

University of California, Merced

Methods to Evaluate How Stress Affects Mental Abstraction

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor  
of Philosophy

in

Psychological Sciences

by

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This dissertation is dedicated to my wife, Karina. Thank you for putting your dreams on hold so that I could chase mine. I hope to do the same for you.

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iii

## Table of Contents

Signature page . . . . .	iii
List of Tables . . . . .	iv
List of Figures . . . . .	v
Acknowledgements . . . . .	viii
Curriculum Vitae . . . . .	ix
General Abstract . . . . .	xv
Chapter 1	
General Introduction . . . . .	1
Chapter 2	
Study I: <i>Development of a Control Group for the TSST that does not Affect Cardiovascular Reactivity</i> . . . . .	3
Abstract . . . . .	3
Introduction . . . . .	4
Methods . . . . .	4
Participants . . . . .	4
Procedure . . . . .	5
Material . . . . .	5
Statistical Analysis . . . . .	6
Results . . . . .	7
Discussion . . . . .	7
Chapter 3	
Study II: <i>Stress and How We See the World: Stress Affects Level of Mental Abstraction Through Changes in Mood</i> . . . . .	9
Abstract . . . . .	9
Introduction . . . . .	10
Pilot Study . . . . .	11
Methods . . . . .	12
Results . . . . .	12
Discussion . . . . .	13
Primary Study . . . . .	13
Methods . . . . .	13
Subjects . . . . .	13
Primary Measures . . . . .	14
Control Variables . . . . .	14
Procedure . . . . .	15
Manipulation . . . . .	15
Statistical Analysis . . . . .	17
Results . . . . .	18
Discussion . . . . .	18
Conclusion . . . . .	21
Chapter 4	
Study III <i>Latent Growth Curve Models for Biomarkers of the Stress Response</i> . . . . .	22
Preface . . . . .	22

Abstract .....	23
Introduction .....	24
Purpose of Manuscript .....	24
Traditional Methods .....	42
Latent Variable Models .....	25
Specific Goals and Intended Audience .....	26
Hypothetical Example .....	26
Basic Details Surrounding Latent Growth Curve Models .....	26
Sample Size Limitations .....	27
Unique Benefits to Biomarker Research .....	28
Path Diagrams .....	29
Types of Important and Under-studied Research Questions .....	29
The Basic LGCM .....	30
Multi-Group (Observed or Unobserved) Growth Model .....	32
Piecewise LGCM .....	34
LGCM for Two Parallel Processes .....	35
Model fit and Assessment .....	36
Statistical Programs to Estimate LGCMS .....	38
Discussion .....	39
Conclusion .....	40
Chapter 5 – General Discussion .....	41
References .....	45
Appendix A: Chapter 2 Supplementary Analyses .....	76
Appendix B: Correlation Table for physiological and subjective stress measures .....	77
Appendix C: Study Protocols	
Study Protocol for Chapter 3 Pilot Study .....	79
TSST and c-TSST Protocol for Chapter 2 and Chapter 3 Stress Study ..	93
Appendix D	
Analysis Code: Chapter 3 .....	112
Analysis Code: Chapter 4 .....	113
Appendix E	
Study Materials .....	133

## List of Tables

<b>Study I</b>	
Table 1a: Participant Characteristics . . . . .	55
<b>Study II</b>	
Table 1b: Full responder participant characteristics . . . . .	56
Table 2b: Parameter estimates for Path models . . . . .	57
<b>Study III</b>	
Table 1c: Types of questions each specification of the LGCM can address . . . .	58
Table 2c: Table of Software Capable of Estimating LVMs . . . . .	59



## List of Figures

### Study I

- Figure 1a: Average change over time of Systolic Blood Pressure. . . . . 58  
Figure 2a: Average change over time of Diastolic Blood Pressure . . . . . 59  
Figure 3a: Average change over time of Heart Rate . . . . . 60

### Study II

- Figure 1b: Average change over time of Systolic Blood Pressure . . . . . 61  
Figure 2b: Average change over time of Diastolic Blood Pressure . . . . . 62  
Figure 3b: Average change over time of Heart Rate . . . . . 63  
Figure 4b: Average change over time of Negative Affect . . . . . 64  
Figure 5b : Path model . . . . . 65

### Study III

- Figure 1c: Evolution of Statistical Methods . . . . . 68  
Figure 2c: Example trajectory plot for a latent growth curve model (LGCM) . . 69  
Figure 3c: Latent growth curve model with linear slope . . . . . 70  
Figure 4c: Latent Growth Curve Model with Linear and Quadratic Slopes . . . . 71  
Figure 5c: Latent Growth Mixture Model . . . . . 72  
Figure 6c: Trajectories for multiple groups (observed or unobserved) . . . . . 73  
Figure 7c: Piecewise Latent Growth Curve Model . . . . . 74  
Figure 8c: Latent Growth Curve Modeling for Two Parallel Processes . . . . . 75  
Figure 9c: Trajectories for cortisol and alpha-amylase during the TSST . . . . . 76

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## General Abstract

Mental abstraction is a process of information reduction. Higher levels of mental abstraction are associated with a broadened-perspective, whereas lower levels of mental abstraction are associated with a narrowed-perspective. Recent work has linked mood to levels of mental abstraction, providing a potential link to stress (which is characterized as a negative mood state). However, there have not been any studies investigating a potential link between stress and mental abstraction. Therefore, the aim of this dissertation was to explore the potential link between stress and mental abstraction. Three research questions were addressed in this dissertation: 1) Does stress affect average levels of mental abstraction? 2) Can the relationship between stress and mental abstraction be explained by negative mood? and 3) Can the relationship between stress and mental abstraction be explained by cardiovascular reactivity to stress? To address these research questions, an experimental design was developed. Participants were randomly assigned to either a stress or no-stress condition. Exposure to the laboratory stressor led to higher levels of mental abstraction, suggesting that stress may lead to a preference for more abstract stimuli. Each chapter of this dissertation is a standalone study detailing different components of this dissertation. Therefore, some of the descriptions about the methodology may seem to repeat. Chapter 2 explains the development of the control procedure. Chapter 3 focuses on the primary purpose of the dissertation, which is to examine the relationship between stress and mental abstraction. Chapter 4 then recommends future methodological directions for evaluating the stress response and how it relates to outcomes variables.

## Chapter 1 Introduction

Stress is a ubiquitous process that most of us experience to some degree every day. It is a dynamic process that can best be characterized as a negative emotional state accompanied by predictable physiological, biochemical, and behavioral changes (Allen, Kennedy, & Cryan, 2014; Lazarus, Folkman, & Gruen, 1985). Acute stress (i.e., short term stress) is associated with changes in several behavioral and psychological processes. Acute stress leads to negative mood (DeLongis et al., 1988), increased impulsivity (Maier & Hare, 2017; Maier, Makwana, & Hare, 2015), and issues with decision-making in risky situations (Preston, Buchanan, Stansfield, & Bechara, 2007; Starcke & Brand, 2012; Starcke, Wolf, Markowitsch, & Brand, 2008). While several mechanisms have been proposed explaining how acute stress leads to psychological and behavioral outcomes, few studies have investigated how stress affects meta-cognition

Mental abstraction is a type of meta-cognitive process involved in information processing. Mental abstraction has been defined as “the process of identifying a set of invariant central characteristics of a thing” (Burgoon, Henderson, & Markman, 2013). It is a process of information reduction that allows for efficient storage or central knowledge. In other words, more abstract processing is associated with broader characterizations that generalize across groups. Likewise, less abstract processing (i.e., more concrete processing) is associated with a more specific characterization that does not necessarily generalize across groups. There are several factors that contribute to the level of mental abstraction used to process information, but mood has been identified as the most important factor (Bless & Burger, 2017). Specifically, positive mood leads to higher levels of mental abstraction, whereas negative mood leads to lower levels of mental abstraction. Because stress is typically characterized as a negative mood state, it is plausible that stress would affect mental abstraction. Additionally, there is considerable overlap among the consequences of stress and mental abstraction. Mental abstraction and stress both affect self-control (Fujita & Roberts, 2010; Maier & Hare, 2017), as well as judgment and decision making (Burger & Bless, 2016; Kowalski-Trakofler, Vaught, & Scharf, 2003; Reyna, 2004). Given the considerable overlap of outcomes and the potential link with mood, stress is likely to affect levels of mental abstraction.

In order to investigate the impact stress has on mental abstraction, an experimental study can be developed. This experiment should include a reliable way to measure mental abstraction and to induce stress. There have been several instruments developed to study mental abstraction, but the Behavioral Identification Form (BIF) is the most commonly implemented (Burgoon et al., 2013). The BIF contains 23 statements accompanied by two descriptors. Participants choose the descriptor they feel best reflects the statement. For each statement, one descriptor is a more abstract choice while the other descriptor is a less abstract (i.e., more concrete choice). The questionnaire is scored by summing the total number of abstract choices selected. The BIF has been used to validate other measures of mental abstraction (Fujita & Roberts, 2010; Lammers, 2012; Malkoc, Zauberaman, & Bettman, 2010) and is sensitive to changes in mood (Watkins, Moberly, & Moulds, 2011). Therefore, the BIF is an adequate measure when investigating the impact of stress on mental abstraction.

To induce stress in the laboratory, the most commonly used paradigm is the Trier social stress test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993; B. M. Kudielka, Hellhammer, & Kirschbaum, 2007). In the TSST, participants are told that they must prepare a speech about their ideal job to a panel of experts in nonverbal communication. Participants are given five minutes to prepare before performing the speech to the committee. The TSST reliably induces physiological measures of stress such as cortisol, salivary alpha-amylase, heart rate, and blood pressure (Hellhammer & Schubert, 2012; Skoluda et al., 2015). To better understand the effects of stress on mental abstraction, a control group to the TSST should be used to rule out confounds and address the counterfactual (Shadish, Cook, & Campbell, 2002). There have been two versions of the TSST developed to serve as control groups in other studies; the placebo TSST (p-TSST; Het, Rohleder, Schoofs, Kirschbaum, & Wolf, 2009). In the p-TSST, participants perform a speech about their ideal job alone in a room. In the f-TSST, participants prepare for their speech with the committee in the room to provide feedback. During their speech, the committee provides positive feedback. Neither the p-TSST nor the f-TSST resulted in increases in cortisol. However, both resulted in increases in salivary-alpha amylase, a marker of sympathetic nervous system activation (Stegeren, Rohleder, van Stegeren, & Rohleder, 2006). Because of the elevations of salivary alpha-amylase during the p-TSST and the f-TSST, they are not the best choice as control groups when the research question is about stress in general.

Therefore, there are two primary aims to this dissertation. The first aim is to develop a version of the TSST that can serve as a control group when the interest is in stress in general. Specifically, this novel version of the TSST, called the control TSST (c-TSST), should not have activation of the sympathetic nervous system. In this study, activation of the sympathetic nervous system is operationalized as increases in heart rate and blood pressure. The development of the c-TSST is described in Chapter 2. The second aim of the dissertation is to investigate whether stress affects levels of mental abstraction. To do this, an experimental study was developed where participants were randomly assigned to the TSST and the c-TSST. After exposure to either condition, participants completed measures of mental abstraction. This study also explored potential explanatory pathways linking exposure to stress with changes in mental abstraction (see Chapter 3). The final study (Chapter 4) provides future methodological directions for the field through a tutorial on latent variable models in stress research. These models are seldom used in this research context, but they are important tools for addressing questions traditional methods cannot answer.

## Chapter 2

### Study I

#### Development of a Control Group for the TSST that does not Affect Cardiovascular Reactivity

##### Abstract

The Trier social stress test (TSST) is a well-established laboratory psychosocial stressor that leads to robust increases in physiological and psychological markers of stress. There are two existing versions of the TSST that can serve as control groups: the friendly-TSST (f-TSST) and the placebo-TSST (p-TSST). While cortisol does not increase due to exposure to the f-TSST or the p-TSST, markers of sympathetic nervous system increase. When interested in the effects of sympathetic nervous system reactivity due to stress, these control groups are not appropriate. Therefore, the purpose of this study was to develop a new version of the TSST that did not lead to increases in markers of sympathetic nervous system as measured by blood pressure and heart rate. One-hundred and sixty-two undergraduate students were randomly assigned to the speech portion of the TSST or the control-TSST (c-TSST). The c-TSST resembles the speech portion of the TSST except that participants write about their ideal job in front of a standing desk with no committee present. The TSST lead to statistically significant increases in systolic blood pressure, diastolic blood pressure, and heart rate, while the c-TSST did not. The c-TSST is useful as a standardized control condition for stress studies in conjunction with other, well established control conditions (i.e., f-TSST and p-TSST). The c-TSST has the potential to further isolate physiological processes and their relationships to distal outcome measures. Future studies should validate the c-TSST with neuroendocrine markers of the stress response (i.e., salivary cortisol and alpha-amylase).

Keywords: Stress, TSST, Control group, Cardiovascular reactivity, Acute stress, Blood pressure, heart rate

## Development of a Control Group for the Speech Portion of the TSST that does not Affect Cardiovascular Reactivity

### Introduction

Researchers interested in understanding how acute stress affects psychological and behavioral processes will often use the Trier social stress test (TSST). The TSST is a commonly used laboratory method to induce acute psychosocial stress that involves a public speech about an ideal job and a verbal arithmetic test (Kudielka, Hellhammer, & Kirschbaum, 2007). When researchers are interested in isolating the specific stress mechanism that is linked to psychological and behavioral processes, participants can be randomly assigned to the TSST or some non-stressful control group. The development of an appropriate control group is crucial to ruling out the counterfactual and isolating the impact of specific processes of interest (Shadish et al., 2002). An appropriate control group must resemble the experimental condition as closely as possible. Presently, there are two versions of the TSST that can serve as control groups, however, there are some limitations to consider for each of them.

The placebo-TSST (p-TSST) and the friendly TSST (f-TSST) are commonly used as control groups for the TSST that were developed to facilitate the isolation of cortisol and its effects on psychological and behavioral processes. In the p-TSST, participants present a speech about their ideal job and perform mental arithmetic in an empty room with no stress committee present (Het et al., 2009). In the f-TSST, the participant discusses their career aspirations and hobbies with the committee before giving their final speech about their ideal job while committee members observe and provide positive feedback (Wiemers, Schoofs, & Wolf, 2012). While salivary cortisol does not increase during the p-TSST or the f-TSST, salivary alpha-amylase does increase, indicating activation of the sympathetic nervous system. If researchers are interested in isolating the impact of other physiological processes involved in acute stress, the p-TSST and the f-TSST may not be acceptable to use as control conditions for the TSST.

Therefore, the purpose of this study was to develop a novel nonstressful version of the TSST that can serve as a control condition for the TSST. The control-TSST (c-TSST) was developed after a modified version of TSST that included only the speech portion. This decision was made because math anxiety is common and can be a source of stress (Baloglu & Kocak, 2006). Recent findings have also demonstrated that the mere anticipation of the speech portion is enough to elicit a stress response, suggesting that the math portion may not always be (Preston et al., 2007; Starcke et al., 2008). The social component was also not included in the c-TSST because social evaluation, whether positive or negative, can still affect physiological markers of stress (Taylor et al., 2010; Wiemers et al., 2012). We hypothesized that the c-TSST would not elicit a sympathetic nervous system response as measured through cardiovascular reactivity.

### Methods

#### Participants

One-hundred and sixty-four undergraduate students (76% female; 53 % Hispanic/Latino, 22% Asian/Pacific Islander, 10% White/Caucasian, 4% Black/African American) over the age of 18 ( $M_{age} = 20.07$  years,  $SD_{age} = 1.37$  years) participated in this study. Participants were recruited from the university subject pool and were awarded course credit for their participation. Participants were asked to refrain from consuming

caffeinated beverages or food and from engaging in strenuous exercise at least 30 minutes before the beginning of the study. The study was approved by the University IRB and informed consent was collected from all participants. Three participants dropped out of the TSST group because they were too distressed. The final sample consisted of 164 participants, 94 in the TSST group and 67 in the control-TSST group. See Table 1a for full participant characteristics.

