RESEARCH ARTICLE

Youth are more Vulnerable to False Memories than Middle-Aged Adults due to Liberal Response Bias

Liesel-Ann C. Meusel BSc, PhD[1,2]; Glenda M. MacQueen MD, PhD[4]; Gurpreet Jaswal BSc[5]; Margaret C. McKinnon PhD[1,2,3]

Abstract

Objective: Numerous studies show changes in vulnerability to false memory formation across development and into senescence. No study, however, has compared false memory formation in the critical transition period spanning late adolescence to middle adulthood. **Method:** Using the Deese-Roediger-McDermott (DRM) paradigm, we explored the effects of age and of emotion on false memory formation in youth (16 to 23 years of age) and in middle-aged adults (29 to 58 years of age). **Results:** We found that youth endorsed more false lure items than middle-aged adults. This increased vulnerability to false memory formation stemmed from a more liberal response bias in the younger group. **Conclusions:** Youth have a more liberal response criterion than middle-aged adults that contributes to an increased vulnerability to false memory formation. Subsequent age-related changes in response bias may reflect the maturation of frontal and temporal regions. In youth, a more liberal response bias may contribute to the heightened propensity for poor decision-making seen in this population.

Key words: *false memory, DRM, development, youth*

Résumé

Objectif: De nombreuses études attestent des changements de vulnérabilité à la formation de faux souvenirs pendant l'enfance et dans la vieillesse. Aucune étude n'a toutefois comparé la formation de faux souvenirs pendant la période critique qui va de la fin de l'adolescence au milieu de l'âge adulte. **Méthodologie:** Le paradigme Deese-Roediger-McDermott (DRM) a servi à étudier les effets de l'âge et de l'émotion sur la formation de faux souvenirs chez des adolescents (entre 16 et 23 ans) et chez les adultes d'âge moyen (entre 29 et 58 ans). **Résultats:** Les adolescents ont accepté davantage de faux leurres que les adultes. Cette vulnérabilité accrue à la formation de faux souvenirs provient d'un biais de réponse moins précis de la part des adolescents. **Conclusion:** Les adolescents ont des critères de réponses moins précis que les adultes, ce qui augmente le risque de fabrication de faux souvenirs. L'évolution du biais de réponse avec l'âge pourrait refléter la maturation des régions frontale et temporale du cerveau. Le biais de réponse explique la propension des adolescents à prendre de mauvaises décisions.

Mots clés: *faux souvenir, DRM, développement, adolescent*

Adolescence and early adulthood are identified as periods of increased risk for the development of neuropsychiatric disorders, often representing a transitional period where first episodes of illness emerge. Despite knowledge of youth's vulnerability to the development of psychopathology over this period, risk factors—such as poor cognitive decision making, risk taking, and immaturity of neural networks underlying response inhibition and cognitive control—remain under-identified. There is substantive reason to suspect that under-development of the neural circuits that mediate cognitive operations such as decision-making, impulsivity, and risk-taking may contribute to an enhanced vulnerability to psychopathology among youth (for a recent review see Hassel, McKinnon, Cusi, & MacQueen, 2011). For example, impulsivity has been linked to the development of mood disorders and to an increased risk for suicide

[1]Department of Psychiatry and Behavioural Neurosciences, McMaster University, Hamilton, Ontario
[2]Mood Disorders Program, St. Joseph's Healthcare, Hamilton, Ontario
[3]Kunin-Lunenfeld Applied Research Unit, Baycrest Centre, Toronto, Ontario
[4]Department of Psychiatry, University of Calgary, Calgary, Alberta
[5]School of Medicine, Queen's University, Kingston, Ontario

Corresponding e-mail: mckinno@mcmaster.ca

Submitted: February 3, 2011; Accepted: February 22, 2012

(Beauchaine, Klein, Crowell, Derbidge, & Gatze-Kopp, 2009).

Critically, brain morphology and white matter connectivity—particularly those areas involved in "top-down" executive control—continue to mature across late adolescence and into early adulthood. In normal development, this period of protracted maturation is marked by the continued refinement of cognitive processes that depend on the integrity of top-down regulatory networks, including response inhibition, foresight (Andrews-Hanna et al., 2011), autobiographical reasoning (Pasupathi & Mansour, 2006), and relational reasoning (Dumontheil, Houlton, Christoff, & Blakemore, 2010). Disruption or delay in the emergence of these top-down control networks may lead to poor decision-making or heightened risk-taking, particularly when strong emotions are involved or reward salience is high. Over time, this trajectory can result in a pattern of internalizing or externalizing behaviour (Van Leijenhorst et al., 2010; Arnett, 1992; Byrnes, 2002) and may contribute to the development of neuropsychiatric illness (Grunbaum, Kann, & Kinchen, 2004; Dahl, 2001; Steinberg, 2005). Here, we examine vulnerability to false memory formation among healthy youth in an attempt to identify more clearly those cognitive processes that remain under-developed among youth.

