Associations between Resting Heart Rate Variability, Depressive Symptoms, and Autobiographical Memory Specificity

THESIS

Presented in Partial Fulfillment of the Requirements for the Degree Master of Arts in the Graduate School of The Ohio State University

By

Nicole Feeling

Graduate Program in Psychology

The Ohio State University

2015

Master's Examination Committee:

Professor Julian F. Thayer, Ph.D., Advisor
Professor Michael W. Vasey, Ph.D., Advisor
Amelia Aldao, Ph.D.
Heart rate variability (HRV), depression symptoms, and reduced autobiographical memory specificity (AMS) have all been independently found to have associations with inhibitory control capacity and executive functioning. Inhibitory control is the ability to effectively inhibit the processing of distracting information in order to achieve a specific goal. Inhibitory control is thought to be able to be depleted, and can be exhausted through cognitively demanding tasks. One index of inhibitory control is vagally-mediated high frequency (HF) HRV, which reflects parasympathetic activity. Vagally-mediated HF-HRV is found to be positively correlated to inhibitory control.

Interestingly, depression is characterized by a variety of cognitive deficits and biases, including reduced inhibitory control and reduced autobiographical memory specificity (AMS). Individuals with reduced AMS tend to recall and describe events from their past in a vague, over-general manner. Reduced AMS has been associated with poor prognosis in depression, and delayed recovery from depressive episodes.

While both depression and AMS have relations to inhibitory control capacity, the relation between HRV and AMS has not yet been investigated, and certainly not the interaction of HRV, AMS, and depressive symptoms. To assess this relationship, participants (N=120) included in the study were given the Autobiographical Memory Test (AMT), Beck Depression Inventory (BDI), and also completed measures of resting
HRV via electrocardiogram (ECG). Half of the participants were assigned to a condition of increased cognitive load (memorizing a six-digit number).

Regression analysis showed that the interaction between HRV measures, BDI, and AMS was significant in the increased load condition such that HF-HRV moderated the relation between depressive symptoms and AMS. Specifically, lower baseline vagally-mediated HF-HRV moderated the effect of depressive symptoms on the number of specific memories such that greater depressive symptoms were associated with fewer specific memories on the AMT. The same interaction was not significant in the lower-load condition. These findings indicate that AMS is not only related to depressive symptoms and executive control, but also to HRV. Specifically these results show that after increased cognitive load, HRV and depressive symptoms interact to predict individuals who are more likely to experience reduced AMS. Given that reduced AMS predicts delayed recovery among depressed patients, a better understanding of the role of self-regulatory capacity, as indexed by measures of inhibitory control and resting HF-HRV on depression symptomatology as well as reduced AMS, might reveal targets for improving treatments.
Acknowledgments

I would like to thank my advisors, Dr. Michael Vasey and Dr. Julian Thayer, for their guidance and support through this project. In addition, I’d like to thank Dr. Amelia Aldao for her helpful feedback and recommendations. Finally I’d also like to thank Dr. Julian Koenig and DeWayne Williams for their valuable advice and feedback.
Vita

2006.................................................................Shaker Heights High School

2010.............................................................B.S. Psychology, Duke University

2013 to 2014 ....................................................Psychology Department Fellow, The Ohio

State University

2014 to present ..............................................Graduate Teaching Associate, Department

of Psychology, The Ohio State University

Publications

tone in borderline personality disorder: A meta-analysis. Progress in Neuro-
Psychopharmacology & Biological Psychiatry, 64, 18-26.

Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF) Veterans: A


Fields of Study

Major Field: Psychology
# Table of Contents

Abstract ................................................................................................................. ii

Acknowledgments ........................................................................................... iv

Vita ......................................................................................................................... v

List of Tables ....................................................................................................... viii

List of Figures ...................................................................................................... ix

Chapter 1: Introduction ...................................................................................... 1

Heart Rate Variability ......................................................................................... 1

Reduced AMS ....................................................................................................... 5

Present Study ........................................................................................................ 8

Chapter 2: Methods .......................................................................................... 10

Participants .......................................................................................................... 10

Procedure ............................................................................................................. 11

Material ................................................................................................................. 13
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis</td>
<td>18</td>
</tr>
<tr>
<td>Chapter 3: Results</td>
<td>20</td>
</tr>
<tr>
<td>Descriptive Statistics</td>
<td>20</td>
</tr>
<tr>
<td>Interaction between BDI and HRV on Number of Specific Memories</td>
<td>20</td>
</tr>
<tr>
<td>Chapter 4: Discussion</td>
<td>22</td>
</tr>
<tr>
<td>Chapter 5: Limitations, Future Directions &amp; Conclusions</td>
<td>27</td>
</tr>
<tr>
<td>Limitations</td>
<td>27</td>
</tr>
<tr>
<td>Future Directions</td>
<td>28</td>
</tr>
<tr>
<td>Conclusion</td>
<td>29</td>
</tr>
<tr>
<td>References</td>
<td>30</td>
</tr>
<tr>
<td>Appendix A: Tables</td>
<td>39</td>
</tr>
<tr>
<td>Appendix B: Figures</td>
<td>43</td>
</tr>
</tbody>
</table>
List of Tables

Table 1. Descriptive Statistics........................................................................................................39
Table 2. Regression Summary for Three-way Interaction.........................................................40
Table 3. Regression Summary in increased load condition.....................................................41
Table 4. Conditional Effect of BDI on Number of Specific Memories at values of lnHF-HRV ..................................................................................................................................41
Table 5. Regression Analysis in low-load condition ...............................................................42
Table 6. Conditional Effect of BDI on Number of Specific Memories at values of lnHF-HRV ..................................................................................................................................42
List of Figures

Figure 1. Moderated Moderation Model (Model 3; Hayes, 2012) ........................................... 43
Figure 2. Basic Moderation Model (Model 1; Hayes, 2012) .................................................. 44
Figure 3. Regression analysis in increased load condition ......................................................... 45
Figure 4. Regression analysis in low-load condition .................................................................. 46
Chapter 1: Introduction

Heart rate variability (HRV) refers to the beat-to-beat variability in the time between adjacent heartbeats. Higher variability typically is associated with better outcomes (Thayer et al., 2012). Lower HRV is associated with increased depressive symptoms and lower inhibitory control (Kemp et al., 2010; Thayer & Brosschot, 2005). Reduced autobiographical memory specificity (AMS) is a memory bias prevalent in depressed populations that is also associated with inhibitory control (Williams et al., 2007; Raes et al., 2010). The current study examines the extent to which HRV, depressive symptoms, and reduced AMS are related. Specifically the study evaluates a possible interaction in which HRV moderates the association between depressive symptoms and reduced AMS.

