sense, the results could be well explained by the socio-emotional selectivity theory (Charles & Carstensen, 2004), which states that older adults may strategically use controlled processing to avoid negative bias and thus promote their overall mental health (e.g., Kensinger, 2008; Mather & Knight, 2005; Yang & Hasher, 2011).

Limitations and Future Directions

There were several limitations of the current study. First, it was not possible to control or verify whether participants read distracters, thus leaving open the possibility that participants may have diverted their eyesight away from distracters in order to reduce interference. This would hinder results on the effect of emotional content of distracters, as participants would need to read the distracter words. However, if participants did not read distracters, there should be no difference between distracters and control probes (i.e., they would both appear to be new words). Given the consistent interference effect (i.e., responses to distracters were longer and less accurate compared to control items), this eyesight diversion possibility is minimized. To further test this possibility, future research could ask participants to read the word out loud during encoding or collect eye-tracking data to measure differential visual allocations.

Second, distracting information in the working memory task was arbitrarily and externally assigned by experimenters. It does not inform us about the interference resolution of

internally generated distractions, such as that produced in proactive interference paradigms.

Nevertheless, future research could address this question by modifying the paradigm to include internally generated distracter items to measure the effect of these items on interference resolution of target information in working memory.

Third, in order to maintain statistical power, free recall was not coded for arousal. Thus, it remains unknown whether recall differs by arousal. Kensinger (2008) offers some insight into this question by finding significant age differences in valence effect for low arousal words, but not for high arousal words, in free recall. This limitation was due to low overall recall (preventing further breakdowns by arousal) but could be resolved in future research by assessing long-term memory through recognition tests, which typically produce higher memory scores (e.g., Kensinger & Corkin, 2003). Additionally, in consideration of the results from Gopie et al. (2011) that showed better implicit, but not explicit, memory for distracting information in older adults than in younger adults, future research could assess subsequent long-term memory of the information with both explicit and implicit tests.

Finally, this study did not examine the mechanisms underlying the emotional effects observed in working memory and long-term memory. However, this study used a paradigm that could be readily modified to study the neural substrates of these effects. Future research could begin by comparing activation patterns in typical working memory regions (e.g., dorsolateral prefrontal cortex) with those in emotion processing regions (e.g., amygdala and ventrolateral prefrontal cortex) for target versus distracting information.

Conclusions and Implications

This study examined the effects of age and emotional content on working memory and long-term memory. To examine whether emotional content facilitates or hinders working memory, the study manipulated the emotional valence and arousal of target and distracting information presented in a working memory task. Results revealed that high arousal positive targets facilitated working memory response times, whereas positive and negative targets facilitated working memory accuracy. However, there was some evidence of differential disruption of emotional valence by age (i.e., disruption from positive distracters for younger adults and from negative distracters for older adults) on working memory accuracy. To examine whether these effects of emotional content were evident in subsequent long-term memory, participants completed a free recall test. Results revealed that younger adults recalled more negative than neutral control items. Finally, this study examined how emotional effects in working memory and long-term memory change with age. The working memory results indicated that older adults, relative to younger adults, were slower and less accurate at rejecting distracter and control probes. Older adults were also slower, but just as accurate (relative to younger adults) at identifying targets. They also showed similar emotional effects as younger adults (i.e., facilitative effects of emotional arousal and valence when identifying targets), but differed on their rejection responses to negative distracters (less accurate than younger adults). In the free recall task, older adults recalled fewer words than younger adults and recalled more target than distracter and control items. In contrast, younger adults showed equal recall of targets and controls compared to distracters. In general, younger adults outperformed older adults on working memory and long-term memory performance, and also showed stronger emotional effects than older adults. This may suggest that older adults are more likely to show emotional

effects (beneficial or disruptive) only under conditions in which they have resources available for deep and elaborative processing of emotional meaning.

By examining the effects of age and emotional content on working memory and long-term memory, the current study contributes to the sparse literature on the effects of age and emotional content on working memory and long-term memory of target and distracting information. It resolves discrepancies between previous studies on younger adults that showed both facilitative and disruptive effects of emotional content on working memory by distinguishing between emotional targets (which can be facilitative to working memory) and emotional distracters (which can be disruptive to working memory). This study also extends these effects to older adults. By examining all of these factors in one study, this research made novel contributions to the literature on emotional effects in working memory and long-term memory, and provided additional research to support theories of inhibitory deficits and preserved emotional processing in aging. Studying this intersection between emotion, aging, and cognition is particularly important, given that older adults experience deficits in working memory and long-term memory but display preserved emotional processing. By examining when emotional content aids or hinders memory performance in older adults, this study may stimulate application of the results to inform the design of training paradigms that teach older adults how to use their maintained emotional processing to compensate for declines in other areas of cognition.