Immaturities in the neural systems that mediate cognitive control and reasoning are thought to underlie biased decision-making in adolescence. When payoffs are high (i.e., money, social), adolescents often show decreased assessment of risk and suboptimal representation of reward valence and value (for a discussion see Geier & Luna, 2009). Whether similar biases in decision-making are detectable under neutral conditions—for example, when there is no social feedback and no monetary reward for performance—is still unknown, however. In the present study, we used the Deese-Roediger-McDermott paradigm (DRM; Deese, 1959; Roediger & McDermott, 1995) to examine memory discrimination ability and response bias in youth compared to middle-aged adults. In particular, we were interested to see whether youth were more vulnerable than middle-aged adults to false memory formation during recognition memory judgments; decisions that are influenced by memory discrimination ability and response bias.

The DRM paradigm (Deese, 1959; Roediger & McDermott, 1995) has been used extensively to study false memory formation. During the study phase of this task, participants are presented with several lists of semantic associates (e.g., LIST 1: tears, sad, tissue, sorrow; LIST 2: excited, smile, laugh, giggle). Each list has a "theme word" or "critical lure word" (e.g., LIST 1: cry; LIST 2: happy) that relates to each of the other words on the list, but is *not presented* in the study phase. During the subsequent memory test, participants are asked to identify words that were presented during the study phase as "old", and to identify words that were not presented during study as "new". Participants are shown the previously studied list words (i.e., "old" words) as well as new words from other lists of semantic associates that were not included in the study phase. Also included in the memory test are the non-presented "critical lure words" from each of the studied lists. Because of the high degree to which each critical lure word relates to all of the other words on its corresponding list, participants tend to misidentify the non-studied critical lure words as "old" more often than the other, non-studied words (for a detailed overview of cognitive theory concerning this task, see Arndt & Gould, 2006; Lampinen, Leding, Reed, & Odegard, 2006; Brainerd & Reyna, 2007; Odegard, Holliday, Brainerd, & Reyna, 2008).

The DRM paradigm has also been used to explore group differences in discrimination and response bias. Discriminability is a subject's ability to correctly identify a previously presented word as "old", whereas response bias is the tendency of a subject to respond a particular way when uncertain. Critically, subjects with a more liberal response bias are more likely to judge a "new" item as "old" at test, whereas subjects with a more conservative response bias are more likely to judge a "new" item as "new" at test. Discrimination and bias indices combine to characterize recognition memory performance, where individual differences in these capacities have been attributed to the integrity of frontal and temporal regions that support accurate responding and decision-making. For example, older adults with impaired frontal lobe functioning show elevated levels of false recognition: discrimination is decreased—reflecting increasing levels of uncertainty—and response biases are more liberal, resulting in a propensity to judge test items as "old". Conversely, rates of false recognition are comparable between youth and older adults with intact frontal lobe functioning (Butler, McDaniel, Dornburg, Price, & Roediger, 2004; Lavoie, Willoughby, & Faulkner, 2006). Increased rates of false recognition are also present in disease states such as Alzheimer's dementia, where frontal and temporal lobe functioning is further compromised (Roediger & Geraci, 2007; Budson et al., 2006a; Balota et al., 1999; Norman & Schacter, 1997).

The period of time marking the transition from late adolescence into early adulthood is also of interest for the study of true and false memory formation. The frontal and temporal brain networks that mediate associative processing and recognition judgments do not reach full adult development until approximately 25 years of age (Gogtay et al., 2004; Gogtay et al., 2006; Sowell, Thompson, Tessner, & Toga, 2001). These same neural regions also contribute to true and false memory recognition. Specifically, both true and false recognition decisions are associated with increases in activation in left ventrolateral prefrontal cortical regions during encoding (Kim & Cabeza, 2007), regions critically involved in semantic processing (Gabrieli, Poldrack, & Desmond, 1998; Buckner, Kelley, & Peterson, 1999). True recognition decisions are also associated with increased activity in

left medial temporal regions, and activation in early visual areas (Kim & Cabeza, 2007). In the DRM paradigm, differences in false recognition between youth and middle-aged adults may reflect emergent changes in the efficiency and integrity of memory and decision-making networks across this transition period that has been heavily associated with increased risk for development of neuropsychiatric illness and may contribute to increased vulnerability.