### **Procedure**

After arrival, participants signed informed consent and entered the experiment room. After height and weight were measured, participants completed the pre-study questionnaires. Physiological measures were then collected via pressure cuff (Time 1—T1). Next, the acclimation period began, requiring participants to sit and relax for 15 minutes. Participants were provided with an assortment of magazines and told they could read any of them during this time. At the end of the acclimation period, physiological measures were collected (T2). Participants were then randomly assigned to the speech portion of the TSST or to the control group. After participants were informed of the task for their condition, physiological measures were collected for anticipatory stress (T3). Upon completion of this task, physiological measures were collected (T4). Physiological measures were then collected again to evaluate recovery from the stressor (T5). Finally, participants completed a demographics questionnaire and were debriefed of the study purpose by the experiment leader.

### **Material**

**Physiological measures.** Heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured using the Omron 10-series Upper arm monitor (Model BP758N). The pressure cuff was placed around the upper arm of the non-dominant arm. HR and BP were measured at all five time points.

**Control variables.** Perceived stress reactivity was evaluated using the *Perceived Stress Reactivity Scale* (PSRS; Schlotz, Yim, Zoccola, Jansen, & Schulz, 2011). The PSRS is a 23-item questionnaire evaluating how reactive people believe they are to stressful situations. For each item, participants select from one of three options that best reflects how they believe they would respond to a stressful situation. Along with the total scores, the PSRS consists of the following subscales: Prolonged Reactivity, Reactivity to Work Overload, Reactivity to Social Conflicts, Reactivity to Failure, and Reactivity to Social Evaluation. For the purpose of this study, the total score was used and exhibited adequate internal consistency in this sample ( $\alpha = .83$ ). Higher scores reflect greater perceived stress reactivity.

Depression was measured with the *Beck Depression Inventory* (BDI; Beck, Ward, & Mendelson, 1961). The BDI consists of 21 items, each with four responses, that are summed for a total depression score. In this sample, the BDI total score exhibited adequate internal consistency ( $\alpha = .86$ ). Higher scores reflect higher levels of depression.

Height and weight were measured to calculate body mass index (BMI).

**Demographics.** Self-reported gender, date of birth, ethnicity, mental health history, substance use history, medication use history, and physical activity level were collected.

**Speech Portion of TSST.** Standard protocol for the speech portion of the TSST was used (see Kirschbaum, Pirke, & Hellhammer, 1993; B. M. Kudielka, Hellhammer, &

Kirschbaum, 2007). The research leader instructed the participants to imagine that they had applied to their ideal job and were asked for an interview. Participants were then told they would have to prepare a speech about their ideal job and present it to a committee of experts in nonverbal communication. The committee consisted of three undergraduate research assistants wearing white laboratory coats; the participant did not know the committee members. Each committee consisted of at least one male and one female. Participants were told that they would be audio and visually recorded to perform voice analysis later. Participants were then given a pen and paper and told they had five minutes to prepare for their speech. They were also told that they could not use their notes during the speech. At the end of the five minutes, the stress committee entered the room, seized any notes, and turned on the video camera and tape recorder. During the speech, the stress committee would provide negative feedback nonverbally, except the committee member designated as the President. If the participant was doing exceptionally well or had been silent for at least 30 seconds, the President would interject with a discouraging comment (e.g., why are you even the best candidate for this position?). At the end of the five minutes, the President interrupted the participant, telling them this portion was done. The research leader then reentered the room and measured HR and BP while the committee stayed in the room and watched the participant. After the stress measurements, the committee left the room, concluding the TSST.

**Control-TSST.** The research leader instructed participants to imagine that they had applied to their ideal job and were asked for a letter of application. Participants were instructed to not worry about spelling or grammar, and to not worry about whether they would have enough time to complete a full letter. To reduce any potential stress that this may cause, participants were also informed that nobody would read their letters, but that their letters may be skimmed after the study to ensure that they wrote about their ideal job. Participants were given a pen and paper and given five minutes to prepare. During this time, participants were instructed to create an outline or anything they thought would help them write their final letter. They were also told that they could use any preparation materials that they made during this time for their final paper. After the preparation period, the research leader instructed the participant to stand behind a standing desk. Participants were then given five minutes to write. At the end of the five minutes, participants were instructed to place their writings into an envelope and seal it. The research leader then collected all writing materials, concluding the c-TSST.

### **Statistical Analyses**

All data were analyzed using SPSS v. 24 (SPSS, 2016). All dependent variables were examined for violations of normality. Greenhouse-Geisser corrections were used for violations of sphericity. Physiological data (HR, SBP, and DBP) were evaluated with a 5 X 2 mixed analysis of variance (ANOVA) with time of measurement as the within-subject factor (T1-T5) and group as the between-subjects factor (TSST vs control-TSST). BMI, BDI, and perceived stress reactivity were controlled for in each analysis. Alpha levels were set at .05 for all analyses. Post-hoc Welch's *t*-tests to compare simple effects were Bonferroni corrected to an alpha level of .005. Welch's *t*-tests were used to handle violations of homogeneity of variance and are the recommended default when using an independent samples *t*-test (Delacre, Lakens, & Leys, 2017).

## Results

### SBP

SBP levels increased in the TSST group and not the c-TSST group. This was reflected in a significant Time X Group interaction effect,  $F(3.288, 512.997) = 39.425$ ,  $p < .001$ , as well as a significant main effect of Group,  $F(1, 156) = 20.733$ ,  $p < .001$ . However, the main effect of Time was not statistically significant,  $F(3.288, 512.997) = 0.927$ ,  $p = .434$ . Post-hoc Welch's  $t$ -tests were estimated to compare differences in average SBP levels between groups at each time point. There were no significant differences in average SBP between groups at T1 ( $p = .433$ ) and T2 ( $p = .176$ ), but there were significant difference at T3 (anticipatory stress;  $p < .001$ ), T4 (post stress;  $p < .001$ ), and T5 (recovery;  $p < .001$ ). See Figure 1a for a graphical depiction of the interaction effect.

### DBP

DBP levels increased in the TSST group and not the c-TSST group. This was reflected in a significant Time X Group interaction effect,  $F(3.713, 579.150) = 57.298$ ,  $p < .001$ , as well as a significant main effect of Time,  $F(3.713, 579.150) = 3.156$ ,  $p = .016$  and main effect of Group,  $F(1, 156) = 22.626$ ,  $p < .001$ . Post-hoc  $t$ -tests were estimated to compare differences in average DBP between groups at each time point. There were no significant differences in average DBP between groups at T1 ( $p = .939$ ) and T2 ( $p = .917$ ), but significant differences existed at T3 (anticipatory stress;  $p < .001$ ), T4 (stress;  $p < .001$ ), and T5 (recovery;  $p < .001$ ). See Figure 2a for graphical depiction of the interaction effect.

### HR

HR levels increased in the TSST group and decreased in the c-TSST group. This was reflected in a significant Time X Group interaction effect,  $F(2.434, 379.728) = 14.861$ ,  $p < .001$ . Neither main effect of Time ( $F(2.434, 379.728) = .796$ ,  $p = .474$ ) nor the main effect of Group ( $F(1, 156) = .667$ ,  $p = .415$ ) were statistically significant. Post-hoc Welch's  $t$ -tests were estimated to compare differences in average DBP between groups at each time point. There were no significant differences in average HR between groups at T1 ( $p = .111$ ), T2 ( $p = .368$ ), T3 (anticipatory stress;  $p = .018$ ), or T5 (stress;  $p = .003$ ), but there were significant differences at T4 (stress;  $p = .003$ ). See Figure 3a for a graphical depiction of the interaction effect.

## Discussion

The purpose of this study was to develop a control condition for the speech portion of the TSST that did not elicit a cardiovascular response. In the c-TSST, participants wrote about their ideal job at a standing desk. Similar to the p-TSST, participants were alone in the experiment room (Het et al., 2009). The social evaluative component was excluded because it is known to elicit sympathetic nervous system reaction even when positive (Cohen & Cohen, 1994; S. Dickerson, Mycek, & Zaldivar, 2008; Wiemers et al., 2012). Similar to the f-TSST, the mathematics component was also excluded (Wiemers et al., 2012). Mathematics is a common source of anxiety and stress for many people (Baloglu & Kocak, 2006; Lai, Zhu, Chen, & Li, 2015). We report a new version of the TSST that does not elicit a cardiovascular response to stress, making it a qualified control group for the TSST. This contrasts with the f-TSST and the p-TSST, which do not elicit a cortisol response but do result in increases in markers of the



sympathetic nervous system (i.e., salivary alpha-amylase). Researchers interested in the effects of stress in general, or who want to isolate the effects of cardiovascular processes in the stress response, can make use of the c-TSST. There are some limitations to consider when interpreting these results. First, our sample was constructed of college students which limits generalizability. However, we used a diverse sample covering several race and ethnicities. While we used a diverse sample, we did not sample enough males to evaluate gender differences. Another limitation is that the c-TSST did not have a social component as with the original TSST. However, previous studies suggest that social evaluation, whether positive or negative, elicits activation of physiological stress processes (Taylor et al., 2010; Wiemers et al., 2012). Therefore, to reduce the stressful of the c-TSST, the social component needed to be removed.

Future studies should validate the c-TSST for neuroendocrine reactivity. Given that there is no cardiovascular response and no social evaluative component, it is unlikely that there will be any elevations in cortisol or salivary alpha-amylase in response to the c-TSST. Larger sample sizes should also be collected to investigate gender and racial/ethnic differences in how participants respond to the c-TSST. Future studies should also compare the performance of the c-TSST to other established control groups such as the f-TSST and the p-TSST. In conjunction with these other control groups, researchers can gain insight into how each physiological aspect of the stress response affect psychological and behavioral processes.

In sum, the c-TSST is a newly developed control group for the TSST that does not elicit a cardiovascular response. The purpose of this study was to provide researchers with another tool for disentangling the effects of stress on psychological and behavioral processes. Ultimately, the decision of the appropriate control group depends on the research questions. While the p-TSST (Het et al., 2009) and the f-TSST (Wiemers et al., 2012) are useful when the research question involves the impact of cortisol, the c-TSST is more appropriate when the research question involves the impact of cardiovascular reactivity. Additionally, the c-TSST could be used to better understand the impact of different elements of the TSST. Ideally, studies will make use of the c-TSST in conjunction with one of the other versions of the TSST to fully understand the impact of each physiological process in the stress response.

## Chapter 3

### Study II

#### Stress and How We See the World: Stress Affects Level of Mental Abstraction Through Changes in Mood

##### Abstract

**Objective:** Exposure to an acute stressor reliably leads to increases in negative affect. Increases in negative affect reliably leads to decreases in levels of mental abstraction. However, there have been no studies investigating a link between stress and mental abstraction. Using an experimental design, this study investigated how exposure to an acute psychosocial stressor affected levels of mental abstraction.

**Methods:** Undergraduate research students were randomly assigned to the Trier social stress test (TSST;  $n = 62$ ) or the control TSST (c-TSST;  $n = 68$ ). Stress reactivity was evaluated using measures of blood pressure, heart rate, and negative affect. Participants completed the Behavioral Identification Form as a measure of mental abstraction upon completion of the TSST or c-TSST. Differences in average levels of mental abstraction between groups were evaluated using Welch's t-test. Path analyses were estimated to explore explanatory pathways between exposure to a psychosocial stressor and mental abstraction.

**Results:** Average levels of mental abstraction were higher in the TSST than in the c-TSST groups ( $p = .003$ ). Path analyses revealed that the relationship between stress and mental abstraction was explained by average levels of negative affect after the stressor ( $\beta_{\text{indirect}} = .129, p = .043$ ). Furthermore, the relationship between stress and mental abstraction was no longer statistically significant after negative affect was included in the model ( $\beta = .153, p = .109$ ). Neither blood pressure nor heart rate explained the relationship between stress and mental abstraction ( $\beta_{\text{indirect}} < .221, ps > .08$ ).

**Discussion:** Exposure to a psychosocial stressor lead to increases in mental abstraction. This relationship was largely explained by negative affect after the stressor and not by measures of cardiovascular reactivity. Limitations and future research directions are discussed.

**Keywords:** Stress, mental abstraction, affect, mood, TSST, perception

## Stress and How We See the World: Stress Affects Level of Mental Abstraction Through Changes in Negative Affect

### Introduction

The stress response is associated with changes in several psychological and behavioral processes. For instance, the stress response leads to changes in mood (DeLongis et al., 1988; Het & Wolf, 2007; Kudielka & Schommer, 2004; McRae et al., 2006; Simon et al., 2006), alterations in judgment and decision-making (Preston et al., 2007; Starcke & Brand, 2012; Starcke et al., 2008), and issues with impulsivity and self-control (Maier & Hare, 2017; Maier et al., 2015). Identification of the mechanisms linking stress to psychological, physiological, and behavioral outcomes is of increasing importance. Mood has been identified as an important factor explaining stress' effects on many outcomes (Lerner, Li, Valdesolo, & Kassam, 2015; Scult, Knodt, Swartz, Brigidi, & Haririr, 2017; Van Eck, Berkhof, Nicolson, & Subn, 1996). While negative mood is a key factor linking stress to many outcomes, little is known about how this process occurs.

The Broaden-and-Build theory helps explain how emotions can affect behavior (Fredrickson, 2001). Broaden-and-build states that positive emotions can broaden perspectives and encourage novel and exploratory thoughts and behaviors. Likewise, negative emotions prompt immediate survival-oriented behaviors. Under broaden-and-build theory, positive emotions lead to greater resiliency to stress and trauma (Cohn, Fredrickson, Brown, Mikels, & Conway, 2009; Tugade, Michele, Fredrickson, Barbara, & Feldman Barrett, 2004), while negative emotions lead to issues with decision making (Lerner et al., 2015) and judgments (Chang, 2017). Further support for broaden-and-build theory is found on research in mental abstraction and mood.

Mental abstraction is a style of information processing defined as “the process of identifying a set of invariant central characteristics of a thing” (Burgoon et al., 2013). In other words, increases in mental abstraction lead to a broadened perspective. Increases in mental abstraction lead people to rely more on prior knowledge of a stimulus, whereas decreases in mental abstraction (i.e., more concrete processing) leads people to rely on characteristics specific to the stimuli (Burgoon et al., 2013). In line with broaden-and-build theory, mood affects mental abstraction. Bless and Burger (2017) identified mood as the most crucial factor influencing levels of mental abstraction. Specifically, positive moods are associated with higher levels of mental abstraction, whereas negative moods are associated with lower levels of mental abstraction. While broaden-and-build theory and mental abstraction provide a framework for how negative mood is related to a more broadened, abstract and automatic processing, little is known about how these theories work in the context of stress.

Stress is characterized as a negative mood state that is associated with predictable changes in physiological and biochemical processes (Dougall & Baum, 2012; R. Lazarus & Folkman S., 1984). According to broaden-and-build theory and mental abstraction, experiencing stress should lead to more concrete processing (i.e., lower levels of mental abstraction). Acute stress has been associated with impairments in executive functioning, including information processing, although not in the way broaden-and-build theory would predict. A recent meta-analysis of all the literature on stress and executive functioning found that acute stress leads to impaired working memory and a reliance on more automatic processing of information (Shields, Sazma, & Yonelinas, 2016). This

automatic processing then facilitates engagement with, or escape from, the stressor. However, abstract information may be easier to process than less abstract information. Mental abstraction is the process of reducing the amount of information from the environment into broader categories or more manageable pieces that encompass many features or behaviors. (Burgoon et al., 2013; Gray & Tall, 2007). Because abstract information is essentially compressed information, it may facilitate automatic processing. Exposure to a stressor may then lead to a preference to process more abstract information (i.e., broader categories). While broaden-and-build theory suggest that increases in negative mood will decrease levels of mental abstraction, research on exposure to stress (a negative mood state) leads to processes that can be characterized as more abstract. Therefore, the purpose of this study was to investigate how stress effects the way people process information or experience the world. To explore the juxtaposition of findings in mental abstraction, broaden-and-build theory, and stress research, the relationships between stress, negative affect, and mental abstraction were explored.