References

- Baumeister, R.F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of General Psychology*, 5, 323-370. doi:10.1037/1089-2680.5.4.323
- Beck, A. T, Epstein, N., Brown, G., & Steer, R. A. (1988). An inventory for measuring clinical anxiety: Psychometric properties. *Journal of Consulting and Clinical Psychology*, 56, 893-897.
- Beck, A.T., Rush, A.J., Shaw, B.F., & Emery, G. (1979). *Cognitive therapy of depression*. New York: Guildford Press.
- Borella, E., Carretti, B., & de Beni, R. (2008). Working memory and inhibition across the adult lifespan. *Acta Neuropsychologica*, 128, 33-44.
- Borg, C., Leroy, N., Favre, E., Laurent, B., & Thomas-Antérion, C. (2011). How emotional pictures influence visuospatial binding in short-term memory in ageing and Alzheimer's disease? *Brain and Cognition*, 76, 20-25. doi:10.1016/j.bandc.2011.03.008
- Bradley, M.M., & Lang, P.J. (1999). Affective norms for English words (ANEW): Instruction manual and affective ratings. *Technical Report C-1*, The Center for Research in Psychophysiology, University of Florida.
- Campbell, K. L., Hasher, L., & Thomas, R. C. (2010). Hyper-binding: A unique age effect. *Psychological Science*, 21, 399-405. doi:10.1177/0956797609359910
- Carlson, M. C., Hasher, L., Connelly, S. L., & Zacks, R. T. (1995). Aging, distraction, and the benefits of predictable location. *Psychology and Aging*, 10, 427.
- Carstensen, L.L., Isaacowitz, D.M. & Charles, S.T. (1999). Taking time seriously: A theory of socioemotional selectivity. *American Psychologist*, 54, 165-181.

- Charles, S.T., & Carstensen, L.L. (2004). A life-span view of emotional functioning in adulthood and old age. In P. Costa (Ed.), *Recent advances in psychology and aging*. Amsterdam: Elsevier.
- Charles, S.T., Mather, M., & Carstensen, L.L. (2003). Focusing on the positive: Age differences in memory for positive, negative, and neutral stimuli. *Journal of Experimental Psychology*, 85, 163-178.
- Conway, A.R.A., et al. (2008). *Variation in working memory*. New York: Oxford University Press.
- Craik, F. I. M., & Jennings, J. M. (1992). Human memory. In F. I. M. Craik, & T. A. Salthouse (Eds.), *The handbook of aging and cognition*. (pp. 51-110). Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.
- Craik, F. I.M., & McDowd, J. M. (1987). Age differences in recall and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 13, 474-479.
doi:10.1037/0278-7393.13.3.474
- Darowski et al. (2008). Age-related differences in cognition: The role of distraction control. *Neuropsychology*, 22, 638-644.
- Darowski, E. S., Helder, E., Zacks, R. T., Hasher, L., & Hambrick, D. Z. (2008). Age-related differences in cognition: The role of distraction control. *Neuropsychology*, 22, 638-644.
doi:10.1037/0894-4105.22.5.638
- Doerksen, S., & Shimamura, A. P. (2001). Source memory enhancement for emotional words. *Emotion*, 1, 5-11. doi:10.1037/1528-3542.1.1.5

- Dolcos, F., & McCarthy, G. (2006). Brain systems mediating cognitive interference by emotional distraction. *The Journal of Neuroscience*, 26, 2072-2079.
doi:10.1523/JNEUROSCI.5042-05.2006
- Emery, L., & Hess, T. M. (2008). Viewing instructions impact emotional memory differently in older and young adults. *Psychology and Aging*, 23, 2-12. doi:10.1037/0882-7974.23.1.2
- Gazzaley, A., Cooney, J. W., Rissman, J., & D'Esposito, M. (2005). Top-down suppression deficit underlies working memory impairment in normal aging. *Nature Neuroscience*, 8(12), 1298-1300. doi:10.1038/nn1543
- Gerard, L., Zacks, R. T., Hasher, L., & Radvansky, G. A. (1991). Age deficits in retrieval: The fan effect. *Journals of Gerontology*, 46, 131-136.
- Gopie, N., Craik, F. I. M., & Hasher, L. (2011). A double dissociation of implicit and explicit memory in younger and older adults. *Psychological Science*, 22, 634-640.
doi:10.1177/0956797611403321
- Hasher, L. (2007). Inhibition: Attentional regulation in cognition. In L. Roediger, III, Y. Dudai, & S.M. Fitzpatrick (Eds.). *Science of memory: Concepts*. Oxford University Press.
- Hasher, L., Lustig, C., & Zacks, R. (2007). Inhibitory mechanisms and the control of attention. In A. R. A. Conway, C. Jarrold, M. J. Kane, A. Miyake & J. N. Towse (Eds.), *Variation in working memory* (pp. 227-249). New York, NY, US: Oxford University Press.
- Hasher, L., Quig, M. B., & May, C. P. (1997). Inhibitory control over no-longer-relevant information: Adult age differences. *Memory & Cognition*, 25, 286-295.
- Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in*