In the present study, false memory formation was measured in a group of youth, and in a group of middle-aged adults. The World Health Organization defines youth as a group ranging from age 10-24 years; our youth sample included subjects aged 16-23 years, as we were particularly interested in the developmental stage of young adulthood rather than the earlier post-pubertal period, which has already been studied extensively using the DRM paradigm. Our middle-aged adults were between the age of 29 and 58 years; a group whose performance on the DRM paradigm has yet to be characterized. Importantly, all individuals in the "middle-aged" group were beyond the age at which frontal and temporal brain networks are presumed to reach full adult development, and not yet at the age at which advanced aging is thought to impact the functioning of these regions.

We were also interested in understanding the effect of word valence on response bias and discriminability. Previous work has shown a more liberal response bias for negative, relative to neutral words; when uncertain, negative words were more likely to be judged as "old". Other studies have found a similar effect of word valence on response bias, where negative stimuli result in a more liberal response bias than do neutral or positive stimuli (Budson, Wolk, Chong, & Waring, 2006; Dougal & Rotello, 2007; Windmann & Kutas, 2001; Windmann et al., 2006; Langeslag & Van Strien, 2008; Sergerie, Lepage, & Armony, 2007). Critically however, when response bias was controlled, there was no effect of word valence (emotional vs. non-emotional) on memory discrimination for semantically related word lists (Budson et al., 2006b).

Aims of the Study

Accordingly, the goal of the present study was to explore levels of false recognition on a DRM task in late adolescents and early adults, relative to adults beyond this transition period. We predicted that middle-aged adults would show decreased false recognition of critical lures compared to youth, and that observable increases in false memory formation in the younger group would coincide with a more liberal response bias. We also predicted a more liberal response bias to negative, compared to neutral and positive words among our participants.

Methods

Participants

Forty participants were recruited into the study using an established research database at St. Joseph's Healthcare, Hamilton. Participants were initially identified by a nurse research coordinator on the basis of a demographic screening questionnaire detailing medical and psychiatric lifetime history. Eligible participants were then assessed by psychiatric nurses using the *Structured Interview for DSM-IV, Axis I Disorders, Patient version* (SCID-I/P; First, Spitzer, Gibbon, & Williams, 1995). Individuals were excluded from participation if there was an ongoing or significant past medical, neurological, or psychiatric illness (e.g., cancer, major depressive disorder), a recent history (within the past 12 months) of an endocrine or other medical disorder known to adversely affect cognition (e.g., Cushing's, uncontrolled diabetes, seizure disorder), or a history of traumatic brain injury and/or loss of consciousness lasting more than 60 seconds. All participants had normal or corrected-to-normal vision and hearing. Each participant provided written informed consent. The study was approved by the Research Ethics Board at St. Joseph's Healthcare, Hamilton.

Participants were divided into two groups based on age. Our youth sample included subjects aged 16-23 years, as we were particularly interested in the developmental stage of young adulthood rather than the earlier post-pubertal period (n=20; 13 female; M=19.7, SD=2.3). We contrasted performance of the youth with a group of middle-aged adults (n=20; 12 female) between 29 and 58 years of age (M=44.8, SD=8.9).

Paradigm

The False Memory Task consisted of 10 lists of neutral words and 20 lists of emotional words (10 positive, 10 negative) matched for word length and Kucera-Francis written frequency (1967). The lists and procedure were adapted (Roediger & McDermott, 1995; Budson et al., 2006a; Clancy, McNally, & Schacter, 1999) and extensively piloted. Each word list consisted of eight words that all converged on one critical lure word (e.g., night, bed, toss, turn, pillow; critical lure: SLEEP). Participants studied 5 neutral, 5 positive, and 5 negative word lists in pseudorandom order. Studied and non-studied word lists were counterbalanced across participants. The word lists were presented from highest to lowest semantic associate. The test items included 45 words from the previously studied lists (selected from positions 1, 3, and 6 of the studied lists) and the non-presented critical lure words related to each of the *studied* lists (5 positive, 5 negative, 5 neutral). As control items for true recognition, we included 15 neutral words from the non-studied lists (selected from positions 1, 3, and 6 of the non-studied, neutral lists). Control items for false recognition were 15 lure words (5 positive, 5 negative, 5 neutral) from the *unstudied* lists. We were primarily interested in measuring

