The Effects of Emotional Arousal on False Recognition in Alexithymia

Anthony N. Correro
Marquette University

THE EFFECTS OF EMOTIONAL AROUSAL ON FALSE RECOGNITION IN ALEXITHYMIA

by

Anthony N. Correro II, B.S.

A Thesis submitted to the Faculty of the Graduate School,
Marquette University,
in Partial Fulfillment of the Requirements for
the Degree of Master of Science

Milwaukee, Wisconsin

May 2015

ABSTRACT
THE EFFECTS OF EMOTIONAL AROUSAL ON FALSE
RECOGNITION IN ALEXITHMIYA

Anthony N. Correro II, B.S.

Marquette University, 2015

Alexithymia is a personality trait characterized by difficulties identifying feelings, difficulties describing feelings, and an externally oriented thinking style (EOT). Further, individuals with alexithymia experience chronic physiological arousal. Prior research has shown that non-clinical participants with alexithymic traits cannot subjectively recognize increased arousal in response to viewing an arousing video. Yet, these individuals will still experience physiological arousal and will still have arousal-induced memory modulation. No studies to date have examined arousal effects on false memory in alexithymia.

The Deese-Roediger-McDermott (DRM) paradigm examines false memory by introducing words associated with a non-presented 'theme' word (i.e., critical lure) as memoranda, which typically causes the lures to be remembered as frequently as studied words. Our prior work with non-alexithymic groups has shown enhanced veridical memory and reduced false memory when arousal is induced *after* learning (i.e., during memory consolidation).

Thus, 130 subjects studied and recalled six DRM lists and then watched a 3-min arousing (n = 61) or neutral (n = 69) video. Recognition was tested 70 min later. A median split was utilized to separate participants into high and low alexithymia groups based on Toronto Alexithymia Scale – 20 (TAS-20) scores. Arousal was expected to interact with alexithymia in such a way to allow individuals with high alexithymia to overcome their EOT.

Arousal enhanced conservative responding for studied words relative to all foils, including critical lures and 'weak associates.' Alexithymia did not impact overall memory performance, but low alexithymia increased confident remembering and high alexithymia increased familiarity processes. Individuals with high alexithymia were more sensitive to both strong and weak false information (critical lures and weak associates, respectively). Arousal was expected to overcome these memory deficits in alexithymia. No direct evidence for an "overcoming" interaction between arousal and alexithymia was found. However, *post hoc* analyses of alexithymia clusters did support various mechanisms of arousal "overcoming" misinformation.

ACKNOWLEDGMENTS

Anthony N. Correro II, B.S.

This study was supported in part by the Way Klingler Sabbatical Research Fellowship, Marquette University (to the faculty research advisor and chair of the thesis committee, Dr. Kristy A. Nielson) and a National Science Foundation Graduate Research Fellowship Program (to ANC).

I would like to thank Steven J. Byers and Carrie E. Massura for assistance with earlier versions of this project; Ilse Van Damme for many of the empirical foundations in this study; Katherine Reiter, Christina M. Figueroa, and Kathleen E. Hazlett for assistance, guidance, mentorship, and friendship; Maha Baalbaki, Ben Johnson, Dave Marra, Travis McCuddy, and Lauren Yadlosky for being the best cohort family I could ever ask for; Drs. James Hoelzle and Nakia Gordon for reading the proposal and document and for serving on my thesis committee; and Dr. Kristy A. Nielson for all of her support, guidance, mentorship, brainstorming, collaboration, and editing as well as for serving as the chair on my thesis committee and for being my research mom.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

Alexithymia is a stable personality trait that refers to an individual's inability to describe or identify their emotions (Luminet, Bagby, & Taylor, 2001; Sifneos, 1973; Taylor, 2000). This trait encompasses a cluster of cognitive and affective characteristics. For example, individuals with alexithymia frequently cannot discriminate between physiological sensations of arousal and affective responses to arousal, are less capable of fantasizing and using imaginal capacities, and are more likely to utilize a cognitive style that is externally oriented (Taylor, 2000; Taylor & Bagby, 2004) . Moreover, individuals with alexithymia have deficits in cognitive processing of emotions and in emotion regulation (e.g., Swart, Kortekaas, & Aleman, 2009; Taylor, 2000; Taylor, Bagby, & Parker, 1991).

Alexithymia has been found to increase one's risk for the development of various psychological disorders, including panic disorder (Parker, Taylor, Bagby, & Acklin, 1993; Zeitlin & McNally, 1993), eating disorders (Cochrane, Brewerton, Wilson, & Hodges, 1993), autism spectrum disorders (Hill, Berthoz, & Frith, 2004), and major depressive disorder (Luminet et al., 2001; Zackheim, 2007). Alexithymia is also a risk factor for psychosomatic medical conditions like hypertension (Jula, Salminen, & Saarijarvi, 1999; Todarello, Taylor, Parker, & Fanelli, 1995) and functional gastrointestinal disease (Porcelli, Taylor, Bagby, & De Carne, 1999). Physiological arousal persists for individuals with alexithymia due to their difficulties recognizing and regulating negative emotions. This chronic arousal likely mediates the onset of psychiatric and medical conditions (Jula et al., 1999; Lumley, Stettner, & Wehmer, 1996).

A concept associated with how individuals high in alexithymia experience arousal is "decoupling" (Friedlander, Lumley, Farchione, & Doyal, 1997; Martin & Pihl, 1986; Papciak, Feuerstein, & Spiegel, 1985). This phenomenon refers to the discrepancy between subjective awareness of emotions and the physiological reactions to emotion. Despite lacking subjective insight into arousal, individuals with high alexithymia showed significant increases in physiological arousal, as measured by heart rate and electrodermal activity, when watching an emotionally arousing videotape of live-action oral surgery (Stone & Nielson, 2001). This lack of enhanced subjective arousal when physiological arousal substantially increased is a reflection of decoupling (Papciak et al., 1985).

The consensus of the extant literature suggests that physiological response and, perhaps even, experience of arousal is intact in alexithymia despite the difficulties processing and interpreting the emotion associated with arousal (Franz, Schaefer, Schneider, Sitte, & Bachor, 2004; Stone & Nielson, 2001; Swart et al., 2009). Typically, after stimuli are perceived and encoded, further processes can occur that consolidate and store them as memory traces. Emotion and arousal are important modulators of such memory processes (McGaugh, 2000). Thus, alexithymia may affect memory in important ways. Indeed, alexithymia is associated with a diminished ability to remember emotive words over a short time period (Vermeulen, Toussaint, & Luminet, 2010). More specifically, difficulty identifying feelings and difficulty describing feelings are negatively correlated with memory for emotive words (Vermeulen et al., 2010).

Other recent studies have attempted to understand the effect of alexithymia on memory processes by examining long-term memory for neutral stimuli and by inducing arousal *after* learning (Nielson & Meltzer, 2009). Moderate arousal induced after learning, regardless of its valence or "tone," has been shown to enhance long-term memory retrieval by modulating memory consolidation (Nielson & Powless, 2007). Müller and Pilzecker (1900) first described memory consolidation as the phase in which memory traces are categorized, organized, and filed for future use. Consolidation starts immediately after working memory ends and extends for minutes, hours, and potentially even days (Anderson, Wais, & Gabrieli, 2006; McGaugh, 2000; Revelle & Loftus, 1992; Walker, 1958).

While numerous studies have manipulated emotional arousal prior to or during encoding, showing that emotional arousal enhances later memory performance (e.g., Corson & Verrier, 2007; Storbeck & Clore, 2005; Van Damme, 2013), these studies cannot readily demarcate whether attention, encoding, motivation, rehearsal, consolidation, or other memory storage processes are specifically affected by the manipulation. Yet, some studies have induced emotional arousal after encoding, therefore isolating its effects to the consolidation phase of memory storage. These studies demonstrated comparable long-term memory enhancement effects via arousal (e.g., Nielson & Arentsen, 2012; Nielson & Jensen, 1994; Nielson & Meltzer, 2009; Nielson & Powless, 2007). Thus, while arousal may affect any of the stages of the memory process, it has been specifically shown to enhance memory consolidation (McGaugh, 2000). Many studies have further shown that the mechanism by which modulation occurs involves the amygdala and secondary effects on medial temporal lobe memory structures (McGaugh, 2004) Specifically, peripheral adrenal responses to arousal affect receptors that alter amygdala and medial temporal lobe activity, including the hippocampus (Erk, von Kalckreuth, & Walter, 2010; Kensinger & Corkin, 2004; McGaugh, 2004).

Given that moderate arousal induced after learning has been frequently shown to enhance later retrieval (Nielson & Jensen, 1994; Nielson & Powless, 2007), Nielson and Meltzer (2009) examined this effect in those with high versus low alexithymic traits. Their results showed poorer immediate recall prior to arousal induction in high alexithymia but comparable long-term veridical memory in high and low alexithymia when arousal was induced after learning. Moreover, both alexithymia groups exhibited comparable physiological responses to arousal (measured via electrodermal activity and heart-rate), but those with high alexithymia did not endorse subjective responses to arousal, reflecting alexithymic decoupling (Stone & Nielson, 2001). Furthermore, the effects of physiological arousal were isolated by having participants study neutral words. That is, the effects of arousal stemmed solely from the film clip shown after learning.

When memoranda have emotive tone (i.e., arousal occurs during learning and is inherent to the memoranda), the story is more complex. In one study (Meltzer & Nielson, 2010), emotive negative, emotive positive, illness-related, and neutral words were implicitly encoded through word ratings, and delayed free recall for all of the study words was assessed. Results showed not only reduced retrieval of negative emotional words in high versus low alexithymia but also greater retrieval of illness words in high alexithymia, thereby demonstrating the importance of stimulus relevance to memory for emotional material. Additionally, a trend for better recall for neutral words in high alexithymia was explicated through the tendency for individuals with alexithymia to preferentially process external information (Taylor, 2000). The neutral words implicitly studied in their experiment were generally more concrete than the illness-related, positive, and negative words. Thus, the non-emotive items may have been more readily attended to in high alexithymia. Speculating from Meltzer and Nielson's conclusions, it is possible that this trend would have reached statistical significance if arousal had been manipulated after learning.

Arousal has been shown to enhance veridical memory, but it has also been shown to reduce false memory in studies using the "misinformation effect" paradigm (English & Nielson, 2010) and the Deese-Roediger-McDermott, or DRM, (Deese, 1959; Roediger & McDermott, 1995) paradigm (Nielson, Correro II, & Byers, 2015; Van Damme, 2013). In the "misinformation effect" paradigm, arousal appeared to act through a reduction of source confusion (English & Nielson, 2010). In the DRM task, participants study lists of words that are semantically related to a nonpresented 'critical lure,' or theme word. When individuals are shown this critical lure on a later recognition test, they frequently endorse having studied it (i.e., a false memory occurs). Further, veridical memory can be investigated by examining participants' patterns of recognizing words that were actually studied.

Van Damme (2013) utilized nonparametric signal detection variables in a DRM study to examine the effects of arousal, induced prior to learning, on false and veridical memory. Regardless of valence, arousal led to reductions in false memory (see also, Anderson et al., 2006; Nielson & Powless, 2007). Ultimately, arousal led to a less liberal response bias, meaning that arousal decreased susceptibility to the dubious critical lures. Also, arousal elicited greater discriminability, thereby improving veridical memory and reducing false memory for critical lures. In a paper under review, Nielson et al. (2015)

replicated Van Damme's findings using arousal induced *after* learning. DRM lists were presented, followed by a 3-minute video (either arousing or neutral). After 70 minutes of distractor activities and completing surveys, memory was tested using a Remember/Know recognition task (Gardiner, 1988; Tulving, 1985). This test consisted of studied items, critical lures, unrelated foils that were not studied, and weaker unstudied associates from the studied lists. Memory performance was enhanced by arousal as evidenced by reduced false alarm rates, and false memory for critical lures and weak associates was reduced by arousal through greater discriminability and a less liberal pattern of responding. Incorporating weak associates on the recognition test was a novel approach in Nielson et al. (2015) to investigate the extent to which arousal reduces susceptibility to various misinformation.