Mental abstraction has been studied in a variety of ways (see Burgoon et al., 2013). One of the most commonly used instruments to study mental abstraction is the Behavioral Identification Form (BIF). The BIF was originally developed to evaluate individual differences in how people think about behaviors (Vallacher & Wegner, 1989), but has since been used to evaluate changes in mental abstraction (Burgoon et al., 2013). The BIF measures mental abstraction by having participants choose between two options (a more abstract and a more concrete) that they believe best explains the behavior. Along with being commonly used to validate manipulations of mental abstraction (see, for e.g., Fujita & Roberts, 2010; Lammers, 2012; Malkoc, Zauberger, & Bettman, 2010), the BIF is sensitive to changes in mood (Watkins et al., 2011). Because the BIF has been validated to measure mental abstraction and is sensitive to changes in mood, it is a viable candidate to investigate how stress affects mental abstraction.

### **Purpose of Study**

Research on executive functioning suggests that acute stress causes more automatic processing. Additionally, research on affect suggests that negative mood leads to lower levels of mental abstraction, which is associated with more deliberate processing. To our knowledge, there have been no studies directly linking acute stress to changes in mental abstraction. Therefore, the purpose of this study is to determine how stress affects the way we process information through changes in mental abstraction. In order to isolate the effects of acute stress on mental abstraction, a laboratory experiment was designed using a modified version of the Trier social stress test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993b) and an equivalent, non-stressful control group. Before the control group can be used to isolate the effects of stress on mental abstraction, a pilot study was conducted to ensure the control group did not affect mental abstraction. The pilot study first explores the effects a control group for the TSST has on mental abstraction. The second study addresses our primary aim, which is to thoroughly investigate the nature of the relationship between acute stress and mental abstraction.

### **Pilot Study**

The purpose of the pilot study was to determine whether the control group developed for the primary study was appropriate to investigate differences in mental abstraction. An equivalent control group should closely approximate the experimental

condition in as many aspects as possible, varying only the mechanism of interests (Shadish et al., 2002). We developed a nonstressful version of the TSST to serve as a control group for the TSST (see Chapter 2). In the control TSST (c-TSST), participants wrote about their ideal job at a standing desk (rather than give a speech in front of a committee). However, thinking about an ideal job can be viewed as a distal goal and may affect levels of mental abstraction (Bruehlman-Senecal, Ayduk, & John, 2016; Nussbaum, Liberman, & Trope, 2006; Trope & Liberman, 2003, 2010). To evaluate the effects of writing about an ideal job (a potentially distal goal) on mental abstraction, half of the participants were randomly assigned to write about their favorite hobby (a temporally invariant task). This group also served to evaluate the counterfactual of writing in general on levels of mental abstraction.

### Methods

**Subjects.** A diverse sample of undergraduate students were recruited from the university subject pool ( $N = 48$ ; 63% female, 52%; Hispanic/Latino, 23% Asian/Pacific Islander, 8% White/Caucasian, 8% African-American/Black; 65% freshman or sophomore, 77% first-generation college student;  $M_{BMI} = 26.46$ ,  $SD_{BMI} = 4.52$ ). Participants were randomly assigned to write about their ideal job ( $n = 25$ ) or their favorite hobby ( $n = 23$ ).

**Primary measures.** The level of mental abstraction was measured through the Behavioral Identification Form (BIF; Vallacher & Wegner, 1989). The BIF contains 25 statements of behaviors that require participants to choose between two explanations of each behavior. One of the explanations reflects more global/abstract processing, while the other explanation reflects more specific/concrete processing. The BIF is scored by counting the total number of statements described using the more abstract explanation, with higher scores reflecting higher levels of mental abstraction. For the pilot study, the BIF was randomly divided into two, 12-item short forms. Participants completed one form of the shortened BIF before the stressor, and the other after the stressor. The order that the forms were presented were randomized for each participant.

**Manipulation.** Participants first completed one of the short forms of the BIF. Next, participants were randomly assigned to write about either their ideal job or their favorite hobby. In both conditions, participants were asked to write as if they were trying to convince somebody that they were the ideal candidate for the position (job condition) or inform somebody why their hobby was the ideal hobby (hobby condition). Participants were given five minutes to prepare (i.e., make an outline or word map) before they were asked to stand behind a standing desk and write about their ideal job (or favorite hobby) for five more minutes. Upon completion of the writing task, participants then completed the next short form of the BIF. Participants then completed a brief demographics questionnaire and were debriefed of the purpose of the study.

**Statistical Methods.** A 2 X 2 repeated measures analysis of variance (ANOVA) with Condition (job vs hobby) as a between groups factor and Time (1 vs 2) as the within groups factor was estimated to evaluate the effect of groups and writing on mental abstraction. Analyses were estimated in SPSS v. 24 (SPSS, 2016) and alpha levels were set at .05.

### Results

The difference in average levels of mental abstraction between participants in the job condition ( $M = 6.35$ ,  $SD = 2.80$ ) and the hobby condition ( $M = 6.88$ ,  $SD = 2.28$ ) was not statistically significant,  $F(1, 46) = 0.888$ ,  $p = .352$ . The difference in average levels of mental abstraction at Time 1 ( $M = 6.27$ ,  $SD = 2.44$ ) and Time 2 ( $M = 7.06$ ,  $SD = 2.66$ ) was statistically significant,  $F(1, 46) = 5.633$ ,  $p = .022$ . The interaction between Condition and Time was not statistically significant,  $F(1, 46) = 1.439$ ,  $p = .237$ .

To further explore the nature of the time effect on mental abstraction, paired-samples  $t$ -tests were estimated within each group. The Time effect was largely driven by changes in average mental abstraction over time in the hobby group ( $t(22) = 2.252$ ,  $p = .035$ ) but not the job group ( $t(24) = .943$ ,  $p = .355$ ).

## Discussion

This pilot study demonstrated the appropriateness of the control group used to evaluate the impact of stress on mental abstraction. While writing in general altered levels of mental abstraction over time, this effect was largely driven by increases in mental abstraction from writing about a favorite hobby. This result could be because writing about a favorite hobby induces a positive mood, and positive moods are related to higher levels of mental abstraction (Bless & Burger, 2017). However, mood was not evaluated in this study. Regardless, writing about an ideal job did not statistically significantly affect levels of mental abstraction in this study and was therefore deemed appropriate as a control group for the primary study. Chapter 2 also detailed how writing about an ideal job did not affect physiological stress reactivity or mood. Therefore, writing about a dream job was deemed an appropriate control group to evaluate the effects of stress on levels of mental abstraction.

### Primary Study

The purpose of the Primary Study was to examine the nature of the relationship between acute stress and mental abstraction. The following three research questions were explored:

1. Does exposure to a psychosocial stressor affect the average level of mental abstraction?
2. Does negative affect after exposure to a psychosocial stressor explain the relationship between stress and average level of mental abstraction?
3. Does cardiovascular reactivity, as measured by blood pressure and heart rate, to a psychosocial stressor explain the relationship between stress and average level of mental abstraction?

## Methods

**Subjects.** A diverse sample of undergraduate students were recruited from the university SONA pool. Using G\*Power (t-test, power  $(1-\beta \text{ prob}) = 0.8$ ), with a medium effect size (Cohen's  $f = 0.25$ ), we would need a total of 128 participants. One-hundred and sixty-one participants were collected and randomly assigned to the stress group ( $n = 94$ ) or the control group ( $n = 68$ ). The stress group was oversampled to accommodate missing data due to nonresponders. Participants whose SBP, DBP, or HR did not increase after the TSST were deemed nonresponders and removed from analysis ( $n = 30$ ). Additionally, 2 more participants had to quit the study because the TSST was too distressful and were removed from the analysis. The final sample consisted of 130 participants (77% female, 53% Latino/Hispanic, 10% White/Caucasian, 4%

Black/African American, and 22% Asian/Pacific Islander). The final TSST group consisted of 62 participants while the control group consisted of 68 participants. For full participant characteristics, see Table 1b. All data were collected between January 2018 and May 2018. The study protocol was approved by the campus Internal Review Board.

### Primary Measures

**Stress Response.** Stress reactivity was evaluated through cardiovascular and self-report measures. Cardiovascular reactivity to the stressor was evaluated through heart rate (HR) and blood pressure (BP). HR and BP were collected through a blood pressure cuff (Omron BP742N 5 Series). BP consisted measurements of systolic blood pressure (SBP) and diastolic blood pressure (DBP). Perceived stress was measured with a visual analogue scale (VAS). The VAS was anchored with “Not at all stressed” at the left, and “Extremely stressed” at the right. Participants marked an “X” along the line to denote how stressed they felt. Perceived stress was calculated by measuring the distance (in centimeters) the “X” was from the left anchor. Measurements were collected at five occasions.

Changes in mood were evaluated through the Positive Affect and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS is a 20-item measure to evaluate positive and negative affective states. Each item reflects a different mood and is rated from 1 (*very slightly or not at all*) to 5 (*extremely*). The PANAS has high internal reliability ( $\alpha$ 's between 0.84 and 0.90), high test-retest reliability ( $r$ 's between 0.45 and 0.71), and factorial validity (factor loadings between 0.89 and 0.95). The PANAS was collected at two occasions (before and after the stressor). In this sample, the PANAS exhibited adequate internal consistency before ( $\alpha = .73$ ) and after the manipulation ( $\alpha = .91$ ).

**Mental Abstraction.** The level of mental abstraction was measured through the BIF Vallacher & Wegner, 1989). The BIF contains 25 statements of behaviors and require participants to choose between explanations of each behavior. One of the choices reflects more global/abstract processing, while the other choice reflects more specific/concrete processing. The BIF is scored by counting the number of statements described using the abstract choice, with higher scores reflecting higher levels of mental abstraction. In this study, the total score of the BIF exhibited adequate internal consistency ( $\alpha = 0.76$ ).

### Control Variables

**Dispositional Mental Abstraction.** Trait levels of mental abstraction were measured with the Temporal Distancing Questionnaire (TDQ; Bruehlman-Senecal & Ayduk, 2015; Bruehlman-Senecal, Ayduk, & John, 2016). The TDQ is an eight-item questionnaire evaluating a person's propensity towards perspective broadening, with higher levels of mental abstraction resulting in more perspective broadening. Items on the TDQ are rated on a 7-point Likert-type scale from 1 (*strongly agree*) to 7 (*strongly disagree*). Factor analytic models provided further evidence for a unidimensional scoring of the TDQ (Bruehlman-Senecal & Ayduk, 2015). In this study, the total score of the TDQ exhibited adequate internal consistency ( $\alpha = .73$ ).

**Perceived Stress Reactivity.** Perceived stress reactivity was evaluated with the Perceived Stress Reactivity Scale (PSRS; Schlotz, Hammerfald, Ehlert, & Gaab, 2011; Schlotz, Yim, Zoccola, Jansen, & Schulz, 2011). The PSRS is a 23-item questionnaire

evaluating how reactive participants believe they are towards stressful events. For each item, participants select one of three options they feel best answers the question with respect to how they perceive themselves. Along with a total score, the PSRS contains five subscales reflecting the following domains: *Prolonged Reactivity*, *Reactivity to Work Overload*, *Reactivity to Social Conflicts*, *Reactivity to Failure*, and *Reactivity to Social Evaluation*. Factor analytic models and invariance testing have established this scoring solution across German, United States, and United Kingdom samples (Schlotz et al, 2011). For this study, the total score was used and exhibited adequate internal consistency ( $\alpha = .82$ ).

**Depression.** Levels of depression were controlled for in path analyses because it has been related to stress reactivity (de Rooij, Schene, Phillips, & Roseboom, 2010; Felsten, 2004) Depression was evaluated using the Beck Depression Inventory (BDI; Beck, Ward, & Mendelson, 1961). The BDI is a 21-item questionnaire where participants choose a description from a selection of four that best represents them. The BDI is scored as a single total score with the following proposed cut-offs: 0-9 indicates minimal depression, 10-18 indicates mild depression, 19-29 indicates moderate depression, and 30-63 indicates severe depression. In this sample, the BDI exhibited adequate internal consistency ( $\alpha = .87$ ).

**Body Mass Index.** Height and weight were collected, and body mass index (BMI) was calculated.

#### **Demographic Variables**

Self-reported gender, age, race/ethnicity, medication and substance use, mental health history, and physical activity were collected.

#### **Procedure**

Prior to the beginning of the experiment, timeslots were randomly assigned to either the TSST or the control condition. Participants, unaware of condition, signed up for time slots via the University's SONA system. Upon arrival, informed consent was collected, and participants completed several questionnaires for control variables. After height, weight, and initial cardiovascular measures (i.e., HR and BP) were collected (Time 1; 15 minutes before onset of stressor), participants began a 15-minute acclimation period. During the acclimation period, participants were provided with a selection of neutral magazines and instructed to sit and relax for 15 minutes. After the acclimation period, HR, BP, and negative affect were collected to establish a baseline measure (Time 2; 1 minute before onset of stressor). Next, participants began the TSST or control condition. After explanation of the task, HR and BP was measured for anticipatory stress reactivity (Time 3; 1 minute after onset of stressor). Upon completion of the task, HR, BP, and mood were measured for stress reactivity (Time 4; 10 minutes after onset of stressor). Participants then completed the mental abstraction questionnaire. After completion of the mental abstraction questionnaire, HR and BP were measured for stress recovery (Time 5; 15 minutes after onset of stressor). Finally, participants completed the demographic questionnaire and were debriefed of the purpose of the study. For a full protocol of the stress and control groups, including a script for each condition, see the Appendix B.

#### **Manipulation**



**Trier Social Stress Test.** Acute stress was induced in the laboratory using a modified version of the TSST (Kirschbaum et al., 1993; B. Kudielka et al., 2007) using only the speaking portion. The math portion was excluded because mathematics is an inherently abstract process that may induce an abstract mindset (Schley & Fujita, 2014) and be directly related to our outcomes of interests. While the mathematics portion of the TSST is an important component to induce stress, research suggest that even the anticipation of only a speaking task reliably induces an acute stress response (S. S. Dickerson & Kemeny, 2004).

This modified TSST was implemented in an experimental room that consisted of a table with four chairs, three on one side and one on the other side. Participants entered the room and were directed to the single chair, sitting with their back facing the door. Participants were told that they would have to give a five-minute speech about their dream job in front of a panel of experts in nonverbal communication. The committee consisted of research assistants<sup>1</sup> instructed to look and act displeased with the speech. Occasionally, the lead research assistant (designated the President) would interrupt with a discouraging remark (e.g., please make eye contact with the committee). Participants were given five minutes to prepare for the speech but were required to surrender any notes to the committee. When the committee entered the room, participants were told to stand on an "X" marked on the floor, asked to surrender their notes, and the chair they were sitting in was moved across the room. A research assistant on the committee would then turn on a video camera and tape recorder. The President informed the participant when the time was up after five minutes.

**Control-TSST.** There have been several processes used for defining a control group for the TSST, with adoption of each one dependent upon specific research questions. For instance, when interested in isolating the effects of cortisol reactivity to a stressor, researchers can choose between the friendly-TSST (f-TSST; Wiemers, Schoofs, & Wolf, 2012) or the placebo-TSST (p-TSST; Het, Rohleder, Schoofs, Kirschbaum, & Wolf, 2009). While cortisol levels do not increase because of the f-TSST or the p-TSST, arousal of the sympathetic nervous system can occur (e.g., salivary alpha-amylase). Any study exploring the effects of cardiovascular reactivity to stress will require an alternative control group. Therefore, a control group, called the control-TSST (c-TSST), that closely resembled the TSST was developed to specifically reduce cardiovascular reactivity.