Table 1. Proportion of true and false recognition, and corrected hit and false alarm rates for positive, negative, and neutral word lists

	Positive mean (SD)		Negative mean (SD)		Neutral mean (SD)	
	Youth	Adults	Youth	Adults	Youth	Adults
Proportion endorsed as "old"						
Previously studied	.76 (.14)	.74 (.17)	.77 (.19)	.81 (.18)	.79 (.18)	.80 (.12)
Related critical lures	.62 (.20)	.55 (.27)	.59 (.29)	.43 (.24)	.68 (.20)	.48 (.27)
Unrelated lure control	.41 (.25)	.34 (.31)	.25 (.27)	.17 (.25)	.28 (.29)	.22 (.28)
Non-studied neutral control					.23 (.21)	.13 (.13)
Hit rate	.74 (.13)	.72 (.16)	.75 (.18)	.79 (.17)	.77 (.17)	.78 (.11)
False alarm rate						
Related critical lure	.60 (.17)	.54 (.23)	.58 (.24)	.44 (.20)	.65 (.17)	.48 (.23)
Unrelated lure control	.43 (.21)	.37 (.26)	.29 (.23)	.22 (.21)	.32 (.24)	.27 (.24)
Non-studied neutral control					.24 (.19)	.15 (.12)

Table 2. Discrimination and bias indices for positive, negative, and neutral word lists

	Positive mean (SD)		Negative mean (SD)		Neutral mean (SD)	
	Youth	Adults	Youth	Adults	Youth	Adults
Correct recognition						
Discrimination Index (P_r)	.50 (.28)	.57 (.14)	.51 (.31)	.64 (.15)	.53 (.29)	.63 (.15)
False Recognition						
Discrimination Index (P_r)	.18 (.25)	.18 (.27)	.28 (.31)	.22 (.28)	.33 (.27)	.22 (.35)
Bias Index (B_r)	.51 (.18)	.44 (.26)	.41 (.22)	.27 (.16)	.45 (.22)	.33 (.21)

Note: Discrimination indices were calculated separately, using hit rates (H) and false alarm rates (FA), for true recognition [previously studied items relative to non-studied control items; e.g., $H_{positive}$– FA], and for false recognition of related critical lures [non-studied related critical lures relative to non-studied unrelated lure control items; e.g., $FA_{R.positive}$– $FA_{U.positive}$]. Bias indices were calculated for false recognition of related critical lures
[e.g., $(FA_{U.positive})/(1-(FA_{R.positive}– FA_{U.positive})$]. H refers to the corrected hit rate for recognition of previously studied positive, negative, or neutral words, FA refers to the corrected false alarm rate for non-studied neutral control words, FA_R is the corrected false alarm rate for non-studied positive, negative, or neutral related critical lures, and FA_U refers to the false alarm rate for non-studied positive, negative, or neutral unrelated lure control items.

correct recognition of the previously studied words, and false recognition (i.e., incorrectly judging a lure as "old") of the related critical lure words.

Statistical Analyses

We calculated the proportion of "old" responses to: i) studied items; ii) non-studied neutral control items; iii) non-studied related critical lures; and, iv) non-studied unrelated lure control items (Table 1). Following Snodgrass and Corwin (1988) we then calculated corrected hit rates and false alarm rates [e.g., $(Hits_{positive}+0.5)/(Presented_{positive}+1)$] for true and false recognition of positive, negative, and neutral word lists (Table 1). In order to account for possible differences in response bias between youth and adults, we used the two-high threshold correction (Snodgrass & Corwin, 1988) to calculate discrimination indices for true and false recognition, and bias indices for false recognition (Table 2). The discrimination index for true recognition reflects the ability to correctly identify previously presented words as "old", whereas the discrimination index for false recognition reflects the ability to correctly identify words that were *not* included on the study list as "new". The bias index for false recognition measures the tendency to respond a particular way under conditions of uncertainty (i.e., when item-specific recollection is low). For example, when presented with a word that was not included on the study list, an individual with a liberal response bias is more likely to incorrectly classify the word as "old"—resulting in apparent increases in false recognition—whereas an individual with a conservative response bias is more likely to classify the word correctly, as "new", resulting in lower rates of false recognition.