**Heart Rate Variability**

High HRV is associated with healthy cardiac activity, and has been found to be protective against heart failure and myocardial infarction (Bigger et al, 1988). HRV has been demonstrated to be a stable trait marker over time; thus resting measures of HRV are of interest as biomarkers (Bertsch et al., 2012; Li et al., 2009; Thayer & Lane, 2009). HRV is typically measured via electrocardiogram (ECG) and is most often expressed as indices derived from either time or frequency-domain analysis.
The parasympathetic and sympathetic branches of the autonomic nervous system are controlled by the central autonomic nervous system (CAN). HRV is mediated by parasympathetic nerves (notably the vagus nerve) which slow heart rate, and sympathetic nerves which accelerate heart rate (Kemp et al 2010). Parasympathetic and sympathetic neurons (under influence from prefrontal activity at the output of the CAN) influence the heart via the stellate ganglia and vagus nerve in the sino-atrial node of the heart. The parasympathetic nerves act quicker, causing HRV to reflect the parasympathetic nervous system’s influence on heart rate via the vagus nerve (Levy, 1990). Because of this, operations of the CAN are directly related to HRV (Thayer & Lane 2000). Vagally mediated HF-HRV measures specifically assess parasympathetic activity, specified by Task Force guidelines (Task Force, 1996).

The prefrontal cortex (PFC) is believed to allow individuals to organize their behavior and effectively respond to environmental demands (Miller & Cohen, 2001). HRV is understood to be linked to cognitive control via top-down inhibitory influence of the PFC on lower order brain areas such as the limbic system. Greater PFC activation leads to increased HRV (Thayer et al., 2012; Lane et al., 2009; Nugent et al., 2011; Ahern et al., 2001). The vagus nerve is thought to connect to the ventromedial PFC (vmPFC), right dorsolateral PFC (dlPFC), and orbitofrontal cortex. This neural circuitry is necessary for various self-regulatory actions (Chikazoe et al., 2007).

**HRV and Cognitive Control.** One such self-regulatory action is executive control, which is broadly construed as the set of cognitive processes that allow for monitoring complex goal-directed behavior in the face of distracting information
Another self-regulatory measure is inhibitory control - the ability to effectively inhibit distracting information in order to achieve a specific goal (Engle et al., 1995). Relationships have been found between HRV and attentional control, HRV and inhibitory control, and HRV and memory control; specifically that individuals with higher HRV (more variability) at rest have been found to perform better on executive function and emotion regulation tasks relative to those with lower HRV (Thayer & Brosschot, 2005; Thayer et al., 2000; Thayer & Lane, 2000; Hansen, Johnsen, & Thayer, 2003; Gillie, Vasey, & Thayer 2014). Thus, HRV has been identified as a marker of self-regulation capabilities (Gillie, Vasey, & Thayer, 2015; Porges, 1991; Porges, 1992; Thayer & Lane, 2000).

Higher baseline HRV is associated with better performance on tasks assessing inhibitory control, working memory, sustained attention, and other tasks demanding executive control (Krypotos et al., 2011; Hansen, Johnsen, & Thayer, 2003; Johnsen et al., 2003; Hovland et al., 2012).

For example, in thought suppression paradigms, successful memory suppression was associated with greater functional connectivity in the same networks associated with HRV (Paz-Alonzo, Bunge, Anderson, and Ghetti, 2013; Benarroch, 1997; Lane et al., 2009). This neuroimaging research demonstrates that higher HRV should be associated with more successful memory suppression. Further, in one study of participants who were instructed to learn and then forget pairings of words (via a standard think-no-think task), those who were able to successfully suppress memory for words they were instructed to forget had higher HRV (Gillie, Vasey & Thayer, 2014). Thus, research
clearly shows that HRV and various forms of cognitive control (including inhibitory control and memory control) are associated.

**HRV and Depression Symptoms.** HRV has also been related to rumination and negative affect (Brosschot and Thayer, 2003; Brosschot and Thayer, 2004). Studies have shown that tasks evoking negative affect are associated with cardiovascular responses that are longer lasting than tasks evoking positive affect. In addition, negative cognitions such as rumination and worry in particular have been associated with unusual HRV patterns (Brosschot and Thayer, 2003; Brosschot and Thayer, 2004; Brosschot et al., 2006; Neumann et al, 2001). Rumination and worry are often discussed in the context of depression, and negative perseveration is thought to be a major component of depressive thought processes (Segerstrom et al., 2000; Nolen-Hoeksema, 2000).

Major Depressive Disorder (MDD) is a debilitating disorder characterized by chronic low mood. Depression has a worldwide prevalence of 8%-12%, and carries a large disease burden (Andrade et al., 2003; Murray & Lopez, 1997). It has been associated with cardiovascular morbidity and mortality, and is associated with an increased risk of death after myocardial infarction (Nashon et al, 2004). Further studies of this relation found that patients with depression have lower HRV (as measured by HF-HRV) compared to healthy control subjects (Friedman & Thayer 1998, Thayer et al, 2000, Kemp et al, 2010; van der Kooy et al, 2006). A recent meta-analysis of the effect of depression and antidepressants on HRV found that medication-naïve depressed patients exhibited reduced HF-HRV, and that depression severity and HRV were significantly negatively correlated (Kemp et al., 2010). In addition, studies have found that
antidepressant medication (with the exception of tricyclic antidepressants) did not seem to have an effect on HRV. Recent findings show that depression is associated with altered HRV patterns (Udupa et al., 2007), and unusual vagally-mediated HRV patterns could be an endophenotype for depression (Yaroslavsky et al. 2014).