As in the TSST condition, participants entered the experiment room and sat in a chair with their backs facing the door. Participants were informed that they would be writing about their ideal job. They were instructed to imagine they were writing a letter to apply for their ideal job with the goal of convincing a hiring committee that they were the ideal candidate. Participants were told that nobody would read their letters but that they would be skimmed after the study to make sure they wrote about their ideal job. Participants were given five minutes to create an outline or anything else they felt would help them write. After the preparation period ended, participants were directed to a standing desk in the middle of the room. They were then given five minutes to write about their ideal job while standing at the desk. Participants could use any preparation materials they had made and were directed to focus on content and to not worry about

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<sup>1</sup> All stress committees consisted of a mixed-gender group of research assistants.

spelling or grammar. At the end of the five minutes, the researcher reentered the room and collected the writing materials.

### **Statistical Analyses**

All data were analyzed using the R programming language (R Core Team, 2018). To explore potential explanatory variables in the relationship between exposure to a psychosocial stressor and levels of mental abstraction, path analyses were estimated using the R package, Lavaan (Rosseel, 2012). Alpha levels for all analyses were set to the nominal .05. All analyses were conducted on samples including only responders to the TSST. Responders were operationalized as participants who exhibited physiological reactivity in all three physiological measures of stress (i.e., SBP, DBP, and HR). Stress reactivity was operationalized as the difference between Time 2 (baseline) and Time 4 (post-stress) for each physiological marker of stress, where larger negative values indicated a larger stress response. Results from the full sample (including nonresponders) did not differ substantively from the responders' sample. See Appendix B for results from the full sample including nonresponders. Assumptions for all analyses were evaluated through a combination of normality plots, histograms, scatterplots, and mean and median location.

To evaluate the impact of each group on stress, four mixed analysis of variances (ANOVAs) were estimated. For each mixed ANOVA, the between group factor was condition and the within group factor was either SBP, DBP, HR, or negative affect. Perceived stress reactivity, depression, and BMI were controlled for in each mixed ANOVA.

*Hypothesis 1:* Investigating whether exposure to a psychosocial stressor affected average levels of mental abstraction, was evaluated using Welch's *t*-test (*Model 1*). Welch's *t*-test is the recommended default when comparing two groups because it can better handle violations of homogeneity of variance and unbalanced designs (Delacre et al., 2017).

*Hypothesis 2:* Investigating whether the relationship between exposure to a psychosocial stressor and average level of mental abstraction is explained by negative affect, was evaluated using a path analysis model. The analysis included the following covariates: negative affect before the stressor/control group (at Time 2), dispositional mental abstraction, and depression. Bootstrapped standard errors were estimated with 5000 iterations for the standard errors of the indirect effect. Models were evaluated using the following absolute model fit indices: the  $\chi^2$  goodness-of-fit, comparative fit index (CFI), and the root mean square error of approximation (RMSEA). Statistically significant  $\chi^2$  values (i.e.,  $p < .05$ ) indicate a poor fitting model. CFI values near 1.0 and RMSEA values near 0 indicate adequate fitting models. Path analyses included participants in the control condition and responders to the TSST. See *Model 2* for a depiction of the model estimated.

*Hypothesis 3:* Exploring whether any physiological measures of stress could also explain the relationship between exposure to a psychosocial stressor; this was evaluated using path analysis models. SBP reactivity (see *Model 3*), DBP reactivity (see *Model 4*), and HR reactivity (see *Model 5*) were explored as potential factors explaining the relationship between exposure to a stressor and mental abstraction. These analyses

included the following covariates: dispositional mental abstraction, depression, BMI, and perceived stress reactivity.

## Results

**Manipulation Check.** All analyses indicated a change in stress reactivity for the TSST group and not the c-TSST group. This finding was supported with statistically significant interactions between Condition and Time for SBP ( $F(4, 496) = 37.06, p < .0001$ ; see Figure 1b), DBP ( $F(4,496) = 62.62, p < .0001$ ; see Figure 2b), HR ( $F(4,496) = 25.71, p < .0001$ ; see Figure 3b), and negative affect ( $F(1, 125) = 65.76, p < .0001$ ; see Figure 4b). Additionally, 77.8% of the participants in the stress group reported feeling stressed. See Appendix A for a table of correlations between stress measures.

**Hypothesis 1 (Model 1).** Mental abstraction was statistically significantly higher in the stress condition ( $M = 16.45, SD = 4.79, n = 62$ ) compared to the control condition ( $M = 14.12, SD = 3.86, n = 68$ ), C.I.<sub>.95%</sub> mean difference: [-3.857, -0.814],  $t(117.24) = 3.04, p = .003, d = .54, C.I.<sub>.95%</sub> d: [0.89, 0.19].$

**Hypothesis 2 (Model 2).** Negative affect was statistically significantly higher in the stress condition ( $M = 20.46, SD = 8.88, n = 63$ ) than in the control condition ( $M = 12.70, SD = 3.55, n = 67$ ), C.I.<sub>.95%</sub> mean difference: [10.15, 5.37],  $t(80.391) = 6.47, p < 0.0001, d = 1.16, C.I.<sub>.95%</sub> d: [1.54, 0.79]. Additionally, higher levels of negative affect related to higher levels of mental abstraction in the TSST condition ( $\beta = .194, p = .019$ ) but not in the control condition ( $\beta = 0.122, p = .430$ ).$

Path analyses revealed that the relationship between exposure to a psychosocial stressor and mental abstraction was not statistically significant when negative affect was included in the model ( $\beta = 0.153, p = .109$ ). The relationships between negative affect and mental abstraction ( $\beta = 0.234, p = .037$ ), as well as between stress and negative affect ( $\beta = 0.552, p < .001$ ), yielded statistical significance. The indirect effect ( $\beta = 0.129, p = .043$ ) and the total effect ( $\beta = 0.282, p = .001$ ) were both statistically significant. The model fit the data adequately ( $\chi^2(12) = 116.07, p < .001$ ; CFI = .987; RMSEA = .046, C.I.<sub>.90%</sub>: [0.00, .137],  $p = .445$ ), and explained 11.7% of the total variation in the BIF. See Figure 5b for a path diagram of the model described.

**Hypothesis 3 (Exploratory Models 3-5).** None of the path analysis models exploring how SBP reactivity (*Model 3*), DBP reactivity (*Model 4*), or HR reactivity (*Model 5*) explained the relationships between exposure to a psychosocial stressor and mental abstraction. The relationship between stress and mental abstraction was still statistically significant in *Model 3* and *Model 5* ( $ps > .30$ ). The indirect effects were not significant for any of the models ( $\beta s < .225, ps > .080$ ). See Table 2b for a full depiction of results from these models.

## Discussion

This is the first study to investigate how stress affects the way information is processed. Mental abstraction, a style of information processing, was significantly higher after exposure to a psychosocial stressor. This relationship appeared to be explained through increased negative mood after stress, but not cardiovascular reactivity. Physiological measures of stress (HR and BP) were not related to levels of mental abstraction. The findings suggest that stress does affect the way information is processed and has implications for how stress affects judgments and decisions. Currently little is known about how stress affects information processing. This study advances the literature

by identifying mood as a potential link between stress and mental abstraction and a plausible explanatory pathway.

There are two competing theories on how stress affects the way people see the world. The literature on mental abstraction states that negative mood should lead to lower levels of mental abstraction (Bless & Burger, 2017). Because stress is characterized as a negative mood state (Dougall & Baum, 2012; R. Lazarus & Folkman S., 1984), exposure to a stressor should lead to lower levels of mental abstraction. However, the literature on executive functioning states that stress leads to more automatic processing. When processing more abstract information (i.e., features of a stimuli), information is reduced (or compressed) into broader, more manageable components (Burgoon et al., 2013). Information that has been compressed may then facilitate automatic processing. Our results are in line with the latter; exposure to a psychosocial stressor was associated with higher levels of mental abstraction. Additionally, levels of negative affect explained this relationship such that greater negative affect lead to higher levels of mental abstraction. This finding was somewhat surprising as the body of research on mood and mental abstraction is rather clear. However, higher negative affect after a stressor may serve as a proxy to other processes involved with the stress response that are related to executive functioning.

In this study, exposure to a stressor lead to more abstract choices on the BIF. Rather than stress leading to a more broadened perspective (as in mental abstraction), it is possible that participants chose the option that was easiest to process. Processing fluency is a meta-cognitive feeling that describes the ease to which information is processed, described as a “ubiquitous metacognitive cue in reasoning and social judgments” (Alter & Oppenheimer, 2008, 2009). Information that has high fluency is easier to process and may be done automatically, while information that has low fluency is more difficult to process and requires greater effort. Participants in the stress condition may have been under increased cognitive load and preferred the more abstract, easily processed choice (Hafner & Stapel, 2010). Additionally, familiarity increases the feeling of fluency. The mere-exposure effect states that repeated encounters with a neutral stimulus leads to positive evaluations. Information that is more familiar is easier to process (Alter & Oppenheimer, 2009). In the BIF, some of the more abstract descriptors may be more familiar to participant (i.e., brushing teeth described as preventing tooth decay or moving a brush around in one’s mouth) and therefore easier to process. Levels of mental abstraction have also been found to attenuate the effects of processing fluency when participants are not primed to think of the benefits of fluency (Tsai & Thomas, 2011). Therefore, processing fluency is a potential target of future research on the psychological and behavioral processes affected by stress. Different measures of mental abstraction are necessary to disentangle these effects. It is possible that a different measure of mental abstraction could yield different results in this context. Burgoon et al. (2013) highlight the various methods for measuring mental abstraction.

While cardiovascular markers of stress (i.e., HR, SBP, and DBP) did not explain the relationship between stress and mental abstraction, other physiological markers not measured may be important. Stress affects several biological processes such as activation of the hypothalamus-pituitary-adrenal (HPA) axis (Allen et al., 2014), which involves the secretion of corticotropin releasing hormone (CRH), adrenocorticotropin releasing

hormone (ACTH), and cortisol. CRH may be an area of interest for how stress affects how people experience or view the world. CRH is a hormone released during the stress response that partially explains the relationship between stress and executive functioning (Uribe-Marino et al., 2016). Other biomarkers released during the stress response, such as adrenaline, cortisol, dehydroepiandrosterone (DHEA), and markers of the immune system, also affect executive functioning (Arnsten, 2009; Segerstrom & Miller, 2004; Shanksy & Lipps, 2013; Steptoe, Hamer, & Chida, 2007; Uribe-Marino et al., 2016). Future research should incorporate these neuroendocrine and immune system markers to further investigate the effects that biological responses to stress have on mental abstraction, as well as information processing in general.

Gender differences are an important factor in the stress response, especially in relation to neuroendocrine reactivity. When using the TSST to induce psychosocial stress, men consistently have a greater neuroendocrine response than women, while women typically exhibit a greater affective response (Kelly, Tyrka, Anderson, Price, & Carpenter, 2008; Kudielka et al., 2007). Additionally, reproductive hormones in women can alter the stress response, depending on stage in menstrual cycle and whether oral contraceptives are taken (Kudielka et al., 2007). While gender is an important moderator for the stress response, there is no evidence of a gender effect on mental abstraction (Soderberg, Callahan, Kochersberger, Amit, & Ledgerwood, 2014). However, gender differences in neuroendocrine reactivity hint at a differential effect of stress reactivity on mental abstraction between men and women. Given the impact of stress hormones on executive functions (such as working memory), a moderated mediation is possible, with pathways linking stress to mental abstraction differing between men and women. Future studies should ensure large enough samples of men and women to explore differences.

An alternative explanation for the observed results is that participants may already be coping with the stressor. It is possible that participants began engaging in a form of avoidance-based coping called self-distancing, by the time they were completing the BIF. Spontaneous self-distancing facilitates adaptive self-reflecting by increasing the psychological distance between the person and the negative event (Ayduk & Kross, 2010b). This coping mechanism helps participants focus on the “why” of the negative event rather than the “how,” permitting a “fly-on-the-wall” or “observer rather than actor” perspective (Ayduk & Kross, 2009, 2010a, 2010b). This explanation is plausible because mental abstraction was measured after the stressor, not during. Furthermore, while participants indicated higher negative affect, positive affect could have increased after the measurement knowing that they were done with the TSST. Future studies should incorporate measures of coping, such as self-distancing, and more frequent measurements of mood to further explore this potential.

There are some important limitations to consider when interpreting these results. First, this study used a convenience sample of undergraduate students, so caution is required when generalizing results beyond this population. However, this was a diverse sample reflecting multiple race and ethnicities. Therefore, these findings on stress and executive functioning may generalize to other samples. Second, mental abstraction was measured after the stressor rather than during. Stress and information processing are dynamic processes that occur continuously over time and are best studied using methods that can capture these dynamics. However, this study used a strong experimental design

with a control group developed specifically to isolate the effect of stress on mental abstraction. Additionally, this is the first study to evaluate mental abstraction in the context of stress. Previous work has relied on negative mood induction by priming mood. In these studies, participants typically browse a slide show or photo album with positively or negatively valenced stimuli present (e.g., smiley or frowning face; for e.g., see Burger & Bless, 2016; Pyone & Isen, 2011). It is possible that the type of negative mood induced in previous work with mental abstraction is different from the type of negative mood induced from the TSST. Future studies should compare how inducing negative mood through the TSST and traditional priming procedures affects the relationship with mental abstraction. Another limitation to consider is how stress reactivity was operationalized. In this study, the difference between pre-stress (Time 2) and post-stress (Time 4) measures served as a proxy for stress reactivity. There are alternative methodological approaches that can better capture stress reactivity using latent variable models (LVMs). LVMs can be specified to investigate how the rate of change in physiological and psychological markers of stress can affect distal outcomes while taking into account individual differences in stress reactivity (see Chapter 4, or Felt, Depaoli, & Tiemensma, 2017).

Future studies could further explore these findings in the context of ecological momentary assessment (EMA). EMA studies allow for the exploration of within-subject effects and permit the examination of mediating variables (Smyth & Stone, 2003; Zawadzki, Smyth, Sliwonski, Ruize, & Gerin, 2017). EMA allows for stress and information processing to be studied as a process, making it possible to disentangle how and when these processes are occurring. It is possible that there are time effects where mental abstraction is different during the stressor compared to after the stressor. This framework will allow for the disentanglement of physiological and psychological processes of stress on mental abstraction and could yield insight into effects that may vary across time. Additionally, multiple measures of mental abstraction can be used to tease out a methodology effect and rule out competing explanations (e.g., processing fluency).

### Conclusion

This study is the first study to investigate how exposure to a psychosocial stressor affects the way people view the world through changes in levels of mental abstraction. There were two competing frameworks for how stress may affect mental abstraction. Broaden-and-Build Theory and research on mood and mental abstraction suggest that increased negative affect would lead to lower levels of mental abstraction. Research on acute stress and executive functioning suggest that stress leads to more automatic processing, which is a more abstract process. Our results were consistent with the latter; exposure to a psychosocial stressor lead to higher levels of mental abstraction. Processing fluency provides a plausible framework through why participants in the stressful condition were more likely to choose the abstract choices. We recommend that future research focus on other meta-cognitive processes and examine these phenomena using momentary based assessments (i.e., EMA). Regardless of the mechanism through how stress affects mental abstraction, this study demonstrated that stress affects the way information is processed, at least after exposure to a stressor.