Correct Recognition. We conducted a mixed-design analysis of variance (ANOVA) on the proportion of previously studied positive, negative, and neutral words correctly recognized (i.e., correctly endorsed as "old"). In order to

control for any possible differences in response bias between youth and middle-aged adults, we also conducted a mixed-design ANOVA on the discrimination indices for previously studied positive, negative, and neutral words. In both analyses, age group (youth vs. middle-aged adults) was a between-subjects factor and word list valence (positive, negative, neutral) was a within-subjects factor.

False Recognition. We conducted a mixed-design ANOVA on the proportion of related critical lures and unrelated lure control items falsely recognized (i.e., incorrectly endorsed as "old"), where age group (youth, middle-age) was the between-subjects factor, and word list valence (positive, negative, neutral) and relatedness (related, unrelated) were within-subjects factors. To control for differences in response bias between the two age groups, we conducted a mixed-design ANOVA on the discrimination indices for non-studied positive, negative, and neutral related critical lures. Age group was the between-subjects variable and word list valence (positive, negative, neutral) was the within-subjects variable. We also conducted a mixed-design ANOVA on response bias for non-studied related critical lures, where age group was the between-subjects factor and word valence was the within-subjects variable.

Results

Correct Recognition. There were no significant main effects or interactions in the proportion of previously studied words correctly recognized, nor were there any significant main effects or interactions in discrimination of previously studied words.

False Recognition. There was a main effect of age group on false recognition, $F(1, 38)=4.18$, $p=.048$, partial $\eta^2=.10$, where youth endorsed significantly more lures, both related and unrelated, than middle-aged adults. There was also a main effect of emotion on false recognition, $F(2, 76)=8.82$, $p<.01$, partial $\eta^2=.19$, where positive lures were endorsed as "old" significantly more frequently than negative lures. As we expected, there was also a main effect of relatedness, $F(1, 38)=75.25$, $p<.01$, partial $\eta^2=.66$, indicating that related critical lures were identified as "old" more frequently than unrelated lure control items by all participants. There were no significant interactions.

We were interested in understanding why youth showed increased levels of false recognition relative to middle-aged adults. When response bias was controlled, there were no significant effects of emotion on discrimination of related critical lures, nor were there any significant age effects (p's$>.05$). These results indicate that, after controlling for response bias, the two age groups had comparable memory discrimination performance.

Our ANOVA on response bias indicated a main effect of emotion, $F(2, 76)=7.92$, $p<.01$, partial $\eta^2=.17$, where the response bias for positive words was significantly more liberal than that for negative words. Importantly, there was also a main effect of age group, $F(1, 38)=4.17$, $p=.048$, partial $\eta^2=.10$, such that youth had a significantly more liberal response bias than middle-aged adults. These results suggest that, when uncertain, younger adults are more likely than older adults to endorse a semantically-related critical lure as "old".

Discussion

The main finding in this study is that youth showed enhanced false memory formation relative to middle-aged adults. Specifically, our analysis revealed that, under conditions of uncertainty, youth were more likely to endorse false lure words from semantically-related lists of positive, negative, and neutral words as "old". This apparent increase in false recognition of critical lure words in the younger group stemmed from a more liberal response bias when making old/new recognition judgments. Indeed, after controlling for this response bias, memory discrimination performance was comparable between the two groups. This effect did not interact with the emotional valence of presented items. On balance, these results indicate that youth are more vulnerable to the formation of false memories than are middle-aged adults, and that this vulnerability stems from a more liberal approach to the judgment of an item's veracity. We speculate that this heightened vulnerability to false memory formation may contribute to the poor decision-making seen among youth, thereby increasing risk for the development of affective and other neuropsychiatric disorders.

These findings are in line with research showing that response bias becomes increasingly conservative across childhood and into young adulthood (Brainerd, Reyna, & Forrest, 2002); our results provide preliminary evidence that response bias continues to become more conservative through the transition from late adolescence into full adulthood, a developmental course that may coincide with the maturation of frontal and temporal networks that mediate these processes (Gogtay et al., 2004; Gogtay et al., 2006; Sowell et al., 2001). Studies examining the neural and neuropsychological correlates of false memory formation across the developmental transition from youth to adulthood would inform these predictions, and aid in delineating changes in the neural networks that underlie accurate and false recognition judgments.