**Reduced AMS**

**Depression and Reduced AMS.** Depression is characterized by a variety of cognitive deficits and biases, including reduced AMS - a style of recalling and describing specific events from one’s past in response to word cues in a vague/over-general way (Dalgleish & Watts, 1990; Matthews & MacLeod, 2004; Williams & Broadbent, 1986). For example, when instructed to recall a memory of a single event, occurring on a single, specific day, in response to the cue word “clumsy,” someone might give a general response such as “I’m clumsy when I’m dancing”, instead of the requested specific response of, “Last week I was dancing with my friends and spilled punch all over myself”. Reduced AMS is particularly prevalent in depressed populations, those with posttraumatic stress disorder (PTSD) and acute stress disorder (ASD), and possibly those with eating disorders (see Williams et al. 2007 for a review). However, reduced AMS has not been found in other related disorders (e.g. general anxiety disorder, social phobia, blood/spider phobia) indicating that reduced AMS is not simply a marker of psychopathology in general (Williams et al. 2007). Reduced AMS has also been associated with poor prognosis in depression, increased depressive symptoms following a traumatic event, and delayed recovery from episodes of psychopathology (Brittlebank, Scott, Williams & Ferrier, 1993; Gibbs and Rude, 2004; Raes et al., 2006; Williams,
Brittlebank et al. (1993) found that reduced AMS predicted delayed recovery in individuals with MDD over and above baseline depressive symptom levels. They also found that even after patients recovered from their depressive episodes, AMS differences remained. Similarly, Spinhoven et al. (2006) found reduced AMS in those with a history of depression but not in a current episode at the time of the study. Reduced AMS has also been found to predict future mood episodes for premenstrual dysphoria, postpartum depressed mood, and depressive symptoms following life events in students (see Williams et al. 2007 for a review), making reduced AMS a possible marker of vulnerability to depression. Thus, understanding reduced AMS could reveal important processes in the onset and maintenance of depression.

**Executive Control and Reduced AMS.** Reduced AMS is associated with deficits in executive control (Raes et al., 2010; Dalgleish et al., 2007) and poor problem solving (Goddard et al. 1996, Goddard et al., 1997, Haddad et al., 2014). In addition, reduced AMS has been associated with rumination/brooding in particular (Sumner et al., 2014). However, while reduced AMS is negatively associated with IQ, it is not satisfactorily accounted for by any single memory or cognitive deficit (Williams et al., 2007).

One theory regarding the development of reduced AMS is the executive control model of reduced AMS (Dalgleish et al., 2007). Memory retrieval is understood to be a task relying on PFC cognitive control (Banich et al., 2009). The standard measure of AMS is the Autobiographical Memory Test (AMT). The AMT consists of a set of cue
words, and subjects are instructed to report a specific memory in response to each cue word. Retrieving memories on the AMT is cognitively demanding, so those lacking in executive control may simply be unable to mobilize cognitive efforts in an effective way to complete the AMT. Previous research suggests that executive control allows an individual to keep up the memory search required to produce specific memories on the AMT in spite of distracting (non-specific) memories that may come to mind first (Dalgleish et al., 2007; Williams et al., 2007; Dalgleish et al., 2008). Thus reduced AMS stems from an inability to follow task instructions due to deficits in executive control (Hertel and Hardin, 1990). Interestingly, executive (and inhibitory) control is thought to be a resource that can be depleted through extended use (Muraven & Baumeister, 2000).

So, one would expect that those with higher cognitive control burdens and those with lower reserves to start with would be most at risk for displaying reduced AMS.

Individuals experiencing emotional disorders are known to exhibit deficits in executive control (Rothbart et al., 2003). Specifically, MDD and PTSD - disorders associated with reduced AMS - are among these disorders associated with executive control deficits (see Hartlage, Alloy, Vazquez and Dykman, 1993; Aupperle, Melrose, Stein, and Paulus, 2012 for reviews). Inhibitory control in particular has been implicated as an important facet of executive control that is not only needed to accurately complete the AMT, but also is a known deficit in depressed samples (Engle et al., 1995; Joorman, Yoon & Zetsche, 2007; Raes et al., 2010). The prominence of reduced AMS in these disorder populations is consistent with the executive control hypothesis. It is important to note that the association between reduced AMS and executive control deficits in disorder
populations does not seem to be due to psychopathological severity alone (Sumner, 2012).

A series of studies in eating disorder patients, depressed volunteers, and healthy volunteers have been conducted using various executive control-demanding tasks to determine the relationship between reduced AMS and executive control in such disorders. For example, in one study of eating disorder patients, performance on a verbal fluency test of executive control was related to reduced AMS measured by AMT performance (Study 1, Dalgleish et al., 2007). In another study, healthy volunteers displayed the same relation with a number generation task instead of the verbal fluency task (Study 3, Dalgleish et al., 2007). Finally, a study in a population of non-clinical students and a population of depressed women found that in both groups poorer performance on an executive control task was related to fewer specific memories given on the AMT (Smets, Wessel, Raes, 2014). Altogether, these studies found that individual differences in executive control were related to performance on the AMT.

Considering the strong evidence for the relation between reduced AMS and executive control (inhibitory control in particular), and the evidence for a relation between HRV and executive control, it seems probable that HRV and AMS are also related. The relationship between depression and both HRV and AMS adds to this likelihood. However, as of yet the two constructs has not been assessed in conjunction.

Present Study

Whereas HRV (a physiological measure) and AMS (a cognitive bias) have never been measured in conjunction before, there is considerable evidence that there may be a
relationship. HRV, AMS and depressive symptoms have all been independently associated with inhibitory control deficits (Lockwood, Alexopoulos, & van Gorp, 2014). Lower HRV has been associated with low executive/inhibitory control, and low executive control has been associated with depression (Kaiser et al., 2003). Reduced inhibitory control is also associated with reduced AMS. While both AMS and HRV have been related to inhibitory control capacity, the relation between HRV and AMS has not yet been investigated. Additionally, the possibility of an interaction among HRV, AMS, and depression has never been investigated.

Much of the past research on reduced AMS has been done in clinical (often depressed) populations. However, studies in nonclinical populations could help clarify reduced AMS levels in healthy controls, as well as allow assess for different levels of depression alongside matching peers without psychopathology. Studies in nonclinical populations can help illuminate the mechanisms behind AMS, without the need for specific recruitment of clinical subjects.

Integrating the previous concepts, HF-HRV is hypothesized to moderate the effect of depression on AMS in a college population. Specifically, higher levels of depressive symptoms (as measured by the Beck Depression Inventory), paired with lower inhibitory control (as indexed by HF-HRV) will be associated with the fewest number of specific memories provided on the AMT.
Chapter 2: Methods

Participants

The sample consisted of 127 (66 male, 61 female) undergraduate students taking
Introductory Psychology at The Ohio State University. Participants were recruited
through the Ohio State University Psychology Department Research Experience Program
(REP). A description of the study was posted on the REP webpage and students were
encouraged to sign up. In addition, some students were emailed invitations to participate
in the study based on prescreening scores. Students participated in the study as part of
their class requirements and received course credit for participating in the study.