## Chapter 4

### Study III

#### Latent Growth Curve Models for Biomarkers of the Stress Response

##### Preface

This chapter contains an article that was previously published in *Frontiers in Neuroscience* (Felt et al., 2017). It begins by describing the stress process and traditional methods for evaluating change over time. Next, a comparison of difference-based approaches is discussed. The chapter is focused on latent variable modeling approaches to evaluate change over time, as well as how these models can be used to understand the antecedents and consequences of stress.

Traditionally, mean-difference-based approaches have been used to evaluate change over time. Mean-difference-based approaches treat time as discrete and do not provide estimates of individual differences. Individual-difference-based approaches, on the other hand, treat time as continuous and provide estimates of individual differences. However, individual-difference-based approaches are seldomly used in stress research published in journals publishing *Health Psychology* research. To illustrate how the methodological approaches of stress researchers has evolved over time, all manuscripts published in the journals *Health Psychology*, *Psychology & Health*, and *Journal of Health Psychology* since 2000 were screened for methods used to evaluate change in biomarkers of stress (i.e., cortisol and alpha-amylase—two commonly used biomarkers of the stress response). Figure 1c presents all of the statistical methods used to evaluate change over time in cortisol and/or alpha-amylase. Since 2000, 78 analyses were reported. There is a clear trend in the evolution of the statistical methods used by stress researchers. Mean-difference-based approaches (i.e., linear models) were the most common methods observed between 2000 and 2006, accounting for 63% ( $n = 49$ ) of the 78 analyses since the turn of the century. Individual-difference-based approaches (i.e., mixed effects models) were the next most frequently used method and account for 35% ( $n = 27$ ) of the total analyses since the turn of the century. Recently, latent variable modeling (LVM) approaches have appeared in *Health Psychology* for this topic area, but only twice since 2010. This evolution of methodological approaches corresponds with the development of more sophisticated research questions being asked within biomarker-related inquiries.

LVM approaches are well suited for evaluating change over time in stress. The acute stress response happens rapidly but requires relatively few time points if the behavior of the biomarker under stressful conditions is known. Cortisol, for instance, peaks 20 minutes after the onset of the stressor with a recovery period (Bozovic, Racic, & Ivkovic, 2013). This study has an online appendix mentioned throughout. For the purpose of this dissertation, the material from the online appendix can also be found in Appendix C.

### Abstract

**Objective:** The stress response is a dynamic process that can be characterized by predictable biochemical and psychological changes. Biomarkers of the stress response are typically measured over time and require statistical methods that can model change over time. One flexible method of evaluating change over time is the latent growth curve model (LGCM). However, stress researchers seldom use the LGCM when studying biomarkers, despite their benefits. Stress researchers may be unaware of how these methods can be useful. Therefore, the purpose of this paper is to provide an overview of LGCMs in the context of stress research. We specifically highlight the unique benefits of using these approaches.

**Methods:** Hypothetical examples are used to describe four forms of the LGCM.

**Results:** The following four specifications of the LGCM are described: basic LGCM, latent growth mixture model, piecewise LGCM, and LGCM for two parallel processes. The specifications of the LGCM are discussed in the context of the Trier Social Stress Test. Beyond the discussion of the four models, we present issues of modeling nonlinear patterns of change, assessing model fit, and linking specific research questions regarding biomarker research using different statistical models.

**Conclusions:** The final sections of the paper discuss statistical software packages and more advanced modeling capabilities of LGCMs. The online Appendix contains example code with annotation from two statistical programs for the LCGM.

**Keywords:** latent growth curve model; stress response; cortisol; alpha-amylase; biomarkers



### **Latent Growth Curve Models for Biomarkers of the Stress Response**

The stress response is a complex, dynamic process. This process can be best characterized as a negative emotional experience accompanied by predictable biochemical, physiological, and behavioral changes that are relevant to adaptation (Baum, 1990; Dougall & Baum, 2012; Lazarus & Folkman S., 1984). Many methods have been developed to evaluate the stress response using self-reported (i.e., subjective) measures and biomarkers (i.e., objective). Self-report measures and biomarkers are collected over time, and therefore require alternative statistical methods that can handle issues of repeated measurements. However, there are many methodologies that stress researchers can choose from, depending on the properties of the data and research questions.

The methodological approaches used within stress research have evolved over time; specifically, the approaches used to evaluate the change in biomarkers. The stress research literature, particularly relating to biomarkers, has commonly incorporated methods such as mean-difference-based approaches (see e.g., Alsalman, Tucker, & Vanneste, 2016; Brouwer & Hogervorst, 2014; Gerber et al., 2017; Kempke, Luyten, Mayes, Van Houdenhove, & Claes, 2016) and mixed effects models (see e.g., Saxbe, Repetti, & Nishina, 2008; Van Lenten & Doane, 2016). However, the field has recently started to incorporate applications of latent variable modeling (LVM) to examine the stress response. This approach, although longstanding in other fields (e.g., Education or Economics), is relatively new to the stress response literature--with only some very recent applications (e.g. Giesbrecht, Bryce, Letourneau, & Granger, 2015; Hagger-Johnson, Whiteman, Wawrzyniak, & Holroyd, 2010; Thornton, Andersen, & Blakely, 2010). The incorporation of more advanced statistical methods such as LVMs represents an evolution of methodological approaches that correspond to the development of more sophisticated research questions being asked within biomarker-related inquiries.

#### **Purpose of Manuscript**

The purpose of this manuscript is to expand upon the most commonly used statistical methods in stress research with biomarkers. An alternative, powerful modeling framework (i.e., the latent growth modeling framework) will be discussed in the context of specific research questions generated from commonly used laboratory stressors. The paper includes a comparison of statistical software for estimating LVMs. Sample code for various statistical software programs will be provided in the online Appendix for each LVM discussed.<sup>2</sup>

#### **Traditional Methods**

Mean-difference-based approaches, such as analysis of variance (ANOVA) and multivariate ANOVA (MANOVA), are useful when researchers are interested in evaluating average change over time (Hedeker & Gibbons, 2006a, 2006b). However, ANOVA and MANOVA approaches are limited in the types of questions that can be

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<sup>2</sup> The online supplementary material can be found at:  
<https://www.dropbox.com/sh/5hthz8ndfozyxyg/AACUZRWrsKOnqCbBhHeSGmTIA?dl=0>

answered. Researchers interested in evaluating the individual differences observed in the stress response (e.g., Schlotz, Hammerfald, Ehlert, & Gaab, 2011; Skoluda et al., 2015) should move to an individual-difference-based approach. This approach typically implements hierarchical linear models (also called multilevel models), which include mixed regression models (MRMs). MRMs provide insight into average change over time while modeling individual variation through the specification of random effects—or the estimation of an intercept and any number of slopes (Hedeker & Gibbons, 2006c). While MRMs also represent a flexible modeling approach, there are specific research questions that are better handled in a LVM framework.

### **Latent Variable Models**

LVM approaches that are used to evaluate change over time include latent growth curve models (LGCMs; McCardle & Epstein, 1987; Muthén & Curran, 1997). In an LGCM, change is modeled as a function of time and is represented through the specification of latent (i.e., unobserved) variables referred to as *growth factors*. A latent intercept and a latent slope (i.e., the growth factors) are estimated based on the individual trajectories. Growth factors provide an estimate of the average trajectory, and individual variation around that trajectory, over time. Since the growth factors are estimated (i.e., latent), they are considered random effects. These model parameters can provide insight into average change and individual difference surrounding that change; model fit indices can also be obtained for LGCMs. While LGCMs can be a useful tool for stress researchers working with biomarkers, they have not appeared in the literature frequently.

Ram and Grimm (2007) provide a tutorial for LGCMs in the context of cortisol research in developmental inquiries, specifically for aging. However, LGCMs have not breached their way into premier neuroscience or health psychology journals, to evaluate change over time in cortisol and alpha-amylase. This could be due to several reasons. First, researchers may not be aware that LGCMs can be relevant to provide insight into their complex hypotheses. Second, the estimation of LGCMs requires the knowledge of specialty software programs. To compound this issue, the coding languages vary across software programs. Mastering these coding languages can be rather arduous and time-consuming. Furthermore, the distinction between LGCMs and other approaches, such as multilevel models and mixed regression models, is not well pronounced. Researchers may not be aware of when an LGCM is more appropriate to use compared to these other approaches.

Within the LVM framework, we can start to incorporate extensions that allow for a more complete version of the stress response to be modeled. For example, the models we present in the current manuscript (e.g., the LGCM) can be viewed as “base models”. In other words, each of these models can be expanded in a variety of ways to incorporate manifest or latent variables influencing various parts of the growth model. These variables can be incorporated as predictors, covariates, outcomes, or distal outcomes. In this case, the model can represent a larger, inclusive system of variables that work together to better capture the stress response and promote a deeper understanding of the

biomarker fluctuations that are related to the stress response. True flexibility of research questions is possible within the latent variable modeling approach.

This family of statistical techniques is, of course, not a novel concept. These models have been explored in a variety of substantive and methodological inquiries for decades. However, these statistical tools are lacking in the stress-related biomarker literature and we feel that incorporating them can help to broaden the scope of questions being examined.

### **Specific Goals and Intended Audience**

Given that the typical statistical approach in biomarker related research can only answer mean-difference-based questions, we felt it was important to highlight the use of a potentially richer and more flexible statistical modeling framework. Since there is no set standard of methodology within the field due to the vastly different data collection patterns that can be used, researchers may not be aware of the most advantageous and appropriate statistical tool for their situation. Our hope is that researchers examining the impact of the stress response on biomarker fluctuations will find these LGCMs useful when constructing future research questions to explore. Therefore, the goal of this paper is to present statistical methodology, in a user-friendly manner, which can answer research questions that are important and under-studied in the stress-related biomarker field. Not only do we discuss how to formulate and interpret findings from relevant LGCMs, but we also show how easy they are to implement by including sample code for a variety of models. This code is available in our online Appendix.

### **Hypothetical Example**

The Trier Social Stress Test (TSST) is a method for inducing a psychological stressor and evaluating the effects on biological responses (Kirschbaum et al., 1993; B. Kudielka et al., 2007). Several studies have confirmed that the TSST reliably induces activation of the HPA axis (Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004) and the sympathetic adrenal medullary (SAM) system (Nater et al., 2005). The TSST consists of a public speaking task and a verbal arithmetic task. The total procedure takes between 11 and 15 minutes to complete. Biological measures of the stress response can be collected before and after the TSST at several time-points (Kirschbaum et al., 1993); for a thorough description of the TSST protocol, see Kirschbaum et al. (1993) or Kudielka et al. (2007).

Describing the different specifications of the LGCM in the context of the TSST allows for the nuances of the models to be described in a way that is relevant and familiar to stress researchers. The types of questions that can be answered, and the modeling issues that may arise, will then be described in the context of a commonly used experimental paradigm in stress research. However, this modeling approach can also be implemented in a variety of longitudinal research settings outside of stress research.

### **Basic Details Surrounding Latent Growth Curve Models**

LGCMs are a class of LVMs designed to capture change over time. Within the context of most biomarker research, data are skewed and need to be transformed before analysis (Miller & Plessow, 2013). However, there have been many advances for LVM

techniques, and now any type of variable (e.g., those on different scales of metric) can be modeled without data transformation (Muthén & Asparouhov, 2002). If the item-type (e.g., binary, ordered categorical, or count) is properly specified in the code, then the software program selects the optimal estimator and data need not be transformed.

Another important factor to consider before estimating an LGCM is the number of time-points data were collected over. In order to test a linear trend, at least three time-points are needed (i.e., three points make a line). When model complexity increases, as when evaluating nonlinear change, the number of time-points needed also increases; for example, complex nonlinear change over time may require four or more time-points (e.g., Grimm & Ram, 2009). LGCMs can also model time-points that are either equal or unequal regarding their spacing. For the basic LGCM, each subject is typically measured on the same measurement occasions (i.e., each subject shares the same time-points, but those time-points need not be equally spaced). However, basic LGCMs can be easily expanded to account for subjects on different measurement occasions (see Muthén & Curran, 1997; Muthén & Muthén, 1998-2016 for further information and an example of implementation).

LGCMs capture change over time through the specification of latent (i.e., unobserved) growth factors. Latent growth factors represent change through the estimation of a latent intercept (i.e., initial level) and latent slopes (i.e., rate of change), which can reflect linear or nonlinear growth patterns (K. Grimm & Ram, 2009). The intercept and slope are latent because they are not variables that exist in the data set. Rather, they are estimated based on the collection of trajectories obtained for each individual. Figure 2c is an example of a plot containing individual growth trajectories. The intercept is reflected by the y-axis, and the slope reflects the rate of change over the time-points (x-axis). Each line represents an individual's trajectory from which an intercept and slope(s) are estimated. These trajectories can then be summarized by an average growth trajectory and measures of variance surrounding the average trajectory. The measures of variance represent the individual slopes surrounding the average trajectory and provide insight into inter-individual differences within the overall growth pattern(s) captured.

### **Sample Size Limitations of LGCMs**

There are some important limitations that need to be considered when deciding between LGCMs and other methods of evaluating change over time. Possibly the most relevant limitation to stress researchers is the issue of sample size. LGCMs can require larger sample sizes than other approaches (e.g., mixed regression models), especially with fewer time-points or as model complexity increases; some studies suggest needing over 1,000 subjects, depending on model complexity (see Cheong, 2011; Hertzog, Lindenberger, Ghisletta, & von Oertzen, 2006; Hertzog & von Oertzen, 2008). However, studies have found that basic LGCMs can perform adequately under smaller sample size situations. For instance, Cheong (2011) found that LGCMs had adequate power to model mediation relationships when the sample size was 200 and there were at least five time-points. Furthermore, Fan (2003) found that, when evaluating linear growth, LGCMs had

more power to detect group differences in latent trajectories than repeated measures ANOVA did. Regardless, sample size is an important limitation because the cost of collecting biomarkers can grow quickly as the sample size increases, especially if researchers do not have a wet-lab locally and have to ship out samples. If the research question dictates the use of LGCMs, and large sample sizes are not achievable, there are alternative methods that can be considered.

Bayesian estimation is an alternative modeling framework that allows researchers to incorporate subjective information into their statistical models that can have a similar effect as increasing power to detect effects (Kaplan & Depaoli, 2013). For example, Zhang, Hamagami, Lijuan Wang, Nesselroade, and Grimm (2007) found that the LGCM could be estimated with as few as 20 subjects under the Bayesian estimation framework. A thorough review of Bayesian estimation and the specific issues involved are beyond the scope of this paper. For less technical reviews of Bayesian estimation, see van de Schoot and Depaoli (2014) and van de Schoot et al. (2014). For a more technical review of Bayesian estimation and how it applies to LVMS such as LGCMs, see Muthén and Asparouhov (2012) and Kaplan and Depaoli (2012).

### **Unique Benefits to Biomarker Research**

The latent growth modeling framework encompasses many forms of LGCMs, which carry unique benefits in biomarker research. Perhaps the most pronounced benefit is that we see an extension of types of research questions that can be examined using this modeling framework. Of course, there are other statistical approaches that would also help to expand topics currently being explored beyond mean-difference-based inquiries. Such approaches include multilevel models and mixed regression models. There are many areas of overlap between these two modeling approaches and the latent variable modeling framework we discuss. Some obvious connections are the fact that latent growth models are indeed multilevel models and that mixed effects can be specified in all approaches. We view the latent variable modeling framework as just one approach that can help to broaden the scope of research questions being examined. One important extension that the latent variable modeling framework provides is the use of multiple indicators for a single construct. In other words, constructs can be included into any of these types of growth models as latent variables with many observed indicators (e.g., items on a scale). These latent constructs can be included as predictors, covariates, or (distal) outcomes within the “base” latent growth modeling being examined. This feature represents the extreme flexibility of the latent variable modeling framework. We cover additional benefits for biomarker research specific to each of the types of models presented in the following sections.