Both older and younger groups showed a more liberal response bias for positive items compared to negative and neutral items (and were thus more likely to endorse positive items as "old" at recognition testing). There were no differences in accurate recognition or bias estimates between negatively valenced and neutral words. These results contrast with findings in other DRM studies, where emotionally-negative words show a more liberal response criterion than non-emotional words or positive words (Budson et al., 2006b; Talmi & Moscovitch, 2004), and with the results

of more standard episodic memory encoding tasks, where negative stimuli were also shown to elicit a more liberal response bias than non-emotional or positive stimuli (Budson et al., 2006b; Dougal & Rotello, 2007; Windmann & Kutas, 2001; Windmann et al., 2006). In the present study, the semantic relatedness and imagery inherent in our DRM word lists may have differentially contributed to levels of recognition and bias. Talmi and Moscovitch (2004) demonstrated that when neutral and emotional word lists are matched for semantic relatedness and imagery, no differences in recall are observed between neutral words and emotional words.

There are several limitations to this study. Sample size was relatively small, and therefore these results should be interpreted with caution. As well, the age range of the younger group was significantly smaller relative to the age range of the older group. The younger sample was restricted to exclude adolescents below the age of 16 years; false memory formation in children and adolescents younger than 16 has been studied extensively already, and performance varies considerably across the developmental period of childhood to young adulthood. Conversely, to our knowledge, there are no studies that have examined false memory formation in the middle adulthood period. Moreover, previous work that has compared young adults to adults older than 65 years of age show that rates of false recognition are comparable between these two groups when frontal lobe functioning in the older group is intact (Butler et al., 2004; Lavoie et al., 2006). Thus, we chose not to restrict the age range of the older sample. As we screened all participants for major medical or psychiatric conditions and previous head injuries and loss of consciousness, it is unlikely that differences in the integrity of frontal lobe functioning between 30 year olds and 50 year olds influenced our results to any significant extent. Future studies should include measures of neuropsychological functioning to address this issue explicitly.

The main finding from this study is that youth had higher rates of false memory formation than middle-aged adults, stemming from a more liberal response bias in the younger group. It is possible that differences in response bias between the older and younger groups reflect emergent changes in the efficiency and integrity of memory and decision-making networks across this transition period. Investigators have suggested that an enhanced understanding of how memory processes develop through adolescence and into early adulthood may be of use in determining whether variations in performance on these tasks reflects a vulnerability to the peak psychiatric morbidity observed during this period. For example, a more liberal bias in the judgment of a past event's personal significance may result in a distorted understanding of the event, misattribution of the event's significance, and an overgeneralized interpretation of the situation. Cognitive distortions such as overgeneralized memory represent a vulnerability marker for depression (Raes, Watkins, Williams, & Hermans, 2008; Kuyken & Dalgleish, 2011), particularly in the context of interpersonal stress (Sumner et al., 2011), and are associated with deficits in interpersonal problem solving, hopelessness, and even suicidal behavior (Arie, Apter, Orbach, Yefet, & Zalzman, 2008). This style of thinking, combined with an attentional bias to negative or threatening stimuli—which also represents a risk factor for depressive and anxiety disorders (Mathews & MacLeod, 2005; Gotlib & Joorman, 2010)—may eventually result in a personal narrative that overemphasizes negative experiences, while placing less significance on positive interactions. Indeed, distortions around the personal significance of past events—including overgeneralization, habitual interpretative styles, and biased processing—are the focus of cognitive behavioural therapy, a first-line treatment for depression and anxiety disorders.

Whether the major findings from the current study—that young have higher rates of false memory formation stemming from a more liberal approach to judging the veracity of events—are relevant to our understanding of how cognitive processes confer vulnerability to emotional dysregulation and increase the likelihood of poor decision making during this transition period remain to be determined.

Acknowledgements / Conflicts of Interest

This work was supported in part by the Ontario Mental Health Foundation in the form of a Research Studentship awarded to LCM, grants to MCM from the Ontario Mental Health Foundation, the National Alliance for Research in Schizophrenia and Affective Disorders, and the Scottish Rite Charitable Foundation, and an Ontario Mental Health Foundation grant to G.M.M. The authors have no financial relationships to disclose.

References

Andrews-Hanna, J. R., Mackiewicz Seghete, K. L., Claus, E. D., Burgess, G. C., Ruzic, L., & Banich, M. T. (2011). Cognitive control in adolescence: Neural underpinnings and relation to self-report behaviors. *PloS One*, *6*(6), e21598.

Arie, M., Apter, A., Orbach, I., Yefet, Y., & Zalzman, G. (2008). Autobiographical memory, interpersonal problem solving, and suicidal behavior in adolescent inpatients. *Comprehensive Psychiatry, 49*, 22-29.