Importantly, no research to date has focused on false memory paradigms with alexithymia, and no studies of alexithymia have used signal detection theory to examine how such arousal effects occur or if they differ based on alexithymic traits. In our prior study (Nielson et al., 2015), alexithymic traits were measured during the retention interval using the Toronto Alexithymia Scale – 20 (TAS-20), which is the most reliable and valid measure of alexithymia (Bagby, Parker, & Taylor, 1994; Bagby, Taylor, & Parker, 1994). However, these scores were not examined relative to the memory data. Thus, the overall purpose of the current study was to examine false memory in the context of alexithymia, specifically ascertaining through signal detection analysis the manner in which neutral stimuli are processed and consolidated in high versus low alexithymia. As a result, the proposed study represented a 2 (arousal: high or neutral) × 2 (alexithymia: high or low) between-subjects quasi-experimental design.

Hypotheses

Response to the manipulation.

The arousing video was hypothesized to result in significantly greater subjective arousal compared to the neutral video (English & Nielson, 2010; Nielson & Powless, 2007). Importantly, those with low alexithymia were expected to exhibit increased arousal ratings after watching the arousing video (versus the neutral clip), while those scoring high on alexithymia were not expected to exhibit the same increase (Nielson & Meltzer, 2009; Stone & Nielson, 2001). Thus, an interaction between arousal and alexithymia was hypothesized, reflecting difficulties in identifying and describing feelings in high alexithymia (Franz et al., 2004).

Memory modulation.

Memory was expected to be altered by arousal equivalently across both alexithymia groups (Nielson & Meltzer, 2009). More specifically, arousal was expected to enhance veridical memory (i.e., increase hit rates). Although physiological arousal was not directly measured, the arousal manipulation was expected to impact physiological arousal, thereby enhancing veridical memory similarly for both those with high and low alexithymia (Nielson & Meltzer, 2009).

Signal detection measures were analyzed for the memory performance of individuals high and low in alexithymia (Nielson et al., 2015; Van Damme, 2013). Arousal was expected to enhance the discriminability of studied information versus unstudied distractors in both high and low alexithymia. Further, arousal was expected to reduce liberal response bias regarding studied words versus distractors, replicating prior research (Nielson et al., 2015; Van Damme, 2013). Neither differences between alexithymia groups nor interactions between arousal and alexithymia were expected, similar to the results of Nielson and Meltzer (2009).

The interaction of arousal and alexithymia for false memory was expected to be more complex than for veridical memory. Similar to previous studies, arousal was expected to reduce false recognition for foils, lures, and weak associates (Nielson et al., 2015; Van Damme, 2013). However, it was hypothesized that false memory would be increased by alexithymia. Specifically, inherent to the DRM paradigm is the implicit semantic activation of the critical lures upon which the study lists are centered (Roediger, Watson, McDermott, & Gallo, 2001). Generally speaking, people with alexithymia were predicted to attend to critical lures more strongly than those with low alexithymia because the lures are external, neutral, and implicitly activated (Meltzer & Nielson, 2010). Moreover, this external cognitive style was expected to reduce the ability to utilize monitoring processes when approached with dubious information.

The combined effects of arousal and alexithymia were expected to result in either of two types of significant interactions for false recognition. One possibility was that high alexithymia would lead to greater false memories, but arousal could reduce these false memories by attenuating source confusion. This is heretofore referred to as the "overcoming" model. Alternatively, arousal could have led to greater false memories in high alexithymia, which arousal would further exacerbate. While there was no definitive basis for a hypothesis predicting one of these scenarios versus the other, the "overcoming" model was predicted. Although those with high alexithymia were generally expected to have greater false memories than those with low alexithymia, arousal was expected to enhance source monitoring in both high and low alexithymia (English & Nielson, 2010; Smeets et al., 2006). As such, it was predicted that this process would overcome, or reduce, the innate externally oriented cognitive style within high alexithymia.

Arousal was expected to lead to greater discriminability of studied words and to reduce liberal response patterns (Nielson et al., 2015; Van Damme, 2013), reflecting arousal-induced enhancement of source monitoring accuracy for misleading information (English & Nielson, 2010). Low alexithymia groups were expected to be better able to discriminate studied items and be less easily swayed by dubious lures than those with high alexithymia because of the impact of the externally oriented cognitive style typical to alexithymia (Meltzer & Nielson, 2010). Furthermore, arousal and alexithymia were expected to interact, such that arousal in high alexithymia would reduce the implicit processing of critical lures (and therefore false memory). This would support an "overcoming" model.

Method

Participants

Participants (n = 130; 90 female, 40 male; M_{age} = 19.48, SD = 1.29) were undergraduate students who received course credit for participation. All procedures were reviewed and approved by Marquette University's Internal Review Board.

Materials

DRM.

Six DRM word lists were compiled from normative data (Stadler, Roediger, & McDermott, 1999) and recorded by a female experimenter presenting lists at a rate of one word every two seconds. Each word list, organized around a critical lure that was not presented during the encoding phase, included the 15 associates most likely to elicit the critical lure (Roediger et al., 2001). The six lists were counterbalanced into six different orders such that each individual list occurred in each serial position. For each group session, only one of the six orders was presented. The order for the session was chosen pseudo-randomly. See Appendix A for the DRM word lists.

Emotional Rating Scale.

Subjective mood and emotional arousal were assessed using the Emotion Rating Scale, or ERS (Nielson & Powless, 2007). This scale required participants to rate their current mood on a scale of 1, *extremely negative*, to 10, *extremely positive*. Separately, this scale also asked that participants label their current arousal level on a scale of 1, *not at all aroused*, to 10, *extremely aroused*. See Appendix B for an example of the ERS.

Arousal manipulation.

Emotional arousal was manipulated using one of two videos ($n_{arousal} = 61$, $n_{neutral} = 69$). Participants in odd-numbered experimental sessions watched the arousal video, which was a 3-minute clip of live-action oral surgery. This clip was shown to elicit moderate subjective emotional arousal and physiological arousal in prior studies (e.g., English & Nielson, 2010; Nielson & Powless, 2007; Nielson, Yee, & Erickson, 2005; Stone & Nielson, 2001). Participants in even-numbered experimental sessions watched the neutral video, which was a 3-minute clip from a PBS documentary concerning the link between heart disease and depression. Prior studies have indicated that this clip is interesting enough to maintain attention without substantively raising arousal level or significantly altering mood (e.g., English & Nielson, 2010; Nielson & Arentsen, 2012). The videos did not overlap semantically with each other or with the DRM lists.

Retention interval.

Following the arousal manipulation, all participants experienced a 70-minute retention interval in which problem-solving tasks ("brain teasers") and 14 questionnaires were completed (see Procedure). None of the materials during this delay were analyzed in this project except the TAS-20.

TAS-20.

The Toronto Alexithymia Scale – 20 (TAS-20) is a self-report measure that consists of 20 questions. This scale is reliable and valid in the measurement of alexithymia (Taylor & Bagby, 2004). For example, studies have demonstrated that the TAS-20 has good internal consistency within a sample of college participants

(Cronbach's α = .81), good test-retest reliability (r = .77), and good convergent and divergent validity (Bagby, Parker, et al., 1994; Bagby, Taylor, et al., 1994). The TAS-20 is composed of three subscales: Difficulty Identifying Feelings, Difficulty Describing Feelings, and Externally Oriented Thinking. High versus low alexithymia groups were demarcated via a median split (Meltzer & Nielson, 2010).

Recognition task.

The delayed recognition test employed the classic Remember/Know paradigm (Gardiner, 1988; Tulving, 1985), where a "No" response indicated the item was not presented during the encoding phase. With this type of recognition test, "Remember" and "Know" responses were correct when endorsed for previously studied material and incorrect when endorsed for brand new words regardless of relatedness to the original word lists. This format allowed participants to respond more confidently with a "Remember" response if they could specifically recall contextual features or internal representations of the word during encoding. "Know" responses reflected less confidence in one's responding and more of an experience of "trusting one's gut."

The recognition test consisted of 162 items presented in pseudo-random order: 90 previously studied list items (all 15 from each list), the six previously unpresented critical lures, 12 previously unpresented 'weak associates' of the studied lists (two per list), and 54 new, unrelated items (i.e., "foils"). These foils were taken from established word norms and were highly imageable and concrete nouns (Paivio, Yuille, & Madigan, 1968). Weak associates were synonyms of the critical lures from the superordinate DRM lists, but none were the top 15 associates in DRM norms (Stadler et al., 1999). Also, these words were not frequently associated with their critical lure or other DRM list items based on word association databases (Russell & Jenkins, 1954; Toglia & Battig, 1978).

Procedure

Experimental sessions were conducted in a group format over one 120-minute session. Informed consent was obtained at the beginning of each session. A demographic survey followed. The DRM lists were then presented one list at a time, with instructions to remember the words, followed by immediate free recall after each list. After all lists were completed, the first ERS was obtained. Next, participants watched either the oral surgery video (high arousal group) or the documentary (neutral group). This was followed by a second ERS. The “brain teasers” and various surveys, including the TAS-20, were then administered until 70 minutes had elapsed. Recognition testing was administered following this delay. Finally, participants were debriefed.

Data Analytic Plan

All analyses were conducted using SPSS Version 21.0. A significance criterion of $p < .05$ was used for all statistical tests. Four 2 (alexithymia: high versus low alexithymia) × 2 (arousal: neutral versus high) ANOVAs were evaluated for descriptive statistics and group equivalence. All four cells of subjects were expected to be comparable for age, grade-point average (GPA), and baseline ratings of mood and of arousal. This would demonstrate group equivalence prior to the arousal manipulation. Two 2 (alexithymia) × 2 (arousal) × 2 (time: baseline versus post-manipulation) mixed ANOVAs were analyzed for the ERS scores. This analysis was conducted as a manipulation check. Fisher’s LSD tests were used for all post-hoc group comparisons.

Recognition analyses were conducted using several two-way ANOVAs. Hit rates for studied words, error rates of unstudied foils, false alarm rates of critical lures, and error rates of weak associates were compared across the arousal and alexithymia groups. Raw rates of memory performance do not take into consideration the degree of overlap between studied and unstudied distributions (sensitivity) or the general tendency to respond in a more conservative or liberal manner (response bias) (Snodgrass & Corwin, 1988). As such, signal detection analyses were used. In particular, non-parametric indices have been deemed best for the DRM paradigm due to the non-normality of data distribution (Van Damme, 2013). Separate 2 (alexithymia) × 2 (arousal) ANOVAs were analyzed for the non-parametric signal detection measures A' and B''. A' ranges from 0 to 1, with a value of 0.5 indicating chance performance and larger values indicating greater sensitivity (Stanislaw & Todorov, 1999). B'' ranges from -1 to 1, where negative values indicate liberal responding and positive values reflect conservative responding.

Results

Median Split on Alexithymia

Group equivalence.

Descriptive statistics and demographic characteristics can be found in Table 1. Four 2 (alexithymia) × 2 (arousal) ANOVAs were evaluated to ensure that groups were equivalent prior to the arousal manipulation. There were no significant differences between the groups with respect to self-reported grade-point average (GPA), sex distribution, self-reported baseline mood and arousal ratings, and immediate free recall performance for studied words, critical lures, or intrusions. However, the low alexithymia group was approximately one year older than the high alexithymia group, $F_{\text{alexithymia}}(1, 126) = 22.45$, $p < .001$, $\eta_p^2 = .15$. Because all participants were within the same developmental stage of emerging adulthood (i.e., aged 18-25), this difference was not interpreted as particularly meaningful. Thus, the groups were not dissimilar at baseline in terms of demographic characteristics or in their ability to attend to and learn the DRM lists.