This study was conducted in the context of a larger study concerned with worry
and effortful control. In accordance with the larger study, some of the students in the
REP sample were specifically recruited based on pre-screen measures of worry and
effortful control. This was to ensure that there would be enough students high in worry
(as measured by the Penn State Worry Questionnaire, PSWQ; Meyer et al., 1990), and
both high and low in effortful control (as measured by the Effortful Control Scale
Persistence/ Low Distractibility subscale, Lonigan & Phillips, 2001) that complex
interactions could be observed. Students meeting these requirements were emailed
invitations to the study and encouraged to participate. While this prescreen was not
designed with the present study in mind, considering the high concordance of effortful
control and executive control/HRV, as well as the high correlations of worry and depression (Segerstrom, Tsao, Alden, & Craske, 2000), it would be expected that the inclusion of these subjects would increase the probability of finding an interaction in this study as well.

Participation was voluntary, and was one of several options for obtaining course credit. All participants were at least 18 years old. Those with a current diagnosis of Attention Deficit Disorder or Attention Deficit/Hyperactivity Disorder, allergies to electrode adhesive and/or those who did not have English as a primary language were not eligible to participate. The eligibility requirements were posted on the REP webpage, and the determination of eligibility was left up to the discretion of volunteers during recruitment.

Of the 127 subjects who participated in the study, only 121 had complete data (complete BDI, AMT, and HRV measures) needed to proceed with analysis. Of those 121, 55 were in the increased load condition, and 66 were in the low-load condition. A missing values analysis at random test was conducted, and it was determined that there were no significant differences between those who had completed sufficient measures for the study and those who didn’t.

Procedure

Materials in this study were presented within the context of a larger study focused on control of thoughts in varying levels of worry and effortful control. All participants completed a series of tasks in a set order. First they completed a 5-minute resting HRV baseline. This baseline measure was followed by a series of questionnaires, including
various self-reports. Next there was a cognitively depleting thought suppression task, in which subjects were counterbalanced such that half were in the increased load condition. During the thought suppression task, subjects were instructed to suppress the thought of a loved one being in a car accident. Subjects were randomly selected to complete an additional cognitive load during this task. Those in the increased load condition were also expected to remember a 6-digit number during the study and were instructed to recall this number on three occasions. Those in the low-load condition did not receive these instructions and were never shown the number. Next the participants completed another unrelated task (a face-dot-probe task), and finally they completed the AMT. After completing the AMT the participants answered a second set of self-report questionnaires. The laboratory session in full lasted between 1.5-2 hours.

The load condition was not implemented with this study in mind, but as part of the larger study on thought control. However, as nonclinical populations -especially college populations- are more likely to display higher executive reserves than clinical populations, adding a load condition to studies can be a way to enhance the ability to capture biases that might not become evident without cognitive strain. If the participants are more depleted, then differences in cognitive control capacity may become more evident. The participants in this study all completed two cognitively depleting tasks during the study (the dot-probe task and the thought-suppression task), however the individuals in the increased load condition also completed a memorization task. Utilizing the increased load condition should have produced the best chance of discovering any interactions, given that the more depleted subjects should show those biases.
Material

Questionnaires: Prescreen

**Penn State Worry Questionnaire** (PSWQ; Meyer et al., 1990). The PSWQ is a measure containing 16 Likert scale items (measured from one to five with one representing “Not at all typical of me” and five representing “Very typical of me”), used to assess trait-like pathological worry. A sample item from the scale is “I am always worrying about something”. It has demonstrated strong internal consistency and overall validity (Meyer et al., 1990; Fresco et al., 2002). The Cronbach’s alpha for the PSWQ has been measured between .86 and .91 (Dear et al., 2011). In order to oversample those high in worry, some participants were recruited to participate in the study via email based on their scores on this measure.

**Effortful Control Scale** (ECS, Lonigan & Phillips, 2001). The ECS consists of 24 items rated on a 5-point scale and is used to assess individual’s self-regulation capacity for attention and behavior. The items are statements such as, “When an activity or task is difficult, I give up,” and the subject is instructed to rate how much each sentence describes how they are most of the time. Responses choices are from 1-5 with a score of “1” representing “Not at all” and a score of “5” representing “Very Much.” While originally the measure was intended for use in child samples, the items have been demonstrated to be appropriate for college students (Vasey, 2008). The ECS produces two subscale scores representing: 1) Persistence/Low Distractibility (12 items) and 2) Impulsivity (12 items). The persistence/low distractibility scale was used in pre-testing to determine individuals high and low in effortful control. The ECS has been reported to
have good psychometric properties, with excellent internal consistency and test-retest reliability over a 7 week time interval (r=.80, Vasey, 2008; Lonigan, Vasey, Phillips, & Hazen, 2004).

**Questionnaires: In Session**

**Demographic Questionnaire.** The demographic questionnaire included items concerning the participant’s age, gender, year in school, ethnicity, marital status, and primary language.

**Beck Depression Inventory II** (BDI-II, Beck et al., 1961). The BDI is a measure assessing depressive symptoms that has been well validated and widely used. The BDI contains 21 items, each scored on a scale of 0-3, with higher scores indicating higher severity of depression. Each item represents a symptom characteristic of depression (e.g. pessimism) and the choices are items escalating in severity within that category. For example, for pessimism, the item’s choices are 0- “I am not discouraged about my future”, 1- “I feel more discouraged about my future than I used to be”, 2- “I do not expect things to work out for me”, and 3- “I feel my future is hopeless and will only get worse.” Scores from 14-19 are thought to be indicative of mild depression, from 20-28 of moderate depression, and above 28 being indicative of severe depression (Beck et al., 1996).

**Assessment of AMS**

Reduced AMS is typically measured with the Autobiographical Memory Test (AMT, Williams & Broadbent, 1986). In the standard AMT, participants are prompted to provide specific memories in response to a series of positively and negatively valenced
cue words (e.g., happy, frustrated, excited). The memories must be different for each word, and cannot have happened within the past week. The responses are then either coded as “specific” or “nonspecific.” Specific memories are memories that clearly indicate a unique event that took place within the course of one day (e.g. the previously mentioned example of “Last week I was dancing with my friends and spilled punch all over myself”). Nonspecific memories are further delineated into either “categorical” memories (memories representing a category of past events without referencing a specific time or place, e.g., “Being clumsy at parties”), or “extended” memories (specific memories for events taking place over a period of time longer than 24 hours, e.g. “I felt clumsy during a weekend cruise when wearing my new heels for the first time”). Non-responses or responses not meeting requirements (e.g. the memory took place within one week of the test) are categorized separately.