Arndt, J., & Gould, C. (2006). An examination of two-process theories of false recognition. *Memory*, *14,* 814-833.

Arnett, J. J. (1992). Reckless behavior in adolescence: a developmental perspective. *Developmental Review, 12*, 339-373.

Balota, D. A., Cortese, M. J., Duchek, J. M., Adams, D., Roediger, H. L., McDermott, K. B., & Yerys, B. E. (1999). Veridical and false memories in heatlthy older adults and in demential of the alzheimer's type. *Cognitive Neuropsychology, 16*, 361-384.

Beauchaine, T. P., Klein, D. N., Crowell, S. E., Derbidge, C., & Gatzke-Kopp, L. (2009). Multifinality in the development of personality disorders: A Biology x Sex x Environment interaction model of antisocial and borderline traits. *Development and Psychopathology, 21*, 735-770.

Brainerd, C. J., & Reyna, V. F. (2007). Explaining developmental reversals in false memory. *Psychological Science, 18*, 442-448.

Brainerd, C. J., Reyna, V. F., & Forrest, T. J. (2002). Are young children susceptible to the false-memory illusion? *Child Development, 73*, 1363-1377.

Buckner, R. L., Kelley, W. M., & Peterson, S. E. (1999). Frontal cortex contributes to human memory formation. *Nature Neuroscience, 2*, 311-314.

Budson, A. E., Todman, R. W., Chong, H., Adams, E. H., Kensinger, E. A., Krangel, T. S., & Wright, C. I. (2006a). False recognition of emotional word lists in aging and Alzheimer disease. *Cognitive and Behavioral Neurology, 19*, 71-78.

Budson, A. E., Wolk, D. A., Chong, H., & Waring, J. D. (2006b). Episodic memory in Alzheimer's disease: Separating response bias from discrimination. *Neuropsychologia, 44*, 2222-2232.

Butler, K. M., McDaniel, M. A., Dornburg, C. C., Price, A. L., & Roediger, H. L. (2004). Age differences in veridical and false recall are not inevitable: The role of frontal lobe function. *Psychonomic Bulletin Reviews, 11*, 921-925.

Byrnes, J. P. (2002). The development of decision-making. *Journal of Adolescent Health, 31*, 208-215.

Clancy, S. A., McNally, R. J., & Schacter, D. L. (1999). Effects of guided imagery on memory distortion in women reporting recovered memories of childhood sexual abuse. *Journal of Traumatic Stress, 12*, 559-569.

Dahl, R. E. (2001). Affect regulation, brain development, and behavioral/emotional health in adolescence. *CNS Spectrums, 6*, 60-72.

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology, 58*, 17-22.

Dougal, S., & Rotello, C. M. (2007). "Remembering" emotional words is based on response bias, not recollection. *Psychonomic Bulletin Reviews, 14*, 423-429.

Dumontheil, I., Houlton, R., Christoff, K., & Blakemore, S.-J. (2010). Development of relational reasoning during adolescence. *Developmental Science, 13*(6), F15-24.

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. W. (1995). Structured interview for DSM- IV Axis I Disorders—Patient Edition, Version 2. New York, NY: Biometric Research Department.

Gabrieli, J. D., Poldrack, R. A., & Desmond, J. E. (1998). The role of the left prefrontal cortex in language and memory. *Proceedings of the National Academy of Science USA, 95*, 906-913.

Geier, C., & Luna, B. (2009). The maturation of incentive processing and cognitive control. *Pharmacology, Biochemistry, and Behavior, 93*(3), 212-221.

Gogtay, N., Giedd, J. N., Lusk, L., Hayashi, K. M., Greenstein, D., Vaituzis, A. C.,…Thompson, P. M. (2004). Dynamic mapping of human cortical development during childhood through early adulthood. *Proceedings of the National Academy of Science USA, 101*, 8174-8179.

Gogtay, N., Nugent, T. F., Herman, D. H., Ordonez, A., Greenstein, D., Hayashi, K. M.,…Thompson, P. M. (2006). Dynamic mapping of normal human hippocampal development. *Hippocampus, 16*, 664-672.

Gotlib, I. H., & Joormann, J. (2010). Cognition and depression: Current status and future directions. *Annual Review of Clinical Psychology, 6*, 285-312.

Grunbaum, J. A., Kann, L., & Kinchen, S. (2004). Youth Risk Behavior Surveillance—United States, (Abridged). *Journal of School Health, 74*, 307-324.