The following main section presents key specifications of the LGCM relevant to stress related inquiries using biomarkers. The organization of the remaining sections is as follows. First, a description of path diagrams and how they are used to represent LGCMs will be provided. Next, we present a sampling of the types of research questions that can be addressed using LGCMs. This is followed by a description of four specifications of the LGCM, as well as issues surrounding model fit. Each specification of the LGCM will

be discussed in the context of the TSST and how they can address specific research questions. We focus on the basic LGCM, a multi-group version, the piecewise LGCM (PLGCM), and the LGCM for two parallel processes. We cover issues tied to assessment of model fit and adequacy related to these models. Finally, two statistical software packages to estimate LGCMs will be discussed; namely, *Mplus* and the freely available program R.

### **Path Diagrams**

Each of the specifications of the LGCM will be described in reference to a corresponding path diagram, which represents any type of LVM in a convenient graphical form. These diagrams allow LGCMs to be discussed through a graphical representation rather than through an equation. In a path diagram, squares or rectangles represent manifest or observed variables that would appear in the data file (e.g., cortisol). Circles represent latent or unobserved variables, such as the growth factors (e.g., latent intercept and slopes) in LGCM. Manifest and latent variables are linked together by paths with arrows at the ends. Single-headed arrows represent paths in which one variable predicts another variable (i.e., a regression path). Double-headed arrows represent the covariation or correlation between two variables, latent or manifest. Numbers beside the paths represent relationships between variables that are fixed in order to preserve the structure of the desired growth model being estimated. Paths without any numbers indicate relationships between variables that will be freely estimated.

### **Types of Important and Under-Studied Research Questions**

The impact of the stress response on fluctuations in biomarkers is a broad topic, and we see room for improved flexibility in the research questions currently being addressed in the field. This section presents five types of research questions that can be answered using the specific LCGM techniques described below.

- 1) What is the continuous rate of change in cortisol?
- 2) What does the change in cortisol look like over time?
- 3) How do cortisol and alpha-amylase relate over time?
- 4) Are there (observed or unobserved) group differences in the rate of change in cortisol?
- 5) Does the rate of change in cortisol predict health outcomes?

These questions are a sample of the types of important and under-studied research questions that can be answered using LGCMs to evaluate change in biomarkers. This is not an exhaustive list of the types of research questions that can be addressed using LGCMs, nor is it a complete list of questions that can be addressed within biomarker research. Rather, the questions were selected to provide a context to discuss the implementation of the different LGCM specifications. Table 1 presents the five research questions in more detail. We present sections on several main specifications of the LGCM. Within each model-specific section, we describe the relevant research questions and how they can be addressed. Issues such as model fit and assessment, as well as issues related to statistical software, are also described.

### **The Basic LGCM**

Figure 3c presents a path diagram of a basic LGCM. The basic LGCM was developed to evaluate the continuous rate of change over time (McArdle & Epstein, 1987). In the basic LGCM, a latent intercept and a latent linear slope is estimated to capture linear change over time. This model is appropriate when the researcher does not expect bends in the trajectories over time.

An example of the basic LGCM can be found in Hagger-Johnson et al. (2010) who aimed to investigate the effects of chronic stress on physical and mental well-being. The linear slope from a basic LGCM yielded a significant relationship between the rate of change in cortisol levels to mental health issues. Specifically, a steeper decline in daytime cortisol levels related to better mental health scores, indicating a link between chronic stress and mental health. However, results from this study are cross-sectional and causation could not be determined. In experimental designs, nonlinear growth factors may need to be estimated to capture the bends in trajectories that an experimental paradigm may cause.

Burant (2016) investigates how LGCMs can be used to capture how depression levels change over time in elderly hospital patients. Using a combination of model fit indices and parameter estimates that correspond with theory, Burant (2016) determined that an LGCM with freely estimated slopes (akin to the latent basis model described below) best described changes in depression over time. This specification of the LGCM was able to capture nonlinear change and provide insight into where the greatest rate of change in depression occurred. Specifically, depression levels declined most quickly after one month, with the rate of change slowing until it reached its lowest levels at six months. One caveat to this model is that it requires larger sample sizes due to more parameters being estimated. For the description of the basic LGCM in this manuscript, quadratic growth will be the focus because of the context in which the models are described (i.e., TSST).”

In the model presented in Figure 4c, a basic LGCM with a quadratic growth factor and six measurement occasions of cortisol is depicted. The latent variables in this model are the intercept and slope (i.e., linear and quadratic) growth factors. When interested in capturing the increase and decrease of biomarkers, nonlinear slopes can be specified (e.g., the quadratic slope in Figure 4c). For the growth factors to represent change over time, the paths between the cortisol measurement occasions and the growth factors may be fixed to specific values. For example, Figure 4c shows the paths from the linear slope term fixed to the following: 0, 1, 2, ...5. Fixing these paths is a way of specifying a particular growth shape within the model (e.g, linear or quadratic). However, for extensions of the LGCM, such as the latent basis model, these loadings can be freely estimated to model any form of nonlinearity. In the case of Figure 2c, these fixed paths from the slope terms would be freed and estimated to represent the degree of nonlinearity in the data (i.e., the paths would no longer say: 0, 1, 2,...5).

In the basic LGCM, the intercept is specified by fixing all paths between the cortisol measurements and the intercept growth factor to one. The linear slope is defined by fixing the path between the first measurement of cortisol and the linear slope growth

factor to zero. This specification makes the intercept represent the first time-point. However, any time-point can be specified to represent the intercept. Paths between subsequent cortisol measurements and the slope growth factor are fixed to represent equal spacing (i.e., with unit increments, as in Figure 4c) or unequal time spacing (i.e., 0, 1, 4, 5 would indicate longer time has elapsed between the 2<sup>nd</sup> and 3<sup>rd</sup> time-points). The quadratic slope is specified through the squared values of the linear slope. Quadratic growth is only one form of nonlinear change, and higher order forms can be specified if desired (see e.g., Grimm & Ram, 2009).

### **Unique Benefits of the Basic LGCM to Biomarker Research**

As we will illustrate in subsequent sections, the LGCM is a highly flexible model that can be manipulated in a variety of ways to answer complex and dynamic research questions. Arguably, one of the most beneficial modifications that can be made to the basic LGCM is to specify various forms of nonlinear change within the model. The LGCM can be estimated in a variety of ways, each capturing a different picture of what kind of growth patterns exist in the data. The LGCM can capture nonlinear change through the specification of polynomial growth factors (e.g., quadratic or cubic), a feature that it shares with mixed regression models (e.g., quadratic and cubic; Bauer, 2007; Meredith & Tisak, 1990; Willett & Sayer, 1994).

However, LGCMs carry added flexibility and can handle other forms of nonlinearity, which often cannot (easily) be implemented in other modeling frameworks (e.g., using mixed regression models). For instance, alternative specifications of the LGCM exist where the pattern of nonlinear change can be estimated. The *latent basis model* is one such model that treats the pattern of change as a latent variable (McArdle & Epstein, 1987; Meredith & Tisak, 1990). In this type of model, the user need not implement a pre-specified growth pattern (e.g., quadratic growth). Instead, the pattern of change is estimated as latent.

Another form of handling nonlinearity is to use an additive model (e.g., the generalized additive model; Hastie & Tibshirani, 1986), which is used to identify nonlinearity without specific knowledge of where the bends in the trajectory (i.e., changes in growth patterns) are located. Example code for these two forms of handling nonlinearity in the model is included in the online Appendix. There is a wide range of modeling techniques that can be used to incorporate or assess nonlinear change within LGCMs, and these are just two examples. For more information on some of these, see Grimm and Ram (2009), Grimm, Ram, and Hamagami (2011), or Ram and Grimm (2007). For models that are nonlinear in the parameters (i.e., with binary indicators), see Blozis and Harring (2016). Due to the flexibility of the latent variable modeling framework, these assessments of nonlinearity can also be incorporated into the more complex versions of the LGCM that are discussed below.

Another benefit of evaluating growth in the LVM framework is the flexibility of the outcomes that can be handled. While both mixed regression models and LGCMs can model multivariate growth, LGCMs have a little more flexibility in how multiple variables are modeled. First, LGCMs can be used to evaluate the growth of other latent



variables (Cheong, MacKinnon, & Khoo, 2003; Muthén & Asparouhov, 2002). This is useful when a construct under study has multiple indicators (e.g., multiple measures of the SAM system). This modeling framework can also be used to handle autoregression, when outcomes at different time-points are allowed to predict one another (e.g., time 1 score predicts the score at time 2); see Bollen and Curran (2004) for more information. The addition of autoregressive elements in the models may be particularly relevant to the stress response because outcome measures are inherently related to measures collected at previous times within person. These are merely included to act as examples of the flexibility of the general LVM framework. Our main focus here is on the LGCM and its immediate extensions into biomarker research.

### **Research Questions Related to the Basic LGCM**

Table 1 presents several types of important and under-studied research questions. Specifically related to the basic LGCM, we can highlight Questions 1, 2, and 5 for this discussion. Question 1 examines whether the rate of change in a given outcome (e.g., cortisol) is continuous in nature. Fitting an LGCM to the data allows the researcher to examine this continuous rate of change and explore different growth patterns, which is closely tied to the next type of research question. Question 2 relates to what patterns of change look like over time for a given outcome (e.g., cortisol). The basic LGCM allows us to examine continuous change over time and express different forms of nonlinearity within the model to uncover the best model that captures patterns of change in the data. Finally, Question 5 examines how the rate of change in a repeated measures outcome (e.g., cortisol) might impact another outcome measure (e.g., other health outcomes). This specification can yield insight into, for example, how changes in cortisol caused by the TSST affects the number of medical visits. The LGCM can be easily modified to act as a predictor model for other outcomes, which can be measured at a single or multiple time-points. For full details on how the basic LGCM can be specified to address a range of questions, see Table 1.

### **Multi-Group (Observed or Unobserved) Growth Model**

The basic LGCM can be extended to handle multiple groups. In this case, the researcher may be interested in examining growth or change-rate differences across different groups of individuals. These groups can be observed groups such as gender, race/ethnicity, disease status, or age. In this case, the model would be called a *multi-group LGCM*, which indicates that the groups are observed. However, groups can also be unobserved, or latent. In this case, the theory is that the sample data were collected for multiple unobserved subpopulations, where individuals from these populations follow different growth patterns. This type of model is often referred to as a *latent growth mixture model* (LGMM), where the word *mixture* indicates that groups are unobserved (i.e., the grouping label for an individual is something that is estimated in the model and is not a label that appears in the data file). Examples of latent groups can include individuals representing different levels of addiction status (Bengt Muthén & Shedden, 1999), individual experiencing different outcomes of a traumatic experience (deRoos-Cassini, Mancini, Rusch, & Bonanno, 2010), and adolescents with different smoking

behaviors (Colder et al., 2001). In the context of the current paper, we might consider a subset of subjects that have a faster recovery time from the TSST compared to another group of subjects. In this case, the LGMM can be used to identify and model these subjects.

For the purposes of discussion, we will continue describing the LGMM here, but the (observed) multi-group LGCM would look much the same (code for both is provided in the online Appendix). When comparing observed multiple-groups to one another, there is typically an iterative process implemented. In particular, constraints are placed within the model (e.g., on the growth factor loadings if freely estimated, the parameter variances, or the covariances) one-by-one to assess exactly where (if at all) the model results differ across groups. This process helps to uncover how growth processes may differ across the observed groups. For more information on this process, please see Li et al. (2001) for an applied example or Muthén and Curran (1997) for a more technical description. The unobserved groups are (typically) handled in a different manner.

As mentioned, the LGMM differs from the basic LGCM only in that multiple unobserved groups (or *latent classes*) are accounted for in the model. The user would estimate the model many times, each with a different number of latent classes specified. Then model fit assessments (described below) and substantive knowledge would be used in combination to determine the “best” number of latent classes, each represented by a substantively different growth trajectory. In other words, the LGMM identifies subpopulations that may have been sampled and estimates an LGCM for each unobserved group that has been identified. It is important to note that LGMMs are highly complex and should be estimated using a set of guidelines. Such guidelines have recently been published in van de Schoot, Sijbrandij, Winter, Depaoli, and Vermunt (2017). Some further modeling concerns about assumptions that have to be made in LGMMs can be found in Bauer (2007). A depiction of the LGMM can be found in Figure 5c. Notice that the only difference between this model and the basic LGCM is the inclusion of the latent variable “c”, which indicates that the entire model is allowed to be estimated for latent groups such that each group can be represented by its own estimated growth trajectory. An LGMM trajectory plot might look something like Figure 6c, where there are groups of trajectories that represent different growth patterns. In this case, we might identify 3 groups, each with their own estimated growth trajectory.

### **Unique Benefits of the LGMM to Biomarker Research**

The multi-group approach to the LGCM is incredibly helpful for modeling different sub-groups on the same outcomes, and then doing subsequent comparisons across those groups. The LVM framework allows for these groups to be either observed or unobserved in nature, with the latter being a specific benefit to working within this modeling context. The ability to model latent groups allows researchers to explore potentially substantively interesting sub-populations and related covariates. This feature could be particularly beneficial when examining whether patterns of change are dictated by underlying characteristics that have not been previously explored.

### **Research Questions Related to the Multi-Group Growth Model**

The type of research question listed in Table 1 that is particularly relevant to this type of latent growth model is Question 4. This question can be used to explore whether there are viable groupings of individuals that substantively differ in their growth rates. When using the TSST, the LGMM may be able to distinguish between high and low responders to the TSST and estimate trajectories for each group. This provides insight into what the stress response of these two different types of responders looks like. The model can also be used in the context of large-scale models, which include additional covariates and outcome measures. Perhaps the groups appear similar in their growth patterns, but differ substantively on other aspects of the larger model—this sort of model can help the researcher to distinguish these nuances. Any of the other research questions listed in Table 1 could be potentially relevant to this group of models, but Question 4 is the research question unique to this type of model. For a nice example showing how the LGMM applies to diurnal cortisol data, see Dmitrieva, Almeida, Dmitrieva, Loken, and Pieper (2013) or Ram and Grimm (2009).

### **Piecewise LGCM**

The PLGCM is also known as the multiphase LGCM or the spline LGCM. Figure 7c presents a path diagram of a two-piece PLGCM. In this specification, there are two phases being modeled, Phase 1 (cort1, cort2, and cort3) and Phase 2 (cort 4, cort 5, and cort 6). Phase 1 represents the time-points before the onset of the TSST (i.e., the baseline period), whereas Phase 2 represents the time-points after the onset of the TSST (i.e., the recovery period). The time-points for Phase 1 and Phase 2 will differ depending on how the study was designed (e.g., more time-points in the recovery period). Additional “pieces” can be specified in the model when the location of more than one bend is known (e.g., a baseline period, a reaction period, and a recovery period). The first piece (i.e., growth factor slope 1) represents linear change in cortisol before the onset of the TSST. The second piece (i.e., growth factor slope 2) represents linear change in cortisol after the onset of the TSST. For this example, we included three waves of data for each phase. The purpose of this was to ensure that each phase would be identified on its own (see Bollen & Curran, 2004). It is possible for each phase to only have two waves, akin to a confirmatory factor analysis with correlated factors and two indicators each. However, Diallo and Morin (2015) found that LGCMs with only two indicators may be underpowered to detect an effect. Therefore, discussion of this model focuses on three waves for each phase of the PLGCM.

Attention to the specifications of the paths between the observed items and the latent growth factors is crucial for estimation of the PLGCM. In Figure 7c, the linear growth factor for the first phase is specified with the first three timepoints (i.e., cort1, cort2, and cort3) fixed to “0”, “1”, and “2”, respectively. Specifying the first three timepoints this way permits the estimation of the linear slope (similar to basic LGCM). However, the final three timepoints are fixed to “2.” This specification prevents information from the final wave of timepoints from being included in the estimation of the first linear slope. In other words, fixing the remaining timepoints to “2” allows the remaining growth information to be absorbed into the second piece. This generalizes to

the second linear slope where the timepoints from the first three waves (i.e., cort1, cort2, and cort3) are fixed to “0.” This specification prevents information from the first three waves from being absorbed into the estimation of the second growth factor (Diallo & Morin, 2015). This allows each piece to capture information across different phases of the trajectory.