Table 1

Mean (SD) demographic characteristics and immediate free recall performance (prior to manipulation) by participant group.

	Neutral		**Arousal**		**ANOVA (F(1,126)**		
	LA	**HA**	**LA**	**HA**	**Cond.**	**Group**	**Inter-action**
	(n = 38)	**(n = 31)**	**(n = 26)**	**(n = 35)**	***p* (η_p^2)**	***p* (η_p^2)**	***p* (η_p^2)**
Demographics							
Age (yrs)	19.79 (1.1)	19.10 (0.9)	20.23 (1.7)	18.91 (1.1)	.54 (.003)	**<.001 (.15)**	.14 (.02)
GPA	3.26 (0.5)	3.15 (0.5)	3.30 (0.5)	3.28 (0.4)	.31 (.01)	.42 (.01)	.58 (.002)
Sex^	9M 29F	10M 21F	7M 19F	14M 21F	-	-	-
Baseline Mood	5.74 (1.7)	5.52 (1.3)	5.73 (1.0)	5.69 (1.2)	.73 (.001)	.58 (.002)	.71 (.001)
Baseline Arousal	3.82 (1.6)	3.55 (1.7)	4.35 (1.6)	3.66 (1.7)	.29 (.01)	.11 (.02)	.48 (.004)
TAS-20: Total	35.84 (4.9)	52.00 (6.6)	36.58 (4.4)	54.71 (8.4)	.13 (.02)	**<.001 (.65)**	.38 (.01)
DIF	10.08 (2.5)	16.03 (5.5)	10.65 (3.5)	16.89 (5.9)	.38 (.01)	**<.001 (.31)**	.86 (<.001)
DDF	8.87 (2.3)	15.74 (3.5)	9.62 (3.0)	16.34 (3.2)	.21 (.01)	**<.001 (.56)**	.89 (<.001)
EOT	16.90 (3.5)	20.23 (3.7)	16.31 (3.3)	21.49 (4.5)	.62 (.002)	**<.001 (.24)**	.17 (.02)
Immediate Free Recall							
Studied Words	51.11 (8.8)	50.65 (6.9)	52.35 (7.0)	51.54 (6.8)	.42 (.01)	.64 (.002)	.90 (<.001)
Critical Lures	2.74 (1.5)	3.23 (1.4)	2.62 (1.4)	2.83 (1.6)	.33 (.01)	.19 (.01)	.60 (.002)
Intrusions	1.29 (1.1)	1.13 (1.2)	1.19 (1.2)	1.4 (1.4)	.70 (.001)	.92 (<.001)	.41 (.01)

Note. Cond. = Arousal; Group = Alexithymia; GPA = Grade-point Average (4-point scale). LA = low alexithymia; HA = high alexithymia; M = male; F = female; Baseline Mood and Arousal = self-reported ratings (scale 1 to 10); TAS-20 = Toronto Alexithymia Scale - 20; DIF = Difficulty Identifying Feelings; DDF = Difficulty Describing Feelings; EOT = Externally Oriented Thinking. ^$\chi^2(1) = 2.01$, $p = .16$, *ns*.

Manipulation checks.

Mood ratings.

Subjective mood and arousal ratings over time were evaluated using two 2 (arousal) × 2 (alexithymia) × 2 (time) mixed ANOVAs. Mood ratings were generally more negative at the second time of assessment, $F_{\text{time}}(1, 126) = 32.68$, $p < .001$, $\eta_p^2 = .21$. Further, mood was reported as more negative for the arousal group, $F_{\text{arousal}}(1, 126) = 4.08$, $p = .046$, $\eta_p^2 = .03$. Most importantly, the interaction between arousal and time was significant, $F_{\text{arousal} \times \text{time}}(1, 126) = 12.51$, $p = .001$, $\eta_p^2 = .09$. *Post hoc* comparisons revealed that participants did not report significantly different mood after manipulation in the neutral condition ($p = .11$); however, participants in the arousal condition reported significantly more negative mood after the manipulation compared to baseline ($p < .001$). There were no main or interaction effects involving alexithymia that reached significance: $F_{\text{alexithymia}}$ $(1, 126) = 0.23$, $p = .63$, $\eta_p^2 = .002$; $F_{\text{alexithymia x arousal}}(1, 126) = 0.62$, $p = .42$, $\eta_p^2 = .01$; $F_{\text{alexithymia x time}}(1, 126) = 0.05$, $p = .82$, $\eta_p^2 < .001$; $F_{\text{alexithymia x arousal x time}}$ $(1, 126) = 0.31$, $p = .58$, $\eta_p^2 = .002$.

Arousal ratings.

For arousal ratings, all three main effects were significant. Participants in the arousal condition reported significantly greater arousal compared to those in the neutral condition, $F_{\text{arousal}}(1, 126) = 14.17$, $p < .001$, $\eta_p^2 = .10$. Participants with high alexithymia reported significantly lower arousal, $F_{\text{alexithymia}}(1, 126) = 4.88$, $p = .03$, $\eta_p^2 = .04$. Also, arousal was significantly greater after manipulation compared to baseline, $F_{\text{timel}}(1, 126) =$

77.73, $p < .01$, $\eta_p^2 = .38$. Clarifying these effects, the interaction between time and arousal was significant, $F_{\text{arousal × time}}(1, 126) = 19.77$, $p < .001$, $\eta_p^2 = .14$. Those in the neutral condition did not significantly change after manipulation ($p = .29$), but those in the arousal condition reported significantly increased arousal ($p < .001$). All other interactions failed to reach significance, $F_{\text{alexithymia × time}}(1, 126) = 0.60$, $p = .44$, $\eta_p^2 = .01$; $F_{\text{arousal × alexithymia}}(1, 126) = 2.70$, $p = .10$, $\eta_p^2 = .02$; $F_{\text{arousal × alexithymia × time}}(1, 126) = 2.23$, $p = .14$, $\eta_p^2 = .02$. Thus, the arousal manipulation led to reports of significantly higher arousal and significantly more negative mood compared to baseline reports.

Veridical recognition of studied words.

Hits.

Across groups, participants correctly recognized 83% of the studied words. Hit rate calculations included a total hit rate of all studied words, as well as separate metrics for remembered (i.e., "R" response) and known responses (i.e., "K" response). The overall hit rates of studied words did not differ by groups, $F_{\text{arousal}}(1, 126) = 1.31$, $p = .25$, $\eta_p^2 = .01$; $F_{\text{alexithymia}}(1, 126) = 0.00$, $p = .98$, $\eta_p^2 < .001$; $F_{\text{arousal × alexithymia}}(1, 126) = 3.34$, $p = .07$, $\eta_p^2 = .03$. Thus, veridical recognition was not significantly different across groups.

"R" responses.

Notably, most responses were to the more specific and confident "R" response (i.e., 64 of the 90 studied words). Raw "R" response hit rates were greater in the low versus high alexithymia group, $F_{\text{alexithymia}}(1, 126) = 4.38$, $p = .04$, $\eta_p^2 = .03$. Thus, although all individuals recognized the studied words similarly, alexithymia reduced veridical recognition of these words. Neither arousal nor its interaction with alexithymia produced significant effects, $F_{\text{arousal}}(1, 126) = 0.06$, $p = .80$, $\eta_p^2 < .001$; $F_{\text{arousal × alexithymia}}(1, 126) = 0.12$, $p = .73$, $\eta_p^2 < .001$

"K" responses.

Raw hit rates for studied words identified with a "K" response were significantly greater for high alexithymia scorers, $F(1, 126) = 6.20$, $p = .01$, $\eta_p^2 = .05$. Arousal effects and the interaction term were nonsignificant, $F_{\text{arousal}}(1, 126) = 1.12$, $p = .29$, $\eta_p^2 = .01$; $F_{\text{arousal × alexithymia}}(1, 126) = 0.64$, $p = .42$, $\eta_p^2 = .01$. Thus, alexithymia led to similar recognition of studied words overall, but through familiarity rather than through more confident, specific retrieval.

Foils.

Arousal led to a significant reduction in error rates to foils (i.e., unstudied, unrelated words), $F_{\text{arousal}}(1, 126) = 6.17$, $p = .01$, $\eta_p^2 = .05$. No significant differences were found for the alexithymia groups or their interaction, $F_{\text{alexithymia}}(1, 126) = 0.06$, $p = .81$, $\eta_p^2 < .001$; $F_{\text{arousal × alexithymia}}(1, 126) = 0.11$, $p = .74$, $\eta_p^2 = .001$.

Discriminability and response bias.

No significant group effects or their interaction were found for discriminability (A') of studied words from foils; $F_{\text{arousal}}(1, 126) = 1.24$, $p = .27$, $\eta_p^2 = .01$; $F_{\text{alexithymia}}(1, 126) = 0.08$, $p = .78$, $\eta_p^2 = .001$; $F_{\text{arousal × alexithymia}}(1, 126) = 1.99$, $p = .16$, $\eta_p^2 = .02$. Yet, arousal led to a more conservative response bias (B'') toward the foils, $F_{\text{arousal}}(1, 126) = 5.21$, $p = .02$, $\eta_p^2 = .04$. The alexithymia groups and their interaction did not differ,

$F_{\text{alexithymia}}(1, 126) = 0.29$, $p = .59$, $\eta_p^2 = .002$; $F_{\text{arousal} \times \text{alexithymia}}(1, 126) = 1.14$, $p = .29$, $\eta_p^2 = .01$.

False recognition of critical lures.

Arousal led to a significant reduction in false retrieval when only raw rates were considered, $F(1, 126) = 9.02$, $p = .003$, $\eta_p^2 = .07$. There were no significant effects of alexithymia or its interaction, $F_{\text{alexithymia}}(1, 126) = 2.32$, $p = .13$, $\eta_p^2 = .02$; $F_{\text{arousal} \times \text{alexithymia}}(1, 126) = 1.23$, $p = .27$, $\eta_p^2 = .01$. Arousal enhanced participants' ability to discriminate studied words from critical lures (A'), $F_{\text{arousal}}(1, 126) = 4.76$, $p = .03$, $\eta_p^2 = .04$, but alexithymia groups did not differ, $F_{\text{alexithymia}}(1, 126) = 2.77$, $p = .10$, $\eta_p^2 = .02$, and there was no interaction, $F_{\text{arousal} \times \text{alexithymia}}(1, 126) = 1.84$, $p = .18$, $\eta_p^2 = .01$. Arousal had a tendency to influence response bias (B'') in the less liberal direction, $F(1, 126) = 3.84$, $p = .052$, $\eta_p^2 = .03$. No effects or interactions of alexithymia were significant, $F_{\text{alexithymia}}(1, 126) = 2.68$, $p = .10$, $\eta_p^2 = .02$; $F_{\text{arousal} \times \text{alexithymia}}(1, 126) = 0.01$, $p = .94$, $\eta_p^2 = .01$.

False recognition of weak associates.