Studies have typically used the number of specific memories, proportion of categorical memories, number of categorical memories, or ratio of categorical memories to specific memories as dependent variables when looking at outcomes of reduced AMS. The number of specific memories is the variable most commonly used (Williams et al., 2007). In general, having a larger number of specific memories (or a lower number of categorical memories) is associated with better outcomes (Williams et al., 2007).

In the current study, the minimal instruction Autobiographical Memory Test (AMT, Williams and Broadbent, 1986; Debeer, 2009) was given to assess overgeneral memory. For this version of the AMT, twelve cue words were used, alternating in valence: happy, clumsy, surprised, angry, interested, sorry, successful, hurt (feelings),
safe, lonely, courageous, and weak. A paper version of the minimal instruction AMT was
given in the manner of Debeer et al. The participant was given the following
instructions:

We are interested in your memories for events, which you yourself have
experienced. On the next pages, you will find 12 words, which describe a feeling.
For each word, please write down a memory of an event that happened to you that
the word reminds you of or in which you felt the feeling described. The event
could have happened recently or a long time ago, but can not have happened in
the past 7 days. It might be an important event or an event that is not important.
For each word, a time limit of 60 seconds will be given. If you reach this limit
before finishing the memory, you will be instructed to turn to the following page.
Finally, please note that you should write down a different memory for each
word. You should not write down the same memory twice.

Four coders scored the AMT, and each coder rated every memory. The memories
were coded as specific, general, categorical, or other (i.e. semantic associates, omissions,
etc). A memory was considered specific if three or more raters coded it as specific. A
memory was considered categoric if two or more raters coded it as categoric. Reduced
AMS was determined by number of specific memories provided. The AMT coders had
high reliability for all the memories (.921 for specific, .913 for extended, .924 for
semantic, .916 for categoric). For the purpose of these analyses, only “number of specific
memories” was used as a predictor of AMS.
**HRV**

HF-HRV was collected via the MindWare 2000D (MW2000D) Impedance Cardiograph package during a 5-minute resting baseline. In order to obtain HF-HRV measures, three electrodes were placed on the subjects. One electrode was placed below the right collarbone, and the second and third electrodes were placed on opposite sides of the lower abdomen of the subjects. During resting measures the participants were instructed to sit quietly but not sleep while spontaneously breathing.

The data was analyzed with the suite of MindWare Technologies Signal Processing Applications (HRV 3.0.15, www.mindwaretech.com/product_physiosoftware.html). The Mindware suite provided the inter-beat interval (IBI) time series. IBIs were imported into Kubios HRV analysis software, allowing for both time- and frequency-domain (autoregressive) indices of HRV (Tarvainen et al., 2009). The time-domain index used was Root mean square of successive differences (RMSSD). Artifacts were visually inspected and removed using appropriate artifact correction levels. This provided very low frequency (VLF) bands (.004-.040), low frequency (LF) bands (0.04-0.15), and HF power bands (0.15-0.40 Hz). HF power and RMSSD are highly correlated, and were highly correlated in the sample (r= .85). Thus, the analysis focuses on HF power bands, because of its relation with RMSSD and because parasympathetic activity is of interest in this study. To normalize the data for analysis all HRV measures (ms$^2$ units) were log transformed. All procedures were done in accordance with Task Force recommendations (Task Force, 1996)
Analysis

An SPSS macro (“PROCESS”) was used to test a series of interaction models including the interaction of BDI x HF-HRV in predicting Number of Specific Memories (as measured by the AMT). First a Moderated Moderation model including Number of Specific Memories as the outcome variable, depression symptoms (as measured by the BDI) as the independent variable, and HF-HRV and Load condition as moderators was tested (Model 3; Hayes, 2012; see Figure 1).

As this study was conducted in a nonclinical population, the interaction was most likely to be seen in the increased load condition. Thus, the interaction model (BDI x HF-HRV predicting Number of Specific Memories) was tested in both load conditions (Model 1; Hayes, 2012) to see if additional load produced differing results (see Figure 2). This was planned regardless of whether the findings of the three-way interaction model proved significant. The increased load condition likely resulted in additional cognitive depletion to participants, and added likelihood of finding differences due to HF-HRV/inhibitory control capacity, thus it was deemed appropriate to test the interaction separately.

Gender was added as a covariate in all analyses, based on previous studies indicating gender differences in HF-HRV and depression (Ryan et al., 1994; Thayer et al., 1998). There were no outliers to account for. PROCESS uses the Johnson-Neyman technique to derive regions of significance, for the purpose of identifying the range of values of the moderator where the simple slope of the predictor variable is significant (Hayes, 2013). In the results section, the region of significance is reported in terms of
standard deviations from the mean of the moderator. The simple slopes for the predictor were examined at higher (1+ SD) and lower (-1/ SD) levels of the moderator to illustrate significant interactions. Finally, HRV measures were log-transformed to provide a normal distribution.
Chapter 3: Results

Descriptive Statistics

The mean BDI score was 12.6 \( (SD = 8.3) \). There was a relatively wide spread of depression severity for the sample; the lowest BDI score was 0, and the highest BDI score was 50, with significant variability in between. According to BDI cutoffs, 24 subjects had mild depression (20% of the total sample), 12 had moderate depression (10% of the total sample), and 5 had severe depression (4% of the total sample). This resembles general population incidence rates (Andrade et al., 2003; Murray & Lopez, 1997).

The means and standard deviations for BDI, number of specific memories, log transformed HRV, PSWQ, and ECS are listed in Table 1. There were no significant differences on measures of HRV, PSWQ, ECS, BDI, or number of specific memories between the load conditions. There was also no significant difference among gender counts between groups. There were 28 males and 27 females in the increased load condition, and 36 and 30 respectively in the low-load condition.

Interaction between BDI and HRV on Number of Specific Memories

To test the three-way interaction of BDI x HF-HRV x Load, first a regression model was used including load condition as an additional moderator (Model 3; Hayes, 2012; see Figure 1). The other variables included were Number of Specific Memories as
the outcome measure, standardized (z-transformed) BDI scores, log-transformed HF-HRV measures, and the BDI x HF-HRV interaction. The findings are displayed in Table 2.1. The three-way interaction of BDI x HF-HRV x Load was non-significant.