Hassel, S., McKinnon, M. C., Cusi, A. M., & MacQueen, G. M. (2011). An overview of psychological and neurobiological mechanisms by which early negative experiences increase risk of mood disorders. *Journal of the Canadian Academy of Child and Adolescent Psychiatry, 20*, 277-88.

Kim, H., & Cabeza, R. (2007). Differential contributions of prefrontal, medial temporal, and sensory-perceptual regions to true and false memory formation. *Cerebral Cortex, 17*, 2143-2150.

Kucera, H., & Francis, W. (1967). Computational analysis of present day American English. Providence, RI: Brown University Press.

Kuyken, W., & Dalgleish, T. (2011). Overgeneral autobiographical memory in adolescents at risk for depression. *Memory, 19*(3), 241-250.

Lampinen, J. M., Leding, J. K., Reed, K. B., & Odegard, T. N. (2006). Global gist extraction in children and adults. *Memory, 14*, 952-964.

Langeslag, S. J., & Van Strien, J. W. (2008). Age differences in the emotional modulation of ERP old/new effects. *International Journal of Psychophysiology, 70*, 105-114.

Lavoie, D. J., Willoughby, L., & Faulkner, K. (2006). Frontal lobe dysfunction and false memory susceptibility in older adults. *Experimental Aging Research, 32*, 1-21.

Mathews, A., & MacLeod, C. (2005). Cognitive vulnerability to emotional disorders. *Annual Review of Clinical Psychology, 1*, 167-195.

Norman, K. A., & Schacter, D. L. (1997). False recognition in younger and older adults: Exploring the characteristics of illusory memories. *Memory and Cognition, 25*, 838-848.

Odegard, T. N., Holliday, R. E., Brainerd, C. J., & Reyna, V. F. (2008). Attention to global gist processing eliminates age effects in false memories. *Journal of Experimental Child Psychology, 99*, 96-113.

Pasupathi, M., & Mansour, E. (2006). Adult age differences in autobiographical reasoning in narratives. *Developmental Psychology, 42*, 798-808.

Raes, F., Watkins, E. R., Williams, J. M., & Hermans, D. (2008). Non-ruminative processing reduces overgeneral autobiographical memory retrieval in students. *Behavioral Research and Therapy, 46*, 748-756.

Roediger, H. L., & Geraci, L. (2007). Aging and the misinformation effect: a neuropsychological analysis. *Journal of Experimental Psychology Learning Memory and Cognition, 33*, 321-334.

Roediger, H. L., & Mcdermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology Learning Memory and Cognition, 21*, 803-814.

Sergerie, K., Lepage, M., & Armony, J. L. (2007). Influence of emotional expression on memory recognition bias: A functional magnetic resonance imaging study. *Biological Psychiatry, 62*, 1126-1133.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117*, 34-50.

Sowell, E. R., Thompson, P. M., Tessner, K. D., & Toga, A. W. (2001). Mapping continued brain growth and gray matter density reduction in dorsal frontal cortex: Inverse relationships during postadolescent brain maturation. *Journal of Neuroscience, 21*, 8819-8829.

Steinberg, L. (2005). Cognitive and affective development in adolescence. *Trends in Cognitive Science, 9*, 69-74.

Sumner, J. A., Griffith, J. W., Mineka, S., Rekart, K. N., Zinbarg, R. E., & Craske, M. G. (2011). Overgeneral autobiographical memory and chronic interpersonal stress as predictors of the course of depression in adolescents. *Cognition & Emotion, 25*(1), 183-192.

Talmi, D., & Moscovitch, M. (2004). Can semantic relatedness explain the enhancement of memory for emotional words? *Memory and Cognition, 32*, 742-751.

Van Leijenhorst, L., Gunther Moor, B., Op de Macks, Z. A., Rombouts, S. A. R. B., Westenberg, P. M., & Crone, E. A. (2010). Adolescent risky decision-making: Neurocognitive development of reward and control regions. *NeuroImage, 51*(1), 345-355.

Windmann, S., & Kutas, M. (2001). Electrophysiological correlates of emotion-induced recognition bias. *Journal of Cognitive Neuroscience, 13*, 577-592.

Windmann, S., Schneider, T., Reczio, J., Grobosch, M., Voelzke, V., Blasius, V.,…Wischnjak, L. (2006). Intact emotion-induced recognition bias in neuropsychological patients with executive control deficits. *Cognitive Affective and Behavioral Neuroscience, 6*, 270-276.