Arousal reduced false recognition of weak associates when only the pure rate of retrieval was considered, $F_{\text{arousal}}(1, 126) = 13.37$, $p < .001$, $\eta_p^2 = .10$. Yet, alexithymia and its interaction had no significant contribution, $F_{\text{alexithymia}}(1, 126) = 2.19$, $p = .14$, $\eta_p^2 = .02$; $F_{\text{arousal} \times \text{alexithymia}}(1, 126) = 0.21$, $p = .65$, $\eta_p^2 = .002$. Further, arousal increased the discriminability (A') of weak associates, $F_{\text{arousal}}(1, 126) = 8.12$, $p = .01$, $\eta_p^2 = .06$, while alexithymia and its interaction did not influence it, $F_{\text{alexithymia}}(1, 126) = 1.92$, $p = .17$, $\eta_p^2 = .02$; $F_{\text{arousal} \times \text{alexithymia}}(1, 126) = 0.71$, $p = .40$, $\eta_p^2 = .01$. Moreover, arousal reduced the tendency toward a liberal response bias (B'') to weak associates, $F_{\text{arousal}}(1, 126) = 4.98$, $p = .03$, $\eta_p^2 = .04$. However, alexithymia and its interaction did not influence response bias, $F_{\text{alexithymia}}(1, 126) = 0.78$, $p = .38$, $\eta_p^2 = .01$; $F_{\text{arousal} \times \text{alexithymia}}(1, 126) = 0.55$, $p = .46$, $\eta_p^2 = .004$.

Post Hoc Cluster Analysis

Clustering approach.

One weakness in the current approach is the potential lack of sensitivity of alexithymia effects due to the median split approach to classifying alexithymia. Recently, Chen, Xu, Jing, and Chan (2011) used cluster analysis on TAS-20 scores to examine alexithymia subgroups in a large sample of non-clinical university students. In addition to non-alexithymia (NA), for which all three subscale scores were relatively low, they identified three distinct subtypes of alexithymia: introvert high alexithymia (IHA), in which difficulty describing and identifying feelings scores were high but externally oriented thinking (EOT) was relatively low; extrovert high alexithymia (EHA), in which the EOT score was high, but DIF and DDF were relatively low; and general high alexithymia (GHA), in which all three subscores were relatively high. The current data were examined using a comparable method. Hierarchical cluster analysis, using Ward's method with squared Euclidean distance, was conducted on the three composites of the TAS-20. The same four clusters identified by Chen et al. (2011) were apparent in the present, much smaller sample. Of the 130 individuals, 46 were classified as NA, 24 as EHA, 39 as IHA, and 21 as GHA. The following *post hoc* analyses were conducted to attempt to better characterize the contribution of alexithymia on veridical and false memory. When interactions were significant, follow-up comparisons using Fisher's LSD method were utilized. Also, because these results are preliminary, statistical trends (p values of .06-.10) were identified and discussed.

Group equivalence.

The overall TAS-20 score, subscale scores, and demographic statistics for each alexithymia group can be found in Table 2. There were no significant differences between the groups with respect to sex distribution, self-reported baseline mood and arousal ratings, and immediate free recall performance for studied words, critical lures, or intrusions.

The arousal groups and its interaction with alexithymia did not differ for age, $F_{arousal}(1, 122) = 0.21$, $p = .65$, $\eta_p^2 = .002$; $F_{arousal \times alexithymia}(3, 122) = 0.49$, $p = .69$, $\eta_p^2 = .01$. Yet, the alexithymia clusters did differ, $F_{alexithymia}(3, 122) = 6.07$, $p = .001$, $\eta_p^2 = .13$. The NA group was significantly older than the IHA ($p < .01$) and the GHA ($p = .04$) groups, but no other alexithymia group comparisons differed. Since the mean group ages ranged from 18.95 years of age to 20.02 years, these differences were not interpreted as particularly meaningful. Self-reported GPA did not differ for the arousal groups or its interaction, $F_{arousal}(1, 122) = 0.97$, $p = .33$, $\eta_p^2 = .01$; $F_{arousal \times alexithymia}(3, 122) = 0.27$, $p = .85$, $\eta_p^2 = .01$. However, the alexithymia clusters did differ significantly, $F_{alexithymia}(3, 122) = 3.35$, $p = .02$, $\eta_p^2 = .08$. The NA group reported higher GPA than the EHA group ($p = .01$). Many factors contribute to GPA, and these scores only reflect self-reported rather than verified GPA. Moreover, mean GPA ranged from 3.00 to 3.40 across groups, thereby suggesting little qualitative difference between groups on this metric. Thus, for the most part, the groups were equivalent on basic demographic variables, and all groups were comparably engaged in attending to and encoding the study lists.

Table 2

Mean (SD) demographic characteristics and immediate free recall for the eight participant groups.

	Neutral				Arousal				ANOVA%		
	NA	IHA	GHA	EHA	NA	IHA	GHA	EHA	Cond.	Group	Inter-action
(n):	(26)	(18)	(10)	(15)	(20)	(21)	(11)	(9)	p (η_p^2)	p (η_p^2)	p (η_p^2)
Demographics											
Age (yrs)	19.89 (1.0)	19.11 (0.9)	19.00 (1.1)	19.53 (1.1)	20.20 (1.6)	18.81 (0.9)	19.27 (1.5)	19.67 (1.9)	.65 (.002)	**.001*** **(.13)**	.69 (.01)
GPA	3.37 (0.4)	3.20 (0.4)	3.26 (0.7)	2.91 (0.6)	3.44 (0.4)	3.20 (0.4)	3.32 (0.5)	3.14 (0.5)	0.33 (.01)	**.02#** **(.08)**	0.85 (.01)
Sex^	3M, 23F	6M, 12F	2M, 8F	8M, 7F	3M, 17F	8M, 13F	3M, 8F	7M, 2F	-	-	-
Baseline Mood	5.81 (1.5)	5.50 (1.4)	5.50 (1.1)	5.60 (1.9)	5.90 (1.4)	5.52 (0.8)	5.73 (1.3)	5.67 (1.0)	0.69 (.001)	.71 (.01)	0.99 (.001)
Baseline Arousal	3.88 (1.5)	3.67 (1.8)	3.40 (1.6)	3.60 (1.9)	4.25 (1.5)	4.10 (1.7)	3.09 (1.7)	4.00 (2.1)	0.49 (.004)	.34 (.03)	.86 (.01)
TAS-20: Total	34.50 (5.3)	49.22 (5.2)	58.10 (5.8)	40.67 (4.3)	35.60 (4.5)	51.10 (4.7)	63.91 (7.3)	42.00 (3.8)	**.01†** **(.05)**	**<.001&** **(.78)**	.35 (.03)
DIF	10.73 (3.4)	13.33 (3.1)	21.40 (5.3)	9.80 (1.8)	10.95 (3.8)	13.76 (3.0)	24.00 (4.1)	10.67 (2.6)	0.11 (.02)	**<.001&** **(.62)**	.60 (.02)
DDF	8.85 (2.5)	14.78 (2.5)	19.10 (2.3)	9.20 (1.7)	9.75 (4.0)	15.19 (2.1)	19.18 (2.9)	10.78 (1.1)	0.13 (.02)	**<.001&** **(.68)**	.78 (.01)
EOT	14.92 (2.2)	21.11 (2.5)	17.60 (3.3)	21.67 (3.0)	14.90 (2.6)	22.14 (3.9)	20.73 (1.1)	20.56 (1.1)	0.2 (.01)	**<.001&** **(.48)**	.14 (.04)
Immediate Free Recall											
Studied Words	52.15 (9.9)	51.67 (7.5)	51.40 (4.5)	47.47 (5.5)	51.80 (7.2)	50.91 (7.9)	52.55 (6.1)	53.56 (6.1)	.28 (.01)	.87 (.01)	.32 (.03)
Critical Lures	2.77 (1.5)	3.22 (1.3)	3.10 (1.7)	2.87 (1.6)	2.50 (1.4)	3.14 (1.4)	1.82 (1.5)	3.44 (1.7)	.34 (.01)	.15 (.04)	.22 (.04)
Intrusions	1.46 (1.2)	1.50 (1.2)	0.80 (1.3)	0.73 (0.7)	1.10 (1.2)	1.57 (1.5)	1.18 (1.5)	1.33 (1.2)	.46 (.01)	.30 (.03)	.44 (.02)

Note. EHA = extroverted high alexithymia; NA = non-alexithymia; GHA = general high alexithymia; IHA = introvert high alexithymia; %ANOVA df = 1,122 arousal; 3,122 alexithymia, interaction; *NA>IHA,GHA; #NA>EHA; †Arousal>Neutral; &All clusters significantly different; ^ $\chi^2(3) = 2.08$, $p = .56$, *ns*.

Manipulation checks.

Mood ratings.

The influence of the manipulation on mood ratings was analyzed using a 2 (arousal) × 4 (alexithymia) × 2 (time) mixed-model ANOVA. Mood tended to be made more negative by the oral surgery clip, $F_{\text{arousal}}(1, 122) = 3.09$, $p = .08$, $\eta_p^2 = .03$. Further, mood ratings were significantly more negative after either manipulation, $F_{\text{time}}(1, 122) = 27.52$, $p < .001$, $\eta_p^2 = .18$. These effects were clarified by a significant interaction, $F_{\text{arousal} \times \text{time}}(1, 122) = 10.65$, $p = .001$, $\eta_p^2 = .08$, such that mood was unchanged in the neutral condition ($p = .15$), but in the arousal group, it became significantly more negative after the manipulation ($p < .001$). There were no significant effects involving alexithymia: $F_{\text{alexithymia}}(3, 122) = 0.42$, $p = .74$, $\eta_p^2 = .01$; $F_{\text{alexithymia x arousal}}(3, 122) = 0.41$, $p = .75$, $\eta_p^2 = .01$; $F_{\text{alexithymia x time}}(3, 122) = 0.19$, $p = .91$, $\eta_p^2 = .01$; $F_{\text{alexithymia x arousal x time}}(3, 122) = 0.55$, $p = .65$, $\eta_p^2 = .01$. Thus, alexithymia type did not differentially influence subjective mood ratings in any condition.

Arousal ratings.

The influence of the manipulation on arousal ratings was analyzed using a 2 (arousal) × 4 (alexithymia) × 2 (time) mixed-model ANOVA. The manipulation led to significantly increased arousal, $F_{\text{arousal}}(1, 122) = 9.48$, $p = .003$, $\eta_p^2 = .07$. Further, arousal ratings were significantly increased after film viewing, independent of film type, compared to baseline, $F_{\text{time}}(1, 122) = 72.94$, $p < .001$, $\eta_p^2 = .37$. Clarifying these main effects, the interaction between arousal and time was significant, $F_{\text{arousal} \times \text{time}}(1, 122) =$

17.00, $p < .001$, $\eta_p^2 = .12$, such that arousal ratings increased more after manipulation in the arousal group versus the neutral group, but arousal reports were similar at baseline. Also, the interaction between time and alexithymia was significant, $F_{\text{alexithymia} \times \text{time}}(3, 122) = 2.80$, $p = .04$, $\eta_p^2 = .06$. All alexithymia groups exhibited significant increases in arousal from baseline to after the manipulation ($p < .01$). But, the NA and GHA clusters exhibited larger increases in arousal ratings while the EHA and IHA clusters reported lesser increases. All other main effects and interactions were not significant, $F_{\text{alexithymia}}(3, 122) = 1.65$, $p = .18$, $\eta_p^2 = .04$; $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 0.51$, $p = .68$, $\eta_p^2 = .01$; $F_{\text{arousal} \times \text{alexithymia} \times \text{time}}(3, 122) = 0.73$, $p = .54$, $\eta_p^2 = .02$.

Veridical recognition of studied words.

Hits.

The main effects of arousal and alexithymia were not significant, $F_{\text{arousal}}(1, 122) = 0.16$, $p = .69$, $\eta_p^2 = .001$; $F_{\text{alexithymia}}(3, 122) = 0.37$, $p = .77$, $\eta_p^2 = .01$. However, the interaction was significant, $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 4.25$, $p = .01$, $\eta_p^2 = .10$. Arousal did not differentially impact retrieval of studied words for the IHA ($p = .54$) or NA ($p = .79$) groups. However, arousal significantly enhanced memory performance for the EHA group ($p = .01$), while it reduced it in the GHA group ($p = .03$). Examination of the pairwise comparisons showed that group differences were primarily within the neutral condition. Under neutral conditions, those in the GHA cluster recognized 85% of studied words, which is significantly more words retrieved than by those in the IHA ($p = .04$), the NA ($p = .08$), and the EHA ($p = .001$) clusters. Meanwhile, those in the EHA cluster recognized 73% of studied words, which is significantly less than what was retrieved by either the GHA or the NA groups (ps = .04). Yet, under arousing conditions, nearly all groups exhibited comparable hit rates ($p > .10$), except for somewhat poorer performance in GHA when contrasted with EHA ($p = .09$).