- research and theory*, vol. 22. (pp. 193-225). San Diego, CA, US: Academic Press.
doi:10.1016/S0079-7421(08)60041-9
- Hedden, T., & Park, D. (2001). Aging and interference in verbal working memory. *Psychology and Aging*, 16, 666-681.
- Ikier, S., Yang, L., & Hasher, L. (2008). Implicit proactive interference, age, and automatic versus controlled retrieval strategies. *Psychological Science*, 19, 456-461.
doi:10.1111/j.1467-9280.2008.02109.x
- 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.
- Katzman, R. (1983). Validation of a short orientation-memory-concentration test of cognitive impairment. *The American Journal of Psychiatry*, 140, 734-739.
- Kensinger, E. A. (2008). Age differences in memory for arousing and nonarousing emotional words. *The Journals of Gerontology*, 63B, P13-P18.
- Kensinger, E. A., & Corkin, S. (2003). Effect of negative emotional content on working memory and long-term memory. *Emotion*, 3, 378-393. doi:10.1037/1528-3542.3.4.378
- Kim, S., Hasher, L., & Zacks, R. T. (2007). Aging and a benefit of distractability. *Psychonomic Bulletin & Review*, 14, 301-305.
- Knight, M., Seymour, T. L., Gaunt, J. T., Baker, C., Nesmith, K., & Mather, M. (2007). Aging and goal-directed emotional attention: Distraction reverses emotional biases. *Emotion*, 7, 705-714. doi:10.1037/1528-3542.7.4.705

- Labouvie-Vief, G. (2003). Dynamic integration: Affect, cognition, and the self in adulthood. *Current Directions in Psychological Science*, 12, 201-206. doi:10.1046/j.0963-7214.2003.01262.x
- Lang P.J., Bradley M.M., Cuthbert B.N. (1999). International affective picture system (IAPS): instruction manual and affective ratings. *Technical Report A-4. The Center for Research in Psychophysiology*, University of Florida.
- Leclerc, C. M., & Kensinger, E. A. (2008). Effects of age on detection of emotional information. *Psychology and Aging*, 23, 209-215. doi:10.1037/0882-7974.23.1.209
- Levens, S. M., & Phelps, E. A. (2008). Emotion processing effects on interference resolution in working memory. *Emotion*, 8, 267-280. doi:10.1037/1528-3542.8.2.267
- Lustig, C., May, C. P., & Hasher, L. (2001). Working memory span and the role of proactive interference. *Journal of Experimental Psychology*, 130, 199-207.
- Maljkovic, V., & Martini, P. (2005). Short-term memory for scenes with affective content. *Journal of Vision*, 5, 215-229. doi:10.1167/5.3.6
- Mather, M., & Knight, M. (2005). Goal-directed memory: The role of cognitive control in older adults' emotional memory. *Psychology and Aging*, 20, 554-570.
- Murphy, N. A., & Isaacowitz, D. M. (2008). Preferences for emotional information in older and younger adults: A meta-analysis of memory and attention tasks. *Psychology and Aging*, 23, 263-286. doi:10.1037/0882-7974.23.2.263
- 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

- Petrican, R., Moscovitch, M., & Schimmack, U. (2008). Cognitive resources, valence, and memory retrieval of emotional events in older adults. *Psychology and Aging, 23*, 585-594. doi:10.1037/a0013176
- Rosler, A., Ulrich, C., Billino, J., Sterzer, P., Weidauer, S., Bernhardt, T., Kleinschmidt, A. (2005). Effects of arousing emotional scenes on the distribution of visuospatial attention: Changes with aging and early subcortical vascular dementia. *Journal of the Neurological Sciences, 229-230*, 109-116.
- Rowe, G., Valderrama, S., Hasher, L., & Lenartowicz, A. (2006). Attentional disregulation: A benefit for implicit memory. *Psychology and Aging, 21*, 826-830. doi:10.1037/0882-7974.21.4.826
- Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*, 1161-1178. doi:10.1037/h0077714
- Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103*, 403-428.
- Shipley, W. C. (1946). *Institute of Living Scale*. Los Angeles: Western Psychological Services.
- Talmi, D., Schimmack, U., Paterson, T., & Moscovitch, M. (2007). The role of attention and relatedness in emotionally enhanced memory. *Emotion, 7*, 89-102. doi:10.1037/1528-3542.7.1.89
- Thomas, R. C., & Hasher, L. (2006). The influence of emotional valence on age differences in early processing and memory. *Psychology and Aging, 21*, 821-825. doi:10.1037/0882-7974.21.4.821

- Watson, D., Clark, L. A., & Tellegan, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, 54, 1063.
- Wechsler, D. (1981). *Manual for the Wechsler Adult Intelligence Scale-Revised*. New York: Psychological Corporation
- Yang, L., & Hasher, L. (2007). The enhanced effects of pictorial distraction in older adults. *Journal of Gerontology: Psychological Sciences*, 62, 230-233.
- Yang, L., & Hasher, L. (2011). Age differences in the automatic accessibility of emotional words from semantic memory. *Cognition and Emotion*, 25, 3-9.
doi:10.1080/02699930903523348
- Zacks, R. T., Radvansky, G., & Hasher, L. (1996). Studies of directed forgetting in older adults. *Journal of Experimental Psychology: Learning*, 22, 143-156. doi:10.1037/0278-7393.22.1.143