As planned, the same interaction model was run in the load conditions separately, removing load condition as a moderator (Model 1; Hayes, 2012). Running the interaction model in the increased load condition, there was a significant main effect for BDI ($R^2$ change = .076, $p = .030$). There was also a significant BDI x HF-HRV interaction term ($p=.046$). When observing the conditional effects of BDI on Number of Specific Memories at varying values of the HF-HRV, the interaction was only significant at lower levels of HF-HRV (at -1 standard deviation of HF-HRV; Effect = -1.203, $p = .029$). The regression summary can be found in Tables 3.1-3.2 and Figure 4. This means that in the increased load condition, at lower levels of HRV, subjects higher in depressive symptoms had fewer specific memories (i.e. reduced AMS). For those with higher HRV, there was no relation between depressive symptoms and the number of specific memories they reported on the AMT.

In the low-load condition, the interaction was not significant ($R^2$ change = .0006, $p = .8513$, see Tables 4.1-4.2 and Figure 3). Thus, for the low-load condition, there was no moderation of the association between BDI and AMS by HF-HRV.
Chapter 4: Discussion

The aim of this study was to assess if inhibitory abilities- as indexed by HF-HRV- moderated the effect of depressive symptoms on reduced AMS. This was done with the intention of clarifying the relations between the interrelated constructs of depression, HF-HRV, and reduced AMS. As it is known that worse depression course and severity are associated with reduced AMS (Brittlebank et al., 1993), if it was determined that HF-HRV moderated that link, it would suggest that both inhibitory abilities as indexed by HRV (Thayer & Lane, 2000) and depressive symptoms are related to AMS.

This study links and expands upon three literatures: HRV, Depression, and AMS. While all three literatures hint at links among each other, they had yet to be studied in conjunction. In the HRV literature, this study shows once again that HRV is linked to memory control. It also adds to the literature on the relation between HRV and depression by explaining a possible process contributing to HRV’s link to depression (reduced AMS). In the depression literature, this study pinpoints a group within college students that are most likely to evidence reduced AMS (those with higher depressive scores paired with lower HRV). And finally, reduced AMS is shown to relate to HRV, as well as depression when paired with increased cognitive load.

Previously, HF-HRV and reduced AMS had not been studied in conjunction, and the three had not been studied together as an interaction model. The findings of this study point to a model in which depressive symptoms and HF-HRV interact to predict
individuals who are more likely to experience reduced AMS, such that those with higher depressive symptoms and lower HF-HRV are more likely to experience reduced AMS. Indeed, this suggests individuals with higher HF-HRV, who have the necessary inhibitory abilities, do not show reduced AMS when paired with higher depressive symptoms in comparison to their lower HF-HRV counterparts. These results are particularly evident under high cognitive load. The significant interaction of HF-HRV moderating the effect of depressive symptoms on AMS under increased cognitive load supports this prediction.

In addition to supporting the hypothesis of an interaction of depressive symptoms and HF-HRV, there was also a near significant effect for gender in the low-load condition. While this was unexpected, it seems that the increased load condition had a differential effect on the participants by gender such that women reported higher numbers of specific memories than men in the low-load condition. In the increased load condition there was no difference. There is some previous research indicating that women provide autobiographical memories at a higher level of specificity than men (Davis, 1999; Pillemer, Wink, DiDonato & Sanborn, 2003). It’s possible that this difference was evident in the low-load condition; however the added manipulation of the load condition caused the men and women to behave similarly in reporting of memories.

Similarly, there was an unexpected difference between conditions for the main effect of depressive symptoms. Depressive symptoms were only predictive of AMS in the increased load condition, not in the low-load condition. Given that depression has a known relationship with AMS, the main effect itself is not surprising; however, the difference between conditions was not predicted. It seems in the increased load
condition, the individuals with higher depressive symptoms were more likely to display reduced AMS than individuals without the additional cognitive load. Perhaps the increased load depleted the subjects with higher depressive symptoms more than the subjects with lower symptoms, and thus a differential effect was seen that was not present in the low-load condition.

The implication of this study for depressed populations is that reduced AMS may not simply be a feature of depression alone, but is a feature of those with depression that also have concurrent low HF-HRV. This gives additional insight into a memory bias that is known mainly to occur in clinical (mainly depression and PTSD) populations. As reduced AMS is associated with worse depression course, this additional knowledge that AMS is also associated with lower HF-HRV adds to the literature on the possible mechanisms of this memory bias.

As for the topic of HRV, the results of this study imply that yet again, HF-HRV is related to self-regulation and cognitive control pathways. This study furthers research linking HF-HRV to executive (and especially inhibitory) control resources (Thayer & Brosschot, 2005; Thayer et al., 2000; Thayer & Lane, 2000; Hansen, Johnsen, & Thayer, 2003; Gillie, Vasey, & Thayer 2014). As HF-HRV, depression, and AMS are all related to executive control, HF-HRV’s connection with executive control capacity is likely at least partially the course by which HF-HRV and reduced AMS are related. Traditionally executive control has been measured via tasks such as the Wisconsin Card Sort Test, or the Stroop Task (Royall et al., 2002). While tasks assessing executive control are very useful, these tasks are often time consuming and stressful for the subject. The prospect of
using HF-HRV as a proxy measure of executive control is a compelling idea and has been proposed by other researches (Thayer et al., 2012).

The standard form of the AMT was developed in clinical populations, and previous research using the standard form of the AMT in college populations has produced less variability, and higher mean numbers of specific memories than traditional clinical populations (Debeer, 2009; Vasey, unpublished data). However, using the minimal instruction version of the AMT provided enough variability to test the interaction. This study displays the efficacy of using the minimal instruction AMT in student populations.

Given previous research on the relation between reduced AMS and inhibitory control (Raes et al., 2010), the finding that HF-HRV only interacted with depressive and reduced AMS in the increased load condition is able to be explained. College students tend to have lower levels of depressive symptoms and have higher executive control resources than populations that are traditionally studied in AMS research (Debeer, 2009). Since executive control and depressive symptoms are the very correlates of AMS being studied, the increased load was necessary to cognitively deplete the subjects enough to find the effects that were being assessed. Overall, the present study suggests that in individuals experiencing higher depressive symptoms as reported on the BDI, HF-HRV may serve as an indicator of who might be more likely to experience reduced AMS. If the findings of this study were replicated, these results would show that not only is low HF-HRV a marker of depression, but also
that individuals with depressive symptoms paired with low HRV might be at risk for additional complications.
Chapter 5: Limitations, Future Directions & Conclusions

Limitations

This study was conducted in the context of a larger study with various aims. Because of this, there were some features of the study that may have hindered the ability to find the three-way interaction of load, depressive symptoms, and reduced AMS. For example, it’s possible that some of the other unrelated measures assessed in this study affected the results, especially the memories reported on the AMT. A study where the participants were given the AMT without any preceding questionnaires may have been preferable.