"R" responses.

There were no significant effects on "R" responses, $F_{\text{arousal}}(1, 122) = 0.14$, $p = .71$, $\eta_p^2 = .001$; $F_{\text{alexithymia}}(3, 122) = 2.05$, $p = .11$, $\eta_p^2 = .05$; $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 1.32$, $p = .27$, $\eta_p^2 = .03$.

"K" responses.

When only considering hits for information called "K," neither arousal nor its interaction enhanced memory, $F_{\text{arousal}}(1, 122) = 1.48$, $p = .23$, $\eta_p^2 = .01$; $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 0.54$, $p = .66$, $\eta_p^2 = .01$. Although most individuals responded "K" infrequently, those in the IHA and GHA clusters were more likely to use familiarity processes to recognize studied words, $F(3, 122) = 2.97$, $p = .04$, $\eta_p^2 = .07$. The IHA group used this response more than the NA ($p = .03$) and the EHA ($p = .048$) groups; the GHA group utilized familiarity more than the NA ($p = .03$) and the EHA ($p = .04$) groups.

Foils. The alexithymia groups and their interaction term did not differ significantly in false retrieval of new words, $F_{\text{alexithymia}}(3, 122) = 1.27$, $p = .29$, $\eta_p^2 = .03$; $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 1.24$, $p = .30$, $\eta_p^2 = .03$. However, arousal reduced the error rates for the unrelated foils, $F_{\text{arousal}}(1, 122) = 5.60$, $p = .02$, $\eta_p^2 = .04$. Inspection of the non-significant interaction contrasts revealed that the effect of arousal on reduced false memories occurred preferentially in the IHA and the EHA clusters.

Discriminability and response bias.

The effects of arousal and alexithymia on discriminability can be found in Figure 1. For *A′*, there were no significant main effects, $F_{\text{arousal}}(1, 122) = 1.11$, $p = .29$, $\eta_p^2 = .01$; $F_{\text{alexithymia}}(3, 122) = 0.74$, $p = .53$, $\eta_p^2 = .02$. However, the interaction was significant, $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 4.56$, $p = .01$, $\eta_p^2 = .10$. Specifically, arousal decreased discriminability for the GHA group ($p = .06$) and increased discriminability for the EHA group ($p = .002$), but arousal did not impact the IHA ($p = .39$) or NA ($p = .93$) groups. Pairwise comparisons revealed that no alexithymia group differences occurred under arousal conditions. Instead, group differences stemmed from neutral conditions. This further demonstrated the disparate impact of arousal on alexithymia.

The effects of arousal and alexithymia on response bias can be found in Figure 2. For *B″*, arousal significantly decreased liberal responding, $F_{\text{arousal}}(1, 122) = 4.44$, $p = .04$, $\eta_p^2 = .04$, and alexithymia trended toward impacting response bias, $F_{\text{alexithymia}}(3, 122) = 2.27$, $p = .08$, $\eta_p^2 = .05$. Specifically, the NA ($p = .04$) and GHA ($p = .02$) groups were less liberal than the EHA group. The interaction was not significant, $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 0.65$, $p = .59$, $\eta_p^2 = .02$.

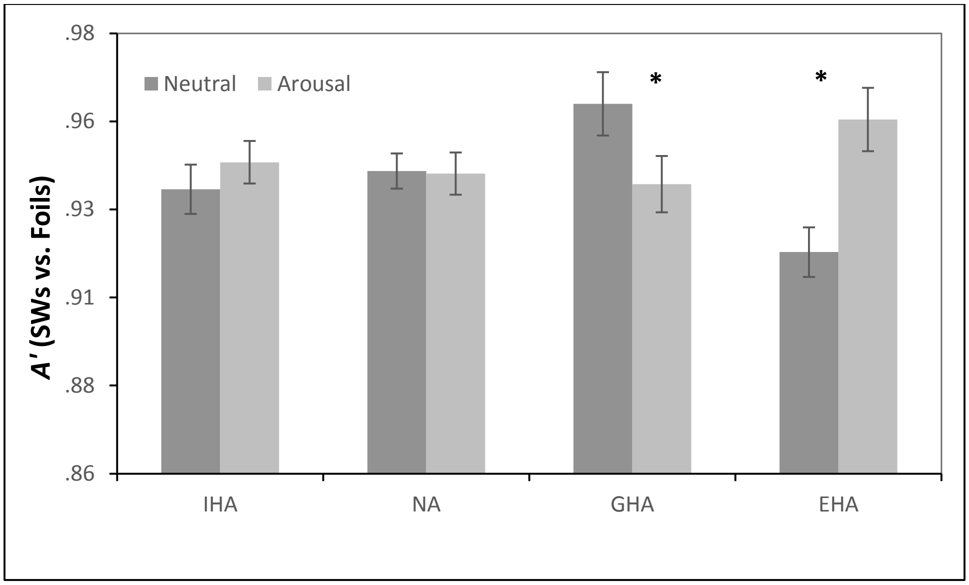

Figure 1. Discriminability for studied words versus foils (mean (± SEM)). Arousal decreased *A′* for the GHA group and enhanced *A′* for the EHA group.

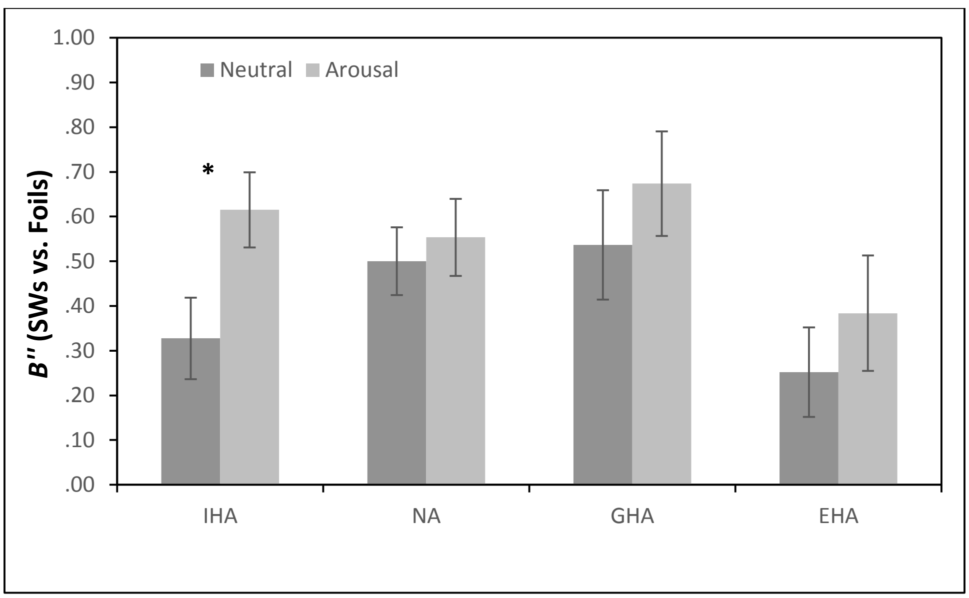

Figure 2. Response bias for studied words versus foils (mean (± SEM)). Arousal increased conservative responding (more positive *B″* values) for the IHA group.

False recognition of critical lures.

Arousal significantly reduced false recognition of critical lures, $F_{\text{arousal}}(1, 122) = 6.60$, $p = .01$, $\eta_p^2 = .05$. Although there was no main effect of alexithymia, $F_{\text{alexithymia}}(3, 122) = 1.35$, $p = .26$, $\eta_p^2 = .03$, the interaction was significant, $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 4.04$, $p = .01$, $\eta_p^2 = .09$. Arousal significantly reduced lure endorsement in the NA ($p < .001$) and GHA ($p = .02$) clusters but the reduction was not significant in the IHA ($p = .61$) or EHA ($p = .86$) clusters.

See Figures 3 and 4 for the effects of arousal and alexithymia on the nonparametric signal detection measures. Arousal trended toward enhancing discriminability (A'), $F_{\text{arousal}}(1, 122) = 3.58$, $p = .06$, $\eta_p^2 = .03$. The main effect of alexithymia was not significant, $F_{\text{alexithymia}}(3, 122) = 0.99$, $p = .40$, $\eta_p^2 = .02$, but the interaction was significant, $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 3.01$, $p = .03$, $\eta_p^2 = .07$. Arousal enhanced discriminability for the NA ($p = .004$) and GHA ($p = .08$) clusters but not for the EHA ($p = .26$) or IHA ($p = .71$) clusters.

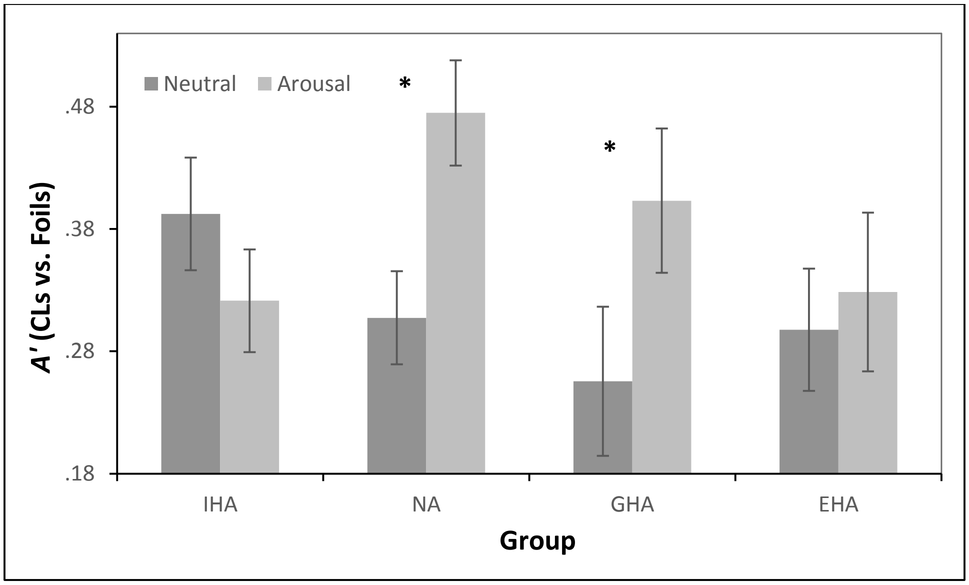

Figure 3. Discriminability for critical lures versus foils (mean (± SEM)). Arousal enhanced *A′* for the NA and GHA groups.

Response bias (*B″*) was not affected by alexithymia or its interaction, $F_{\text{alexithymia}}(3, 122) = 0.67$, $p = .56$, $\eta_p^2 = .02$; $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 1.87$, $p = .14$, $\eta_p^2 = .04$. Yet, arousal decreased liberal responding, $F_{\text{arousal}}(1, 122) = 3.25$, $p = .07$, $\eta_p^2 = .03$. Although the interaction was not significant, inspection of the contrasts showed this pattern of decreased liberal responding after arousal was apparent in the NA and GHA groups but less so in the IHA and EHA groups.