### **Unique Benefits of the PLGCM to Biomarker Research**

The PLGCM is an alternative specification of the LGCM for researchers interested in capturing nonlinear change over time when there is knowledge as to the location of the bend in the trajectory (Kohli & Harring, 2013). The PLGCM is specifically relevant to the data collection protocol using the TSST since growth rates can be viewed as different phases—before and after the acute stressor.

### **Research Questions Related to the PLGCM**

Research Questions 1, 2, and 5 (see Table 1) are most relevant to this type of growth model. Akin to the basic LGCM discussed above, Questions 1 and 2 can also be addressed through the piecewise version of this model. Given that the location of the bend in the trajectory will be known when implementing the TSST, the PLGCM can provide more accurate insight into the rate and nonlinear change in cortisol. With the PLGCM, Question 1 can be addressed in two parts: rate of change in the reactivity period (first linear slope growth factor), and rate of change in the recovery period (second linear slope growth factor). Question 2 is addressed because the location of the bend in the trajectory is specified (rather than estimated) and can provide more accurate results regarding the growth trajectory. The PLGCM can also be easily extended to address Question 5 when assessing whether the piecewise growth curve acts as a predictor for any other health outcome. This notion falls into the inherent flexibility of the LVM framework.

### **LGCM for Two Parallel Processes**

Figure 8c presents a path diagram for the LGCM for two parallel processes [also referred to in the literature as the Bi-variate LGCM (Muniz-Terrera et al., 2017), multivariate LGCM (Bollen & Curran, 2004), multiple domain LGCM (B. B. M. Byrne & Crombie, 2003), and the associative LGCM (Bollen & Curran, 2004)]. This model is an alternative specification of the LGCM for researchers specifically interested in how the trajectories of two systems are related to one another (Cheong et al., 2003). In this example, trajectories for cortisol and alpha-amylase are simultaneously estimated through separate growth factors. In other words, there are two cortisol-specific growth factors (i.e., intercept and slope) and two alpha-amylase-specific growth factors estimated. The way that the trajectories of cortisol and alpha-amylase relate can now be modeled through the relationships of their specific growth factors. Figure 8c provides an example of how the relationships between the growth factors of these two biomarkers can be modeled. The direct paths between the latent growth factors of cortisol and alpha-amylase can be specified in any way to accommodate specific research questions about how these processes relate. Most importantly, the specification of the LGCM for two parallel

processes presented in Figure 8c is specified to estimate linear change of both processes. Because there will be nonlinear change in both cortisol and alpha-amylase due to the TSST, the LGCM for two parallel processes can be specified to account for nonlinear change. The LGCM for two parallel processes can also be specified to account for nonlinear growth change (e.g., quadratic or freely estimated slopes), or it can be combined with the PLGCM when the location of the bend in the trajectory is known. Ultimately, decisions for specifying the LGCM for two parallel processes should be driven by the research questions and data characteristics.

### **Unique Benefits of the Parallel Process LGCM to Biomarker Research**

The parallel process model is perhaps the most encompassing model that we describe here. This model shows potential to be most complex because any of the other LGCM variations we have discussed can be embedded within each process within this model (e.g., one process can include a mixture component, piecewise growth, etc.) The benefit of this model is that it allows researchers to be extremely malleable when research questions are being developed. There need not be a single outcome measure across time, and other elements (e.g., mixture components and nonlinear growth curve functions) can be embedded in different ways within each of the processes.

### **Research Questions Related to the Parallel Process LGCM**

Research Question 3 (see Table 1) is most applicable to the parallel process LGCM. This question deals with how two separate outcomes can relate over time. However, it is also important to note that the LGCM for two parallel processes can answer any of the other questions in Table 1 for each process simultaneously. The relationship between cortisol and alpha-amylase is explicitly modeled in how the growth factors for each process are related. Specifically, the LGCM for two parallel processes provides insight into how the baselines (i.e., intercept growth factors) and rates of change (i.e., slope growth factor[s]) are related in each system. Modeling how the growth factors of cortisol and alpha-amylase are related can provide more insight into how activation of the HPA-axis is related to activation of SAM system. For full details on how the LGCM for two parallel processes can be specified to address a range of questions, see Table 1. Finally, for an example of plotting two parallel process growth trajectories, see Figure 9c. In this figure, we can see that cortisol and alpha-amylase substantially vary in their growth patterns over time, even though the baseline assessment is comparable.

### **Model Fit and Assessment**

Model fit and assessment is typically an important part of implementing any type of LGCM. Model fit statistics are measures of how well a statistical model reflects the data. Model fit can be evaluated through two different classes of statistics: (1) absolute model fit, and (2) relative model assessment measures. The following sections will discuss the two classes of statistics and the types of questions that they can aid in answering when implementing LGCMs.

#### **Absolute Model Fit**

Absolute fit statistics are used to determine how well a statistical model reflects the data. This category includes the closeness-of-fit measures, badness-of-fit measures,

and the  $\chi^2$  goodness-of-fit test (Bentler, 1990; Bentler & Bonett, 1980). Closeness-of-fit measures include the comparative fit index (CFI) and the Tucker-Lewis index (TLI); there are many additional measures, but these are arguably the most common because they are reported in most LVM software. CFI and TLI values close to 1.0 indicate a statistical model that adequately reflects the data. Generally, CFI and TLI values above .96 (for CFI) or .95 (for TLI) reflect excellent fit and values of .90 reflect mediocre fit (Bentler, 1990; B. Byrne, 1994; Lomax & Schumacker, 2004). Badness-of-fit measures include the root mean square error of approximation (RMSEA) and the standardized root mean square (SRMS). RMSEA and SRMS values closer to zero indicate a statistical model that adequately reflects the data. Generally, RMSEA and SRMS values of .01 reflect excellent fit, values of .05 reflect good fit, and values of .08 reflect mediocre fit (MacCallum, Browne, & Sugawara, 1996). The  $\chi^2$  goodness-of-fit statistic indicates that a statistical model adequately reflects the data when the corresponding  $p$ -value is above the nominal .05 level. Caution should be exercised when interpreting the  $\chi^2$  goodness-of-fit statistic as the statistic is sensitive to sample size, with larger sample sizes sometimes erroneously indicating model misfit (Satorra & Saris, 1985). These measures can all be used to assess whether a model fits the data or not. Sometimes there are inconsistencies in the results, where some measures indicate the model fits the data and other measures do not. If this discrepant result occurs, it is imperative to reflect on the substantive information driving the model when assessing the final model. It should be noted that model fit indices may not perform equally across all models and all modeling contexts, and reliance on the rule-of-thumb cut-offs can yield misleading results (Barrett, 2007; Hayduk, Cummings, Boadu, Pazderka-Robinson, & Boulianne, 2007; Nylund, Asparouhov, & Muthén, 2007). For instance, Nylund et al. (2007) found that the correct number of mixtures in a growth mixture model were only identified by the bootstrap loglikelihood ratio test and the Bayesian information criterion. With this in mind, model selection and evaluation should not rely solely on these rules-of-thumb for absolute model fit. Rather, model evaluation should come from a combination of relative and absolute model fit, as well as how well the parameter estimates fit with previous literature or theory.”

### **Relative Model Assessments**

Relative model assessment indices are used to compare competing statistical models and include information criteria (IC) and likelihood-ratio tests. IC assessments include the Akaike information criterion (AIC; Akaike, 1981), the Bayesian information criterion (BIC; Schwarz, 1978), and the sample-sized adjusted BIC (saBIC), to name a few. IC values can be compared across two or more models, where the first represents the original model and the subsequent models represent competing models (varying to some degree from the original model). The statistical model with the lowest IC is then selected as the optimal model; i.e., the one reflecting the data patterns best. Likelihood-ratio tests can also be used to compare two models via  $\chi^2$ -difference test. The difference in  $\chi^2$  values between two models is calculated and compared to a  $\chi^2$  distribution with degrees of freedom equal to the difference in parameters estimated between the two models. A  $p$ -

value lower than the nominal .05 indicates that the models are significantly different from one another, and the model with the lower  $\chi^2$  value is then selected as the optimal model. Relative model assessment measures are especially useful when researchers are trying to determine whether to assess linear or nonlinear change in the LGCM. Researchers can estimate one LGCM that specifies a linear slope and another LGCM that specifies nonlinearity. Then the model assessment measures can be used to help the researcher determine the pattern of change that best reflects the data patterns being modeled.

### Statistical Programs to Estimate LGCMs

The estimation of LGCMs requires the use of statistical software programs capable of estimating LVMs. There are several statistical software packages used to estimate LGCMs that differ in modeling capabilities, complexity of the program, and price. Table 2 presents the modeling features of the most commonly used statistical software programs for estimating LGCMs (i.e., Amos, SAS, Stata, Mplus, EQS, and Lavaan through the R programming environment). The purpose of Table 2 is to provide the reader with relevant features of each program so that they can make a decision as to which program best meets their needs. We discuss and provide code for three different software programs: *Mplus* (Muthén & Muthén, 1998-2016), Amos (Arbuckle, 2014), and the R package Lavaan (R Core Team, 2018; Rosseel, 2012), with the latter being of no cost for users.

*Mplus* is one of the more flexible LVM programs. Researchers can evaluate change over time for any type of variable (i.e., continuous, binary, ordered-categorical, unordered-categorical, count, and censored). Furthermore, *Mplus* has multiple options for handling missing data, including full-information maximum likelihood and multiple imputation. Compared to the other programs presented in Table 2, *Mplus* is decidedly the most user-friendly with a website (<http://www.statmodel.com>) that contains example code for many different types of models. *Mplus* is also capable of more advanced modeling techniques such as estimating unobserved groups (i.e., latent mixture modeling) and Bayesian estimation. The cost of this program is \$1095 for an academic license, with an annual fee of \$175 to keep the license current and qualify for upgrade downloads when made available. Example code and contrived data to estimate each of the LGCM specifications in *Mplus* can be found in the online Appendix.

The next software package discussed is Amos (Arbuckle, 2014). Amos is another user-friendly program that has many of the same modeling capabilities as *Mplus*. Rather than relying on a syntax-based coding language like *Mplus* (and the R package, Lavaan, detailed next), Amos uses a graphical interface where the user specifies the model by drawing a path model using point-and-click tools. One limitation of Amos is that it is a more expensive program than other programs such as *Mplus*, with an annual fee starting at \$811.00 per license. Another limitation of Amos is that the modeling capabilities are less flexible than *Mplus*, where features such as multilevel modeling can be combined easily with LGCMs. However, data management in Amos can still be housed in SPSS file formats, which may be easier to manage than text and csv files required by *Mplus*. In

order to estimate the specifications of the LGCM discussed, a user is able to draw the models as they appear in Figures 3-8.

The final software package discussed is the R package, Lavaan. Lavaan has many of the same modeling capabilities as *Mplus*, but is a free program and provides the additional benefits of being part of the R programming environment (i.e., it is an open source program that is easily linked to other packages in R). One limitation of Lavaan is that it does not feature all of the modeling capabilities of *Mplus*, such as multiple imputation or Bayesian estimation. However, there are R packages designed to handle these issues that can be used alongside (or instead of) Lavaan, such as the R package MI (Su, Yajima, Gelman, & Hill, 2011) for multiple imputation and BLavaan (Merkle & Rosseel, 2016) for Bayesian estimation. While Lavaan is decidedly less user-friendly than other programs presented in Table 2, it is free and contains most of the modeling features of its more expensive counterparts. Example code and a contrived data set to estimate each of the specifications of the LGCM in Lavaan can be found in the online Appendix.

### Discussion

The aim of the current paper was to present LGCMs, in a user-friendly manner, which can answer research questions that are important and under-studied in the stress-related biomarker field. We discussed how to formulate and interpret findings from relevant LGCMs, and showed how easy they are to implement by including sample code for a variety of models.

LGCM methodology provides advantages to researchers interested in studying change over time of biomarkers of the stress response. The LGCM provides insight into the rate at which a variable changes over time through the specification of latent growth factors. Latent growth factors answer questions about the rate of change of a variable, and how that rate of change relates to other variables. Different specifications of the LGCM were selected to address specific research questions developed through the context of the TSST; namely, the basic LGCM, the multi-group growth model, the PLGCM, and the LGCM for two parallel processes. We also presented a description of a selection of the most commonly used statistical software programs available to estimate LGCMs. Our hope is to help researchers identify research questions that can be better handled through this flexible modeling framework.

### Cautions for All LGCM-Based Approaches

Model specification is an important issue within any sort of modeling framework. In the case of latent growth models, there are many features that one must be aware of when specifying the model. If, for example, the nonlinear function incorporated into the model is not representative of the patterns in the population, then substantive results may be impacted with this specification error embedded. Likewise, there is a part of the model that controls how related measures for the same subject are at different times, as well as how related (if at all) observations for different subjects are allowed to be. These elements in the model are controlled through within-individual and between-individual covariance matrices. The researcher can control whether time-points or people are



allowed to covary through the manipulation of these matrices. Wu and West (2010) found that misspecification in the within-individual or the between-individual covariance structure can impact model fit statistics and change substantive conclusions. Therefore, it is always important to examine the specification of the model carefully and fully report the settings used to aid in interpretation of findings; see van de Schoot et al. (2017) for more details surrounding proper specification and reporting of latent growth models.

Applied researchers are often understandably concerned with whether a growth model specified actually fits the data patterns. For example, a researcher could specify a quadratic-shaped growth curve and examine whether it fits reasonably well compared to other growth shapes. In this case, a researcher would likely use model comparison measures (e.g., AIC or BIC) to make that assessment. One point of caution specific to growth models is that fit assessment does not just arise at the model-level. It is also possible to examine person-level fit, to see how well each individual's trajectory fits along with the specified model. One issue that can arise in nonlinear growth is that one form of nonlinearity (e.g., quadratic) may fit the full data best, but it could be that this growth shape is not what represents the bulk of individual growth trajectories. As an example, it is possible to have a quadratic model fit the full data set best, but have most of the individual trajectories follow a linear trajectory. In this case, there is a mismatch between overall and person-level fit with respect to the optimal model to select for interpretation. In this case, it is imperative to fully report findings and any discrepancy yielded. For more information on person-level fit, see Coffman and Millsap, (2006).

### **Conclusion**

In summary, the LGCM and its various specifications is one tool in an array of quantitative methodologies for the study of change over time in biomarkers of the stress response. The choice of proper statistical methodology should be driven by a number of factors, including the research question and the sample size. The methods described in this article provide a perspective that can be of great relevance to stress researchers. The purpose of this paper was to increase awareness of LGCMs and how they can be useful to stress researchers investigating biomarkers. The accessibility of more statistical methods permits the continued evolution and development of the types of research questions that can be asked.

## Chapter 5 General Discussion

The primary purpose of this dissertation was to determine whether a link between stress and mental abstraction existed. In order to do this, an experiment was developed using the Trier social stress test (TSST) and a control group designed specifically for this study. As described in Chapter 2, the control group did not affect stress reactivity as measured by heart rate and blood pressure. Additionally, a small pilot test in Chapter 3 revealed that the control group did not affect levels of mental abstraction, deeming it appropriate to use in the primary study. The primary study revealed a link between stress and mental abstraction, suggesting that stress does affect how information is processed.