In addition, the AMT took place after two cognitively depleting tasks that all subjects completed. Those in the increased load condition had an additional load, but it’s possible that the depletion from the other tasks lessened the difference between our increased load and low-load conditions. This would reduce the power of the analyses to find the interaction. The type of load used in the study also could have been improved. While the expected interaction of HRV on depressive symptoms and AMS did occur in the increased load condition, the memorization task was a minimal load. The number that the participants memorized was only six digits, and seven-digit numbers are more commonly used for similar load tasks. A Stroop task, or another more cognitively challenging task might have increased the cognitive depletion of the subjects in the study more than the simple recall task. Having a more taxing load condition, or a more
pronounced difference between load conditions in college students may have depleted the subjects more and allowed for more pronounced differences between conditions.

Finally, it is typical in studies of HRV to control for physical fitness, BMI, medication, and other variables that have been shown to affect heart rate and HRV (Karason et al., 1999; Kemp et al., 2010). This information was not collected during the study, and thus BMI and medication status were not controlled. It’s possible that there could be medication differences or weight differences between the subjects, which could affect the results of the interaction between HRV and depression on AMS.

**Future Directions**

As this study was part of a larger study on executive control and HRV, replication of this study is important. The findings of this study indicate that future studies in college populations should make use of a load condition to replicate the interaction of HRV on depressive symptoms and AMS.

Future research in other populations would be useful to determine the generalizability of these findings. College students are generally less depressed, and higher in executive control resources than the general population. Due to this population difference, studies in mixed samples (clinical population mixed with general population) where the subjects are likely to have higher levels of depressive symptoms and/or lower levels of executive control capacity, may not need the load condition to produce the effect. The interaction of HRV with depression’s relation with reduced AMS would be most evident in populations with a large range of depression severity, as well as larger ranges of executive control capacity. In addition, as trauma history is associated with reduced AMS (de Decker, Hermans, Raes, &
Eelen, 2010), replication in populations including traumatized subjects might also produce stronger results.

Finally, one would expect that the individuals predicted to have reduced AMS in the model of this study would also be most at risk for worse depression course and severity than other individuals with similar levels of depressive symptoms (Peeters et al., 2002; Kleim & Ehlers, 2008). More research into the relationship of HF-HRV and AMS can help determine if HF-HRV patterns could be used as a marker of individuals within depressed populations who might need additional treatment, or have different outcomes than other depressed patients.

**Conclusion**

In conclusion, the hypothesis that HRV moderates the effect of depressive symptoms on autobiographical memory specificity was supported in the participants in the condition under high cognitive demand. Including an increased load condition sufficiently depleted the subjects in order to produce the predicted interaction. Neither the sample as a whole, nor those in the control condition displayed the interaction of HF-HRV on the relation between depressive symptoms and AMS that was being studied. The findings of this study support past research on the inter-relations of HF-HRV, depression, and AMS, and extend it by pointing out a potential mechanism (the interaction between HF-HRV and depression). As reduced AMS is a marker of worse depression course and severity, being able to predict patients that might have reduced AMS (and likely worse outcomes) could be helpful in treatment in the future.
References


Haddad, A.D.M., Harmer, C.J., Williams, J.M.G. (2014). Executive dysfunction and


R. Richardson (Eds.), Attention and information processing in infants and adults: Perspectives from human and animal research (pp. 201-223). Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.


Table 1. Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Total Sample: Mean (SD)</th>
<th>Load Condition: Mean (SD)</th>
<th>Control Condition: Mean (SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF-HRV</td>
<td>6.56 (1.23)</td>
<td>6.64 (1.18)</td>
<td>6.47 (1.20)</td>
<td>.309</td>
</tr>
<tr>
<td>BDI</td>
<td>11.82 (8.29)</td>
<td>12.85 (8.63)</td>
<td>10.95 (7.95)</td>
<td>.308</td>
</tr>
<tr>
<td>Specific Memories</td>
<td>6.20 (2.94)</td>
<td>6.46 (2.85)</td>
<td>5.99 (3.03)</td>
<td>.854</td>
</tr>
<tr>
<td>PSWQ</td>
<td>53.75 (13.37)</td>
<td>54.02 (14.09)</td>
<td>53.53 (12.84)</td>
<td>.724</td>
</tr>
<tr>
<td>ECS</td>
<td>72.71 (8.65)</td>
<td>71.42 (9.43)</td>
<td>72.83 (7.83)</td>
<td>.404</td>
</tr>
<tr>
<td>Sex</td>
<td>64 Men</td>
<td>28 Men</td>
<td>36 Men</td>
<td>.690</td>
</tr>
<tr>
<td></td>
<td>57 Women</td>
<td>27 Women</td>
<td>30 Women</td>
<td></td>
</tr>
</tbody>
</table>

Note. BDI scores were standardized. HF-HRV = natural log-transformed high frequency heart rate variability; BDI: Beck Depression Inventory; Specific Memories: Number of specific memories as measured by the Autobiographical Memory Test; PSWQ: Penn State Worry Questionnaire; ECS: Effortful control scale
### Regression Analysis 1: Model 3 including Load as a Moderator