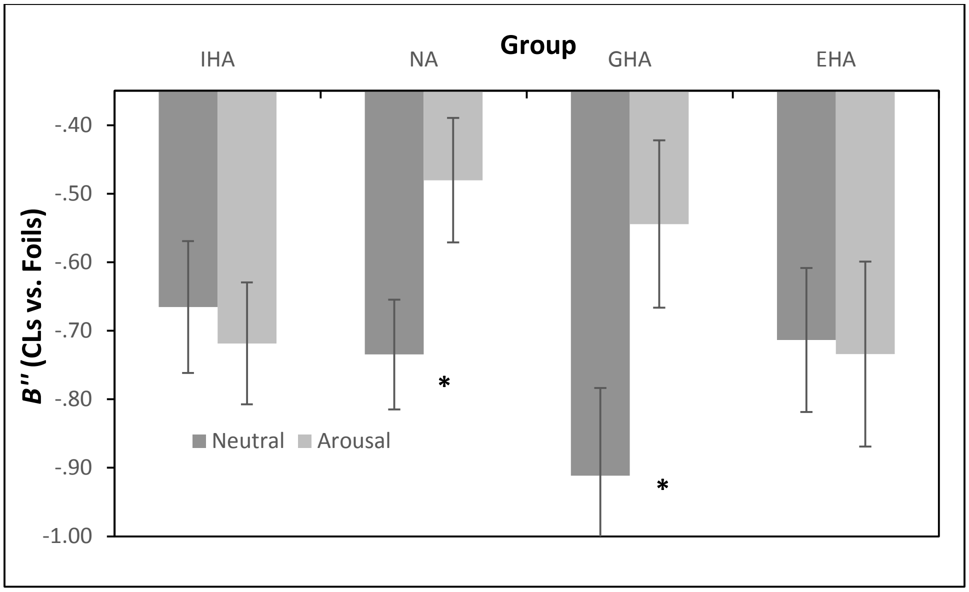

Figure 4. Response bias for critical lures versus foils (mean (± SEM)). Arousal reduced *B''* for the NA and GHA groups.

False recognition of weak associates.

The alexithymia groups did not differ significantly for false retrieval of weak associates, $F_{\text{alexithymia}}(3, 122) = 1.76$, $p = .16$, $\eta_p^2 = .04$. However, arousal led to a reduction in false memory for these items, $F_{\text{arousal}}(1, 122) = 20.18$, $p < .001$, $\eta_p^2 = .14$, and the interaction was significant, $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 3.79$, $p = .01$, $\eta_p^2 = .09$. Specifically, arousal decreased rates of false recognition for the GHA ($p < .001$) and EHA ($p = .02$) groups, but it did not differentially impact false memories for the IHA ($p = .59$) or NA ($p = .25$) groups.

Figures 5 and 6 contain the data regarding arousal and alexithymia effects on the nonparametric measures. The alexithymia groups did not differ significantly in terms of their ability to discriminate studied words versus weak associates (*A'*), $F_{\text{alexithymia}}(3, 122) = 1.97$, $p = .12$, $\eta_p^2 = .05$. However, arousal significantly increased discriminability,

$F_{\text{arousal}}(1, 126) = 14.18$, $p < .001$, $\eta_p^2 = .10$, which interacted with alexithymia, $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 4.64$, $p = .004$, $\eta_p^2 = .10$, showing that arousal preferentially enhanced discriminability in GHA ($p = .01$) and EHA ($p < .001$), rather than IHA ($p = .76$) or NA ($p = .56$). These differences primarily stemmed from the neutral condition, where the GHA and EHA groups had poorer discriminability than the IHA and NA groups.

When aroused, participants responded less liberally to weak associates, $F_{\text{arousal}}(1, 122) = 5.26$, $p = .02$, $\eta_p^2 = .04$. Alexithymia and its interaction did not alter response bias, $F_{\text{alexithymia}}(3, 122) = 0.34$, $p = .80$, $\eta_p^2 = .01$; $F_{\text{arousal} \times \text{alexithymia}}(3, 122) = 1.08$, $p = .36$, $\eta_p^2 = .03$.

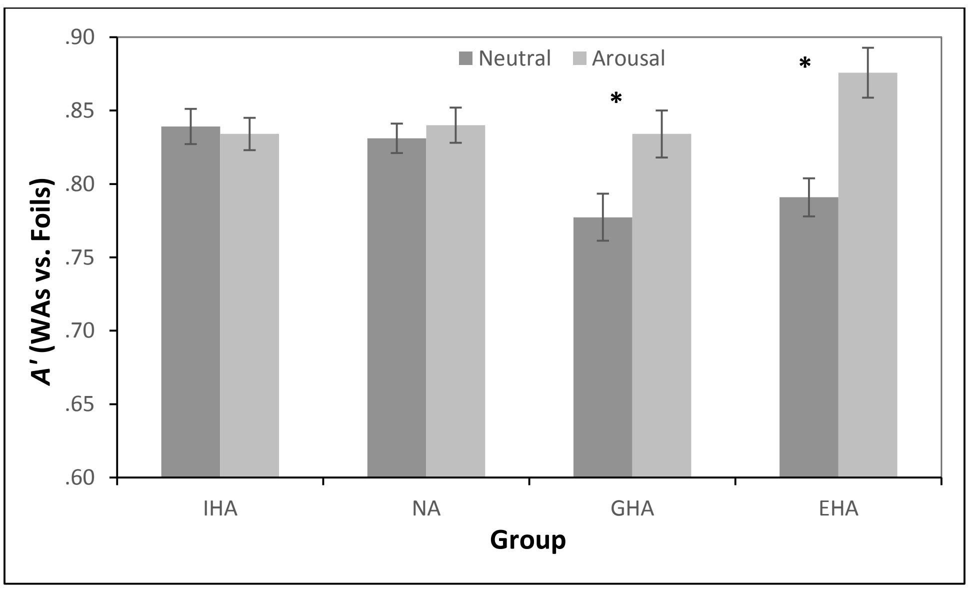

Figure 5. Discriminability for weak associates versus foils (mean (± SEM)). Arousal enhanced *A′* for the GHA and EHA groups.

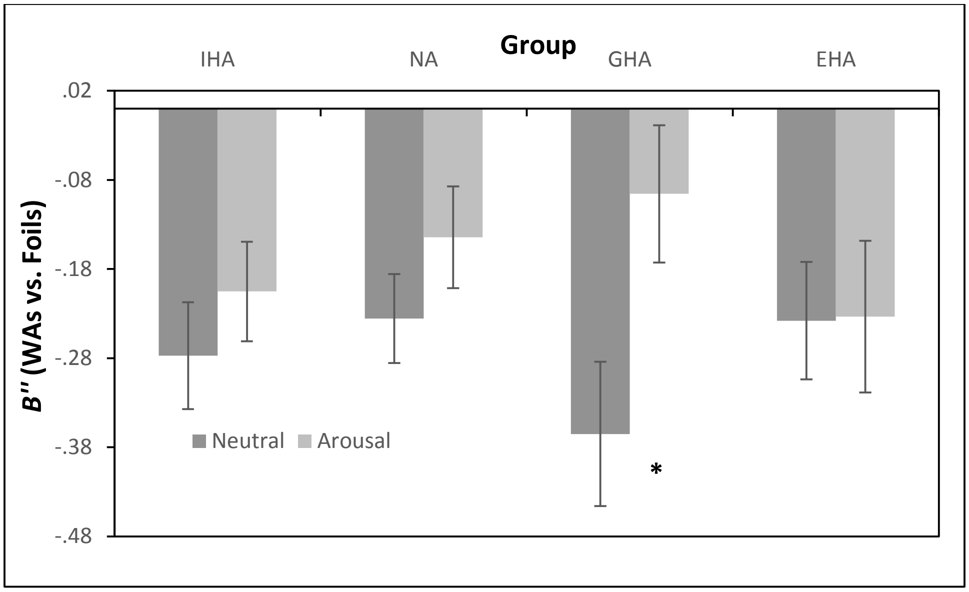

Figure 6. Response bias for weak associates versus foils (mean (± SEM)). Arousal enhanced *B''* for the GHA group.

Discussion

The purpose of this study was to understand how arousal impacts the memory of individuals with high or low alexithymia. Alexithymia is a personality trait with a range of characteristics including difficulties identifying feelings, difficulty describing feelings, and having an externally oriented cognitive style (Sifneos, 1973; Taylor, 2000; Taylor & Bagby, 2004). Although individuals with alexithymic traits are not as subjectively aware of their emotions as those without alexithymia, they do exhibit intact physiological responses to arousing stimuli (Stone & Nielson, 2001). Importantly, arousal is known to modulate memory, specifically by impacting the consolidation of memory traces within the medial temporal lobe (Kensinger & Corkin, 2004; McGaugh, 2004; Nielson & Powless, 2007). Despite their limited awareness of emotion and arousal, individuals with high alexithymia are susceptible to memory modulation by arousal (Nielson & Meltzer, 2009). Yet, no study had previously examined arousal-induced modulation of false *and* veridical memory differences in alexithymia.

As expected, the arousing clip led to more negative mood ratings and higher arousal ratings compared to the neutral video (Nielson & Meltzer, 2009; Stone & Nielson, 2001). Further, compared to high alexithymia, the low alexithymia group reported significantly greater subjective arousal in response to the arousing video (Nielson & Meltzer, 2009; Stone & Nielson, 2001). However, the expected interaction of alexithymia and arousal was not significant for arousal or mood. These results contrast previous findings. The Emotion Rating Scale (Appendix B) used in this study clearly demarcates mood and arousal and requires separate ratings for each construct but may not have been sensitive to capture subjective differences in mood or arousal in alexithymia.

Veridical Recognition in High vs. Low Alexithymia

Prior research has demonstrated that arousal enhances long-term recognition of information for individuals with both high and low alexithymia (Nielson & Meltzer, 2009). Thus, arousal was expected to enhance veridical memory regardless of alexithymic characteristics. However, this result was not entirely replicated. Arousal did not significantly enhance memory for studied words. Research has shown that encoding information using a deep level of processing (e.g., semantic relatedness) results in better memory than learning words using a shallow level of processing (McCabe, Presmanes, Robertson, & Smith, 2004). The DRM lists in this study impose a deeper semantic level of encoding through their semantic relatedness than would necessarily occur if a list of unrelated words were presented (e.g., Nielson & Meltzer, 2009). Thus, arousal may have had less impact than expected on sensitivity in veridical recognition because task conditions led to deeper encoding. However, arousal did lead to a significant reduction in foil endorsement and to less liberal responding (i.e., B''), as expected and partially replicating prior studies (Nielson et al., 2015; Nielson & Powless, 2007; Van Damme, 2013).

In light of depth of processing, participants with high alexithymia more often used familiarity or gut-reactions (i.e., “K” responses) in recognition than those with low alexithymia, who more frequently endorsed “R” responses, reflecting deeper encoding. Alexithymia reduces the ability to recognize physiological sensations or utilize imaginal thinking (Taylor, 2000). Thus, those with high alexithymia likely rely more on familiarity-based retrieval processes because internal representations of words and monitoring processes are potentially not accessible. However, when correcting for guessing, alexithymia was not expected to affect discriminability or response bias for studied words versus completely novel words. In fact, no significant effects of alexithymia on these measures were found. This outcome is consistent with prior literature that has demonstrated comparable memory performance in those with high and low alexithymia for neutral studied information after arousal (Nielson & Meltzer, 2009). So, although memory performance was comparable, the path to recognizing information was disparate in high versus low alexithymia.

False Recognition

As expected, arousal significantly reduced false recognition via enhanced discriminability and less liberal responding (Nielson et al., 2015; Van Damme, 2013). Furthermore, arousal reduced false recognition of the weak associates via enhanced discriminability and less liberal responding, which also replicated the findings by Nielson et al. (2015). Additionally, individuals with high alexithymia endorsed more false information than those with low alexithymia, though there were not significant interactions between arousal and alexithymia for either critical lures or weak associates.

An "overcoming" model was hypothesized for how arousal and alexithymia would interact to affect false memories of dubious information. The rationale behind this hypothesis stemmed from a finding in the study by Meltzer and Nielson (2010). In their study, delayed free recall trended towards significance when comparing low versus high alexithymia. High alexithymia scorers nominally recalled more neutral than affective words. These neutral words were implicitly studied via ratings on a list that also contained multiple types of affective words. It was hypothesized that an externally oriented cognitive style, as common in alexithymia, might have lent itself to the processing of implicitly encoded neutral information that is implicitly encoded (Meltzer & Nielson, 2010; Vermeulen & Luminet, 2009). The DRM paradigm used in the current study inherently induces implicit activation in semantic networks (Roediger et al., 2001). Neutral critical lures are the primary items activated, but misinformation for other related words can also occur (Nielson et al., 2015). The "overcoming" interaction was hypothesized because arousal is known to enhance source monitoring accuracy for veridical information even when misleading information is also presented (English & Nielson, 2010). However, this expected interaction was not found, thereby failing to support the "overcoming" model. Yet, the high alexithymia groups exhibited poorer memory performance than the low alexithymia groups under neutral conditions, but the difference was absent under arousal conditions, suggesting that both groups responded to arousal. This perhaps provided indirect evidence for an overcoming model. Importantly, while this sample exhibited good range of alexithymia scores, it was not a clinical sample. Thus, the more extreme scores of alexithymia were not well represented, which may preclude sensitivity of nuanced effects, particularly when using a median split. As such, *post hoc* analyses of alexithymia subgroups were analyzed.

Post Hoc Cluster Analyses

The use of a median split to create disparate groupings is an artificial and crude method that is often criticized. Moreover, it may lack sensitivity to detect group differences. The present results suggested this might be the case. As such, a more nuanced method of examining alexithymia was sought. Chen et al. (2011) recently examined alexithymia in a data-driven manner using cluster analysis with a large sample of Chinese college students. They detected four distinct alexithymia subtypes based on

TAS-20 scores. Thus, we employed this same methods with our smaller sample. Chen's clusters were closely replicated: 21 participants fit the GHA cluster, 39 fit the IHA cluster, 46 fit the NA cluster, and 24 fit the EHA cluster. The primary difference in our clusters from Chen's was the EHA cluster, where the DIF and DDF scores were lower in our sample. Yet, the primary characterization as high externally oriented thinking was quite consistent with Chen's description.

Arousal impacted the alexithymia groups in different ways. Response by the NA group was comparable to other studies examining arousal effects in the DRM (Nielson et al., 2015; Van Damme, 2013). Also, this group showed a similar pattern to the low alexithymia group from the median split analyses. Specifically, the NA group exhibited reduced error rate in veridical memory, as well as reduced false memory for strong and weak "lures" as a result of arousal. These effects were due to enhanced discriminability and reduced liberal response bias. In contrast, arousal increased the conservative responding in IHA when only considering studied words versus foils. Thus, arousal improved veridical memory, but not false memory in IHA. In addition to the poor emotion recognition and expression typical of IHA, this group may also lack the ability to recognize other cognitive components that could contribute to rejecting false memories (Gallo, 2004; Roediger et al., 2001). However, the increase in veridical recognition reflects enhanced source monitoring and better verbatim memory traces (Brainerd, Reyna, & Kneer, 1995; English & Nielson, 2010).

On the other hand, arousal significantly *reduced* veridical recognition for those in the GHA cluster through reduced discriminability of studied words versus foils. Yet, in comparison to all of the other groups, the GHA group had the most conservative response bias in this metric. Furthermore, arousal reduced false recognition for both critical lures and weak associates via augmented discriminability and attenuated liberal response bias. These data support the contention that in GHA, arousal enhanced item-specific processes during consolidation, rather than the typical relational processes evident in the DRM paradigm (McCabe et al., 2004). Item-specific processing has been shown to reduce false memories (McCabe et al., 2004; Nielson et al., 2015). However, an item-specific approach toward veridical information is a less efficient, more superficial approach to consolidating information, especially in comparison to deeper, semantic processing (Hunt, 2003). Thus, although true memories were reduced, arousal may have allowed those with GHA to overcome their high externally oriented thinking style through item-specific consolidation. Comparatively, the IHA group also overcame deficits stemming from their alexithymic characteristics. Yet, GHA was most conservative potentially reflecting a more rigid item-specific approach.

Conversely, the EHA group was affected by arousal in a way consistent with the originally proposed “overcoming” model. This group had better veridical memory because arousal enhanced discriminability. However, arousal only enabled this group to overcome the externally oriented thinking style for *weakly* misleading information. Although this group endorsed strong misinformation, they were better able to discriminate studied items versus weak associates when aroused. The TAS-20 scores of the EHA group indicated they had better ability to recognize and describe feelings than either of the other alexithymia groups. Perhaps this internal awareness aided the EHA group to strongly consolidate veridical information and reject weakly misleading words.

But, these individuals still exhibited an externally oriented thinking style and as such, arousal could not overcome activation of the strong lures.

The results of the present study indicate that people with alexithymia have more nuanced arousal-induced memory patterns than previous studies have been able to examine when only considering alexithymia as a dichotomous variable (Meltzer & Nielson, 2010; Nielson & Meltzer, 2009). Individuals with difficulties identifying feelings and difficulties describing feelings (i.e., IHA) are at a high risk for recognizing misinformation. Yet, individuals who utilize externally oriented thinking styles (i.e., EHA and GHA) can overcome false memories, albeit it may occur through different mechanisms. Moreover, depending on the characteristics of one's personality and cognitive approach, memory modulation for false information can come at a price of diminished or altered true memories. This contention stems from the fact that to reject false information disqualifying monitoring processes, like recall-to-reject, are interwoven with the consolidation of one's veridical experiences (Gallo, 2004).

Clinical Implications

Even though the participants in the present study were from a non-clinical sample, the results have clinical implications for alexithymia. Understanding the ways in which memories are malleable provides insight into the ways in which humans experience, interpret, and remember their world. Using cognitive and experimental methods to understand the limits of accurate memory and the ways in which people are susceptible to misinformation enables researchers and clinicians to build on this knowledge. Future clinical scientists should consider constructing memory rehabilitation programs for people experiencing various types of neuropsychological impairment by reducing the creation of false memories. Perhaps interventions can provide individuals with alexithymia various tools to help them remember information better. For example, individuals with EHA characteristics can be instructed to emphasize the strengths of their externally oriented thinking style.

Further, this study has implications for neuropsychology. Some of the personality traits that may contribute to error variance within individuals' performance on neuropsychological tests have been identified. Also, individuals with alexithymia likely have executive dysfunction for abstract thinking, performance monitoring, and logical operationalization due to their concrete and external thinking styles.

Limitations and Future Directions

The current study could have benefitted from a larger sample. Although the study had 130 participants, a larger sample might be better able to detect nuanced differences among alexithymia subgroups. Relatedly, the current sample was designed to examine alexithymia as a trait in the general population, rather than in clinical populations. Thus, the extreme clinical range of alexithymia is not heavily represented. Additional studies examining greater extremes of alexithymia in studies of memory, false memory, and memory modulation are lacking.

Our understanding of memory in alexithymia could be further advanced by incorporating direct investigations of neural functioning. Long-term memory formation involves contributions from both the dorsolateral and ventrolateral prefrontal cortices, specifically the inferior frontal gyrus and the middle frontal gyrus, as well as the left parahippocampal cortex and left fusiform gyrus (Murray & Ranganath, 2007). Moreover, relational encoding more readily activates the dorsolateral prefronal cortex, while item-specific encoding generates greater ventrolateral prefrontal and parahippocampal gyrus activation (Murray & Ranganath, 2007). Importantly, the frontal lobes, particularly the orbitofrontal cortices and the anterior cingulate have been implicated in some of the emotional and cognitive consequences of alexithymia (Larsen, Brand, Bermond, & Hijman, 2003). Thus, differences in these areas, whether foundational to or a result of alexithymia, may be responsible for item-specific process alterations in alexithymia. Neural data would permit a more nuanced understanding of the neural bases for how alexithymia affects memory formation and associated response to arousal.

In the current study, assumptions were necessarily made regarding the cognitive processes used by participants. Future studies could manipulate the encoding instructions to encourage item-specific encoding or relational encoding, which would explore the conscious impact of performance monitoring during encoding. Although this may potentially compound the effects of arousal on encoding versus consolidation, this approach might elucidate how alexithymia affects the creation of memories, the externally oriented thinking style, and the processing of information. Additional factors that could be explored include having participants provide rationales for their decisions on the recognition test or varying the instructions for how to approach the recognition test. The present study was not able to explore the effect of metacognitive monitoring processes during the recognition phase, which could impact memory performance. This information could potentially highlight how individuals with alexithymia make judgments regarding learned versus deceptive information.

Conclusion

In conclusion, arousal leads to reductions in false recognition via more conservative response biases for foils, via enhanced discriminability for critical lures, and via enhanced discriminability and less liberal response biases for weak associates. Individuals with low and high alexithymia characteristics have similar overall veridical memory performance, but the level of confidence in response to studied information varies differentially between these groups. These differences likely represent a weakness for participants with high alexithymia either in using monitoring processes during recognition or in encoding imaginal representations of information. *Post hoc* comparisons revealed that when alexithymia subtypes are considered, arousal-induced memory modulation is more nuanced, and evidence for an "overcoming" model is supported. Future studies should consider incorporating alexithymia subtypes to ascertain the true nature and functioning of alexithymia.

BIBLIOGRAPHY

Anderson, A. K., Wais, P. E., & Gabrieli, J. D. (2006). Emotion enhances remembrance of neutral events past. *Proc Natl Acad Sci U S A, 103*(5), 1599-1604. doi: 10.1073/pnas.0506308103

Bagby, R. M., Parker, J. D., & Taylor, G. J. (1994). The twenty-item Toronto Alexithymia Scale--I. Item selection and cross-validation of the factor structure. *J Psychosom Res, 38*(1), 23-32.

Bagby, R. M., Taylor, G. J., & Parker, J. D. (1994). The Twenty-item Toronto Alexithymia Scale--II. Convergent, discriminant, and concurrent validity. *J Psychosom Res, 38*(1), 33-40.

Brainerd, C. J., Reyna, V. F., & Kneer, R. (1995). False-Recognition Reversal - When Similarity Is Distinctive. *J Mem Lang, 34*(2), 157-185. doi: DOI 10.1006/jmla.1995.1008

Chen, J., Xu, T., Jing, J., & Chan, R. C. (2011). Alexithymia and emotional regulation: A cluster analytical approach. *BMC Psychiatry, 11*, 33. doi: 10.1186/1471-244X-11-33

Cochrane, C. E., Brewerton, T. D., Wilson, D. B., & Hodges, E. L. (1993). Alexithymia in the eating disorders. *Int J Eat Disord, 14*(2), 219-222.

Corson, Y., & Verrier, N. (2007). Emotions and false memories: valence or arousal? *Psychol Sci, 18*(3), 208-211. doi: 10.1111/j.1467-9280.2007.01874.x

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *J Exp Psychol, 58*(1), 17-22.

English, S. M., & Nielson, K. A. (2010). Reduction of the misinformation effect by arousal induced after learning. *Cognition, 117*(2), 237-242. doi: 10.1016/j.cognition.2010.08.014

Erk, S., von Kalckreuth, A., & Walter, H. (2010). Neural long-term effects of emotion regulation on episodic memory processes. *Neuropsychologia, 48*(4), 989-996. doi: 10.1016/j.neuropsychologia.2009.11.022

Franz, M., Schaefer, R., Schneider, C., Sitte, W., & Bachor, J. (2004). Visual event-related potentials in subjects with alexithymia: modified processing of emotional aversive information? *Am J Psychiatry, 161*(4), 728-735.