Table 2. Regression Summary for Three-way Interaction

<table>
<thead>
<tr>
<th>Step/ variables added</th>
<th>$R^2$</th>
<th>$R^2$ change</th>
<th>Coeff (SE)</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model:</td>
<td>.061</td>
<td></td>
<td></td>
<td></td>
<td>.513</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td>3.825 (4.72)</td>
<td>.811</td>
<td>.419</td>
<td></td>
</tr>
<tr>
<td>HF-HRV</td>
<td></td>
<td>.119 (.71)</td>
<td>.168</td>
<td>.867</td>
<td></td>
</tr>
<tr>
<td>BDI</td>
<td></td>
<td>5.627 (5.57)</td>
<td>1.011</td>
<td>.314</td>
<td></td>
</tr>
<tr>
<td>BDI x HF-HRV</td>
<td></td>
<td>-.754 (.82)</td>
<td>-.916</td>
<td>.361</td>
<td></td>
</tr>
<tr>
<td>Load</td>
<td></td>
<td>1.608 (3.01)</td>
<td>.535</td>
<td>.594</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td>.645 (.56)</td>
<td>1.152</td>
<td>.252</td>
<td></td>
</tr>
<tr>
<td>BDI X Load</td>
<td></td>
<td>-4.623 (3.19)</td>
<td>-1.448</td>
<td>.150</td>
<td></td>
</tr>
<tr>
<td>HF-HRV x Load</td>
<td></td>
<td>-.178 (.45)</td>
<td>-.393</td>
<td>.695</td>
<td></td>
</tr>
<tr>
<td>BDI x HF-HRV x Load</td>
<td>.015</td>
<td>.619 (.47)</td>
<td>1.320</td>
<td>.190</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* BDI scores were standardized. HF-HRV = natural log-transformed high frequency heart rate variability; Male was coded as 1, Female as 2; Load is scored as 1- low-load condition, 2- high-load condition; *p*<.05; all coefficients drawn from the final model.
## Regression Summary: Model 1 in Increased Load Condition

Table 3. Regression Summary in increased load condition

<table>
<thead>
<tr>
<th></th>
<th>R²</th>
<th>R² change</th>
<th>Coeff (SE)</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>.098</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>7.913 (2.20)</td>
<td>3.593</td>
<td>.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HF-HRV</td>
<td>-.175 (.32)</td>
<td>-.552</td>
<td>.583</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BDI</td>
<td>-3.826 (1.71)</td>
<td>-2.237</td>
<td>.030*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>-.200 (.79)</td>
<td>-.255</td>
<td>.800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BDI x HF-HRV</td>
<td>.076</td>
<td>.507 (.25)</td>
<td>2.049</td>
<td>.046*</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* BDI scores were standardized. HF-HRV = natural log-transformed high frequency heart rate variability; Male was coded as 1, Female as 2; *p<.05; all coefficients drawn from the final model.

Table 4. Conditional Effect of BDI on Number of Specific Memories at values of lnHF-HRV

<table>
<thead>
<tr>
<th>HF-HRV</th>
<th>Effect</th>
<th>se</th>
<th>t</th>
<th>p</th>
<th>LLCI</th>
<th>ULCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.175</td>
<td>-1.203</td>
<td>.535</td>
<td>-2.247</td>
<td>.029*</td>
<td>-2.278</td>
<td>-.1276</td>
</tr>
<tr>
<td>6.465</td>
<td>-.549</td>
<td>.373</td>
<td>-1.470</td>
<td>.148</td>
<td>-1.299</td>
<td>.201</td>
</tr>
<tr>
<td>7.755</td>
<td>.105</td>
<td>.443</td>
<td>.237</td>
<td>.814</td>
<td>-.785</td>
<td>.994</td>
</tr>
</tbody>
</table>

*Note.* HF-HRV = natural log-transformed high frequency heart rate variability; *p<.05; HRV values at -1, +1 standard deviation levels.
**Regression Summary: Model 1 in Low-load Condition**

Table 5. Regression Analysis in low-load condition

<table>
<thead>
<tr>
<th></th>
<th>R²</th>
<th>R² change</th>
<th>coeff</th>
<th>se</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model:</td>
<td>.052</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.508</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td></td>
<td>4.899</td>
<td>2.236</td>
<td>2.191</td>
<td>.032</td>
</tr>
<tr>
<td>HF-HRV</td>
<td></td>
<td></td>
<td>-.136</td>
<td>2.332</td>
<td>-.410</td>
<td>.683</td>
</tr>
<tr>
<td>BDI</td>
<td></td>
<td></td>
<td>.605</td>
<td>2.722</td>
<td>2.222</td>
<td>.825</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td>1.369</td>
<td>.786</td>
<td>1.741</td>
<td>.087</td>
</tr>
<tr>
<td>BDI x HF-HRV</td>
<td>.001</td>
<td></td>
<td>-.076</td>
<td>.403</td>
<td>-.188</td>
<td>1.851</td>
</tr>
</tbody>
</table>

*Note.* BDI scores were standardized. HF-HRV = natural log-transformed high frequency heart rate variability; Male was coded as 1, Female as 2; all coefficients drawn from the final model.

Table 6. Conditional Effect of BDI on Number of Specific Memories at values of lnHF-HRV

<table>
<thead>
<tr>
<th>HF-HRV</th>
<th>Effect</th>
<th>se</th>
<th>t</th>
<th>p</th>
<th>LLCI</th>
<th>ULCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.460</td>
<td>.190</td>
<td>.627</td>
<td>.303</td>
<td>.763</td>
<td>-1.064</td>
<td>1.444</td>
</tr>
<tr>
<td>6.642</td>
<td>.100</td>
<td>.390</td>
<td>.258</td>
<td>.798</td>
<td>-.679</td>
<td>.879</td>
</tr>
<tr>
<td>7.824</td>
<td>.011</td>
<td>.604</td>
<td>.018</td>
<td>.986</td>
<td>-1.197</td>
<td>1.218</td>
</tr>
</tbody>
</table>

*Note.* HF-HRV = natural log-transformed high frequency heart rate variability; HRV values at -1, +1 standard deviation levels.
Appendix B: Figures

Figure 1. Moderated Moderation Model (Model 3; Hayes, 2012)

Note. BDI scores were standardized. HF-HRV = natural log-transformed high frequency heart rate variability.
Figure 2. Basic Moderation Model (Model 1; Hayes, 2012)

Moderator: HF-HRV

Independent variable: Depression Symptoms

Dependent variable: Number of Specific Memories

Note. BDI scores were standardized. HF-HRV = natural log-transformed high frequency heart rate variability.
Figure 3. Regression analysis in increased load condition

Note. BDI X HF-HRV interaction predicting Number of Specific Memories as provided on the AMT in the high-load condition. Decrease in number of specific memories indicates reduced AMS. Legend: Blue- lower HRV; Green- higher HRV.
Figure 4. Regression analysis in low-load condition

Note. BDI X HF-HRV interaction predicting Number of Specific Memories as provided on the AMT in the low-load condition. Decrease in number of specific memories indicates reduced AMS. Legend: Blue- lower HRV; Green- higher HRV.