Friedlander, L., Lumley, M. A., Farchione, T., & Doyal, G. (1997). Testing the alexithymia hypothesis: physiological and subjective responses during relaxation and stress. *J Nerv Ment Dis, 185*(4), 233-239.

Gallo, D. A. (2004). Using recall to reduce false recognition: diagnostic and disqualifying monitoring. *J Exp Psychol Learn Mem Cogn, 30*(1), 120-128. doi: 10.1037/0278-7393.30.1.120

Gardiner, J. M. (1988). Functional aspects of recollective experience. *Mem Cognit, 16*(4), 309-313.

Hill, E., Berthoz, S., & Frith, U. (2004). Brief report: cognitive processing of own emotions in individuals with autistic spectrum disorder and in their relatives. *J Autism Dev Disord, 34*(2), 229-235.

Hunt, R. R. (2003). Two contributions of distinctive processing to accurate memory. *J Mem Lang, 48*(4), 811-825. doi: 10.1016/S0749-596X(03)00018-4

Jula, A., Salminen, J. K., & Saarijarvi, S. (1999). Alexithymia: a facet of essential hypertension. *Hypertension, 33*(4), 1057-1061.

Kensinger, E. A., & Corkin, S. (2004). Two routes to emotional memory: distinct neural processes for valence and arousal. *Proc Natl Acad Sci U S A, 101*(9), 3310-3315. doi: 10.1073/pnas.0306408101

Larsen, J. K., Brand, N., Bermond, B., & Hijman, R. (2003). Cognitive and emotional characteristics of alexithymia: a review of neurobiological studies. *J Psychosom Res, 54*(6), 533-541.

Luminet, O., Bagby, R. M., & Taylor, G. J. (2001). An evaluation of the absolute and relative stability of alexithymia in patients with major depression. *Psychother Psychosom, 70*(5), 254-260. doi: 56263

Lumley, M. A., Stettner, L., & Wehmer, F. (1996). How are alexithymia and physical illness linked? A review and critique of pathways. *J Psychosom Res, 41*(6), 505-518.

Martin, J. B., & Pihl, R. O. (1986). Influence of alexithymic characteristics on physiological and subjective stress responses in normal individuals. *Psychother Psychosom, 45*(2), 66-77.

McCabe, D. P., Presmanes, A. G., Robertson, C. L., & Smith, A. D. (2004). Item-specific processing reduces false memories. *Psychon Bull Rev, 11*(6), 1074-1079.

McGaugh, J. L. (2000). Memory--a century of consolidation. *Science, 287*(5451), 248-251.

McGaugh, J. L. (2004). The amygdala modulates the consolidation of memories of emotionally arousing experiences. *Annu Rev Neurosci, 27*, 1-28. doi: 10.1146/annurev.neuro.27.070203.144157

Meltzer, M. A., & Nielson, K. A. (2010). Memory for emotionally provocative words in alexithymia: a role for stimulus relevance. *Conscious Cogn, 19*(4), 1062-1068. doi: 10.1016/j.concog.2010.05.008

Müller, G. E., & Pilzecker, A. (1900). Experimentelle beitrage zur lehre vom gedachtnis. [Experimental contributions in learning memory]. *Zeitschrift für Psychologie Erganzungsband, 1*, 1-288.

Murray, L. J., & Ranganath, C. (2007). The dorsolateral prefrontal cortex contributes to successful relational memory encoding. *J Neurosci, 27*(20), 5515-5522. doi: 10.1523/JNEUROSCI.0406-07.2007

Nielson, K. A., & Arentsen, T. J. (2012). Memory modulation in the classroom: selective enhancement of college examination performance by arousal induced after lecture. *Neurobiol Learn Mem, 98*(1), 12-16. doi: 10.1016/j.nlm.2012.04.002

Nielson, K. A., Correro II, A. N., & Byers, S. J. (2015). *Arousal and the DRM: Enhanced Veridical Memory and Reduced False Memory*. Research article. [Manuscript under review].

Nielson, K. A., & Jensen, R. A. (1994). Beta-adrenergic receptor antagonist antihypertensive medications impair arousal-induced modulation of working memory in elderly humans. *Behav Neural Biol, 62*(3), 190-200.

Nielson, K. A., & Meltzer, M. A. (2009). Modulation of long-term memory by arousal in alexithymia: the role of interpretation. *Conscious Cogn, 18*(3), 786-793. doi: 10.1016/j.concog.2009.06.001

Nielson, K. A., & Powless, M. (2007). Positive and negative sources of emotional arousal enhance long-term word-list retention when induced as long as 30 min after learning. *Neurobiol Learn Mem, 88*(1), 40-47. doi: 10.1016/j.nlm.2007.03.005

Nielson, K. A., Yee, D., & Erickson, K. I. (2005). Memory enhancement by a semantically unrelated emotional arousal source induced after learning. *Neurobiol Learn Mem, 84*(1), 49-56. doi: 10.1016/j.nlm.2005.04.001

Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. *J Exp Psychol, 76*(1), Suppl:1-25.

Papciak, A. S., Feuerstein, M., & Spiegel, J. A. (1985). Stress reactivity in alexithymia: decoupling of physiological and cognitive responses. *J Human Stress, 11*(3), 135-142. doi: 10.1080/0097840X.1985.9936750

Parker, J. D., Taylor, G. J., Bagby, R. M., & Acklin, M. W. (1993). Alexithymia in panic disorder and simple phobia: a comparative study. *Am J Psychiatry, 150*(7), 1105-1107.

Porcelli, P., Taylor, G. J., Bagby, R. M., & De Carne, M. (1999). Alexithymia and functional gastrointestinal disorders. A comparison with inflammatory bowel disease. *Psychother Psychosom, 68*(5), 263-269. doi: 12342

Revelle, W., & Loftus, D. A. (1992). The implications of arousal effects for the study of affect and memory. In S.-A. k. Christianson (Ed.), *The handbook of emotion and memory* Lawrence Erlbaum Associates, Inc.

Psychology Press.

Roediger, H. L., 3rd, & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *J Exp Psychol Learn Mem Cogn, 21* (4), 803-814. doi: 10.1037/0278-7393.21.4.803

Roediger, H. L., 3rd, Watson, J. M., McDermott, K. B., & Gallo, D. A. (2001). Factors that determine false recall: a multiple regression analysis. *Psychon Bull Rev, 8*(3), 385-407.

Russell, W. A., & Jenkins, J. J. (1954). *Studies on the Role of Language in Behavior (Technical Report No. 11): The Complete Minnesota Norms for Responses to 100 Words from the Kent-Rosanoff Word Association Test*. Minneapolis, MN: University of Minnesota.

Sifneos, P. E. (1973). The prevalence of 'alexithymic' characteristics in psychosomatic patients. *Psychother Psychosom, 22*(2), 255-262.

Smeets, T., Jelicic, M., Merckelbach, H., Peters, M., Fett, A., Taverniers, J., . . . Dautzenberg, J. (2006). Enhanced memory performance on an internal-internal source monitoring test following acute psychosocial stress. *Behav Neurosci, 120*(6), 1204-1210. doi: 10.1037/0735-7044.120.6.1204

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: applications to dementia and amnesia. *J Exp Psychol Gen, 117*(1), 34-50.

Stadler, M. A., Roediger, H. L., 3rd, & McDermott, K. B. (1999). Norms for word lists that create false memories. *Mem Cognit, 27*(3), 494-500.

Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behav Res Methods Instrum Comput, 31*(1), 137-149.

Stone, L. A., & Nielson, K. A. (2001). Intact physiological response to arousal with impaired emotional recognition in alexithymia. *Psychother Psychosom, 70*(2), 92-102. doi: 56232

Storbeck, J., & Clore, G. L. (2005). With sadness comes accuracy; with happiness, false memory: mood and the false memory effect. *Psychol Sci, 16*(10), 785-791. doi: 10.1111/j.1467-9280.2005.01615.x

Swart, M., Kortekaas, R., & Aleman, A. (2009). Dealing with feelings: characterization of trait alexithymia on emotion regulation strategies and cognitive-emotional processing. *PLoS One, 4*(6), e5751. doi: 10.1371/journal.pone.0005751

Taylor, G. J. (2000). Recent developments in alexithymia theory and research. *Can J Psychiatry, 45*(2), 134-142.

Taylor, G. J., & Bagby, R. M. (2004). New trends in alexithymia research. *Psychother Psychosom, 73*(2), 68-77. doi: 10.1159/000075537

Taylor, G. J., Bagby, R. M., & Parker, J. D. (1991). The alexithymia construct. A potential paradigm for psychosomatic medicine. *Psychosomatics, 32*(2), 153-164.

Todarello, O., Taylor, G. J., Parker, J. D., & Fanelli, M. (1995). Alexithymia in essential hypertensive and psychiatric outpatients: a comparative study. *J Psychosom Res, 39*(8), 987-994.

Toglia, M. P., & Battig, W. F. (1978). *Handbook of semantic word norms*. Hillsdale, NJ: Erlbaum.

Tulving, E. (1985). Memory and consciousness. *Can Psychol, 26*(1), 1-12. doi: 10.1037/h0080017

Van Damme, I. (2013). Mood and the DRM paradigm: An investigation of the effects of valence and arousal on false memory. *Q J Exp Psychol (Hove), 66*(6), 1060-1081. doi: 10.1080/17470218.2012.727837

Vermeulen, N., & Luminet, O. (2009). Alexithymia factors and memory performance for neutral and emotional words. *Personality and Individual Differences, 47*(4), 305-309. doi: 10.1016/j.paid.2009.03.018

Vermeulen, N., Toussaint, J., & Luminet, O. (2010). The influence of alexithymia and music on the incidental memory for emotion words. *Eur J Personality, 24*(6), 551-568. doi: 10.1002/per.758

Walker, E. L. (1958). Action decrement and its relation to learning. *Psychol Rev, 65*(3), 129-142. doi: 10.1037/h0049177

Zackheim, L. (2007). Alexithymia: the expanding realm of research. *J Psychosom Res, 63*(4), 345-347. doi: 10.1016/j.jpsychores.2007.08.011

Zeitlin, S. B., & McNally, R. J. (1993). Alexithymia and anxiety sensitivity in panic disorder and obsessive-compulsive disorder. *Am J Psychiatry, 150*(4), 658-660.

Appendix A

DRM Word Lists.

Studied words with non-presented critical targets in header (bold):

Anger	**Chair**	**Rough**	**Needle**	**Sleep**	**Sweet**
mad	table	smooth	thread	bed	sour
fear	sit	bumpy	pin	rest	candy
hate	legs	road	eye	awake	sugar
rage	seat	tough	sewing	tired	bitter
temper	couch	sandpaper	sharp	dream	good
fury	desk	jagged	point	wake	taste
ire	recliner	ready	prick	snooze	tooth
wrath	sofa	coarse	thimble	blanket	nice
happy	wood	uneven	haystack	doze	honey
fight	cushion	riders	thorn	slumber	soda
hatred	swivel	rugged	hurt	snore	chocolate
mean	stool	sand	injection	nap	heart
calm	sitting	boards	syringe	peace	cake
emotion	rocking	ground	cloth	yawn	tart
enrage	beach	gravel	knitting	drowsy	pie

Weak associates:

hostile	bench	rocky	hypodermic	lullaby	syrup
annoyed	bleacher	chapped	stitch	hibernate	sticky

Appendix B

Emotion Rating Scale.

How would you rate your mood right now?

1	2	3	4	5	6	7	8	9	10

Extremely negative Moderate/Neutral Extremely Positive

How would you rate the amount of *emotional arousal* you are experiencing right now?

1	2	3	4	5	6	7	8	9	10

Not at all aroused Moderately aroused Extremely aroused