Exposure to a stressor lead to higher levels of mental abstraction. This is in contrast to previous work on the effects of mood on mental abstraction, where negative mood leads to lower levels of mental abstraction (Bless & Burger, 2017). However, it appears that negative mood associated with stress may impact how information is processed differently. Research on stress and executive functioning suggest that stress leads to more automatic processing to facilitate survival (Shields et al., 2016), which better matches the results from this dissertation. However, it is possible that additional meta-cognitive processes are responsible for the findings.

Processing fluency is a potential mechanism explaining the results. Processing fluency is a meta-cognitive feeling caused by the ease of processing information (Alter & Oppenheimer, 2009). All information is processed in a range from high fluency (i.e., easy to process and requiring little effort) to low fluency (i.e., difficult to process and requiring extra effort). It is possible that the more abstract choices on the mental abstraction questionnaire were chosen because they were easier to process. Future stress inquiries may benefit from incorporating processing fluency into their studies. Additionally, alternative measures of mental abstraction are necessary to disentangle the effect processing fluency might have on the mental abstraction questionnaires.

A major strength of this study was the strong experimental design. The control group was carefully developed to closely resemble the stress condition. The control group did not elicit a physiological or emotional stress response, nor did it affect mental abstraction. This permitted the isolation of the effect of interest and helped rule out some potential confounds (Shadish et al., 2002). While this study used a strong experimental design, there are some important limitations to consider. First, mental abstraction was measured after the stressor and not during. It is possible that the relationship between stress and mental abstraction could be different during the stressor than it is after the stressor. The second limitation is how stress reactivity was operationalized. In this study, stress reactivity was defined as the difference between pre- (T2) and post- (T4) stress measures. A different operationalization of stress reactivity may have yielded different results for the physiological measures. Future studies should attempt different approaches when modeling stress reactivity.

In chapter 4, a methodological framework was proposed to model stress reactivity and investigate relationships with various outcomes, including mental abstraction (Felt et al., 2017). In this chapter, latent variable models are described that operationalize stress reactivity as a latent variable. This alternative modeling framework provides insight into the trajectories of the stress response taking into consideration individual differences. In

this framework, multiple stress processes can be modeled simultaneously, and the differential impact of each processes can be assessed. Additionally, future research should investigate momentary stressors using ecological momentary assessment (EMA). EMA allows researchers to study processes as they occur in the moment rather than in a laboratory setting. One benefit of EMA's is that they can help disentangle between- and within-person processes, shedding light onto the how and why of phenomena (Smyth & Stone, 2003; Zawadzki et al., 2017).

In sum, this dissertation identified a potential link between stress and the way individuals perceive the world. This was the first study to investigate a link between stress and mental abstraction, and it provided insight to a potential link between stress and psychological and behavioral processes. Regardless of the mechanism through how stress affects scores on the mental abstraction questionnaire, this study demonstrated that stress can affect the way information is processed.

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Table 1a: Participant Characteristics

	TSST (n = 100)	c-TSST (n = 67)
Age (M±SD)	20.05 (1.26)	20.1 (1.43)
Gender (%)		
Male	26.5	19.1
Female	71.6	79.4
Ethnicity (%)		
African-American	2.9	2.9
Asian/Pacific Islander	20.6	19.1
Caucasian/White	7.8	11.8
Hispanic/Latino	56.9	54.4
Bi-racial	3.9	4.4
First Generation College (%)	68.6	72.1
Academic Standing (%)		
Freshman	42.2	39.7
Sophomore	19.6	23.5
Junior	12.7	16.2
Senior	19.1	20.6
BMI (M±SD)	25.05 (5.22)	25.12 (4.99)
BDI (M±SD)	28.01 (5.79)	29.19 (7.17)
PTSD Diagnosis (%)	2.0	2.9
Anxiety Disorder (%)	12.7	17.6
Hormonal Contraceptive (%)	17.5	23.9
Medication (%)		
Cortisol	1	1.5
Anti-Depressants	2.9	4.4
Anti-Anxiety	1	10.3
Recreational Drug Use (%)	10.8	7.5
Physical Activity Level (M±SD)	4.44*	4.15*

Note: \* indicates a physical activity level between running less than 1 mile per week to as many as 5 miles per week or fewer than 30 minutes to 3 hours of equivalent exercise per week.

Table 1b: Full responder participant characteristics

	TSST (n = 62)	c-TSST (n = 67)
Age (M±SD)	20.04 (1.30)	20.1 (1.43)
Gender (%)		
Male	28.6	19.1
Female	69.8	79.4
Ethnicity (%)		
African-American	4.8	2.9
Asian/Pacific Islander	25.4	19.1
Caucasian/White	7.9	11.8
Hispanic/Latino	50.8	54.4
Bi-racial	4.8	4.4
First Generation College (%)	69.8	72.1
Academic Standing (%)		
Freshman	42.9	39.7
Sophomore	25.4	23.5
Junior	9.5	16.2
Senior	20.6	20.6
BMI (M±SD)	24.84 (4.80)	25.12 (4.99)
BDI (M±SD)	27.73 (6.17)	29.19 (7.17)
PTSD Diagnosis (%)	1.6	2.9
Anxiety Disorder (%)	14.3	17.6
Hormonal Contraceptive (%)	17.5	23.9
Medication (%)		
Cortisol	1.6	1.5
Anti-Depressants	4.8	4.4
Anti-Anxiety	1.6	10.3
Recreational Drug Use (%)	9.5	7.5
Physical Activity Level (M±SD)	4.36*	4.15*



Table 2b: Parameter estimates for Path models including physiological measures

Model	Path	beta	p value	R <sup>2</sup>	X <sup>2</sup> (df = 9)	X <sup>2</sup> p-value	CF I	RMSEA A
Model 3					100.46	< .001*	1	0*
	BIF ON			0.074				
		Conditio n	0.284	0.019*				
		SBP	0.017	0.897				
	SBP ON			0.499				
		Conditio n	-	<.001*				
	Indirect Effect		0.012	0.898				
	Total Effect		0.272	0.001*				
Model 4					145.81	<.001*	1	0*
	BIF ON			0.103				
		Conditio n	0.049	0.735				
		DBP	0.281	0.069				
	DBP ON			0.636				
		Conditio n	-	<.001*				
	Indirect Effect		0.221	0.08				
	Total Effect		0.271	0.002*				
Model 5					52.56	<.001*	1	0*
	BIF ON			0.079				
		Conditio n	0.228	0.022*				
		HR	0.085	0.325				
	HR ON			0.269				
		Conditio n	-	<.001*				
	Indirect Effect		0.043	0.304				
	Total Effect		0.272	0.002*				

Note: BIF = Behavioral identification form; SBP = Systolic blood pressure; DBP = Diastolic blood pressure; HR = Heart rate.

\* indicates statistically significant effect at  $\alpha = .05$ .

Table 1c: Types of questions each specification of the LGCM can address

Question	Basic LGCM	LGMM	PLGCM	LGCM for 2 Parallel Processes
1. What is the continuous rate of change in cortisol?	Provides information on the rate of cortisol change throughout the study. When nonlinear slopes are specified, gives insight into the rate of the nonlinearity present.	Provides information on how the rate of change in cortisol differs across unobserved groups.	Provides information on the rate of cortisol change during the baseline phase (slope 1) and the recovery phase (slope 2)	Provides information on the rate of change for two processes (i.e., cortisol and alpha-amylase), whether linear or nonlinear
2. What does the change in cortisol look like over time	Can gain insight into the stress reaction and the recovery period through the specification of nonlinear growth factors.	Provides information on how the trend differs across unobserved groups (e.g., linear in one group and quadratic in another).	Can evaluate the change in cortisol over time for the baseline and recovery periods separately.	Can address in the same way as the basic LGCM, LGMM, and PLGCM depending on specification. Addresses these question for each process and provides insight into how they are related across processes.
3. How do cortisol and alpha-amylase relate over time?	Can evaluate growth of cortisol and alpha-amylase through a multivariate LGCM or can control for the effect of alpha-amylase at each measurement of cortisol.	Provides information into how these relationships differ across unobserved groups.	Can evaluate growth of cortisol and alpha-amylase through a multivariate PLGCM or can control for the effect of alpha-amylase at each measurement of cortisol.	Evaluates how activation of each system is related through relationships specified between growth factors of each system.
4. Are there (observed or unobserved) group differences in the rate of change in cortisol?	Can control for the effects of a grouping variable (i.e., time-invariant covariate) or can compare the trajectories and rates of changes of each group.	Can evaluate differences in the trajectories and rate of changes for unobserved groups (e.g., extreme responders vs normal responders)	Can control for the effects of a grouping variable (e.g., gender) or can compare the trajectories and rates of changes of each group.	Can control for the effects of a grouping variable (e.g., gender) or can compare the trajectories and rates of changes of each group.
5. Does the rate of change in cortisol predict health outcomes?	Can answer whether the rate of change in cortisol affects a health outcome (e.g., the number of medical office visits)	Provides insight into how cortisol predicts health outcomes may differ across unobserved groups	Can answer whether the rate of change in cortisol at baseline or recovery affects a health outcome (e.g., the number of medical office visits).	Same as the basic LGCM and the PLGCM, except can now include how the rate of change in alpha-amylase also affects health outcomes (e.g., the number of medical office visits).

Note: LGCM = latent growth curve model; PLGCM = piecewise LGCM, LGMM = latent growth mixture model

Table 2c: Statistical methods for assessing growth and the software that can estimate these models

Method	SPSS: AMOS v. 23	SAS PROC CALIS v. 9.4	STATA v. 14	Mplus v. 7.4	EQS v.6.3	R: Lavaan** v.0.5-20
Latent Growth Curve Model	X	X	X	X	X	X
Latent Growth Mixture Model	X	X	X	X		
Data Types						
Continuous	X	X	X	X	X	X
Binary	X	X		X	X	X
Ordered-Categorical	X	X		X	X	X
Unordered-Categorical				X		
Count			X	X		X
Estimator						
ML/MLR	X	X	X	X	X	X
WLS/WLSM/WLSMV/A						
DF		X	X	X		X
Bayesian	X	X	X	X		X
Missing Data						
Full-Information Maximum Likelihood	X		X	X	X	X
Multiple Imputation	X	X	X	X	X	
Price of Program (In USD)*						
Annual Academic License	811	9200	445	175	NA	Free
Perpetual Academic License	1840	NA	895	1095	595	Free

\*All prices are for the full versions of each program as of June 2016. In some instances, removing some features can reduce the cost of the program.

\*\* R package Blavaan is a Bayesian extension of the R package Lavaan

Figure 1a: Average change over time of Systolic Blood Pressure in the TSST and the c-TSST

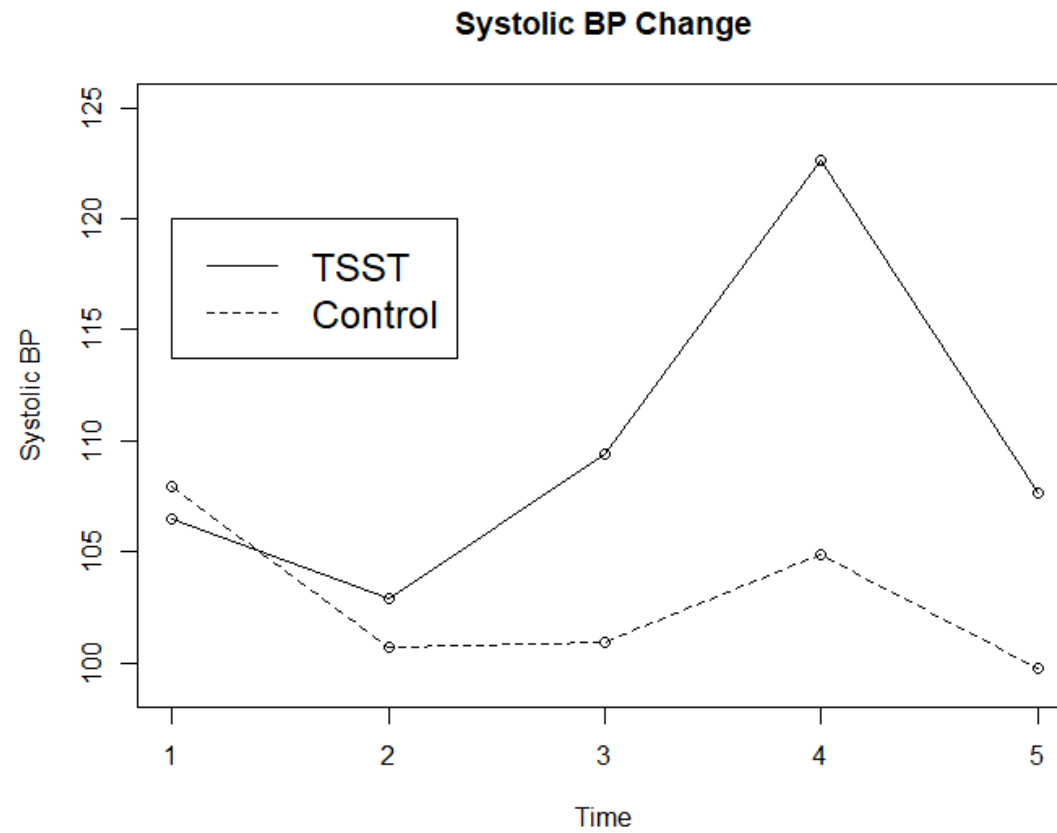


Figure 2a: Average change over time of Diastolic Blood Pressure in the TSST and the c-TSST

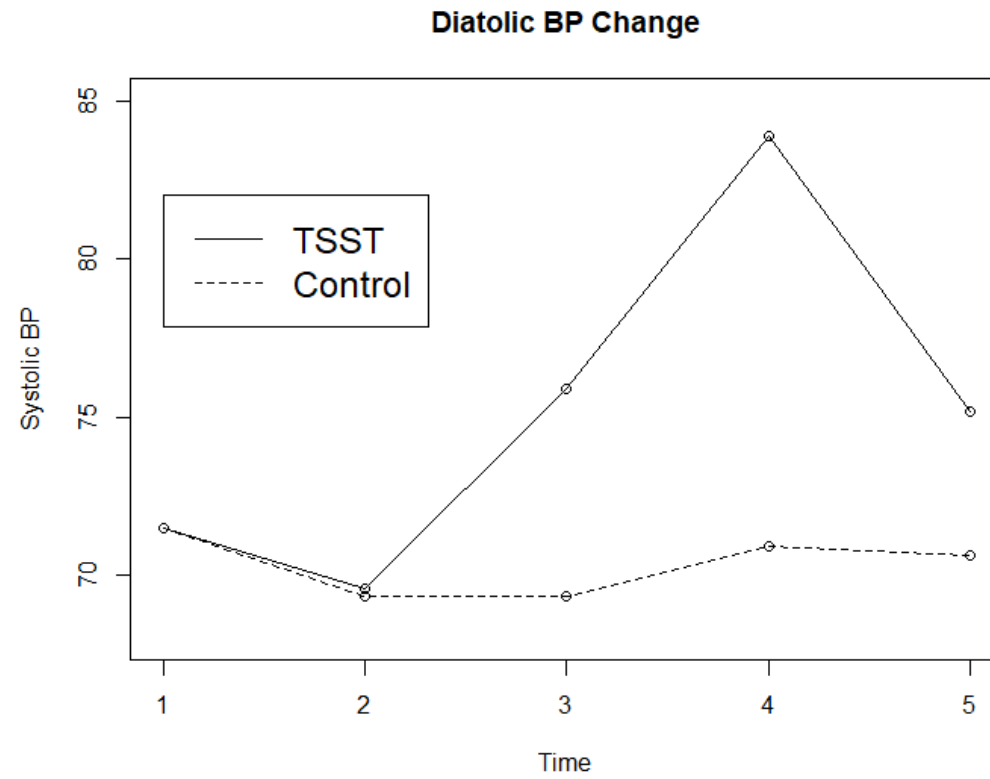


Figure 3a: Average change over time of Hear Rate in the TSST and the c-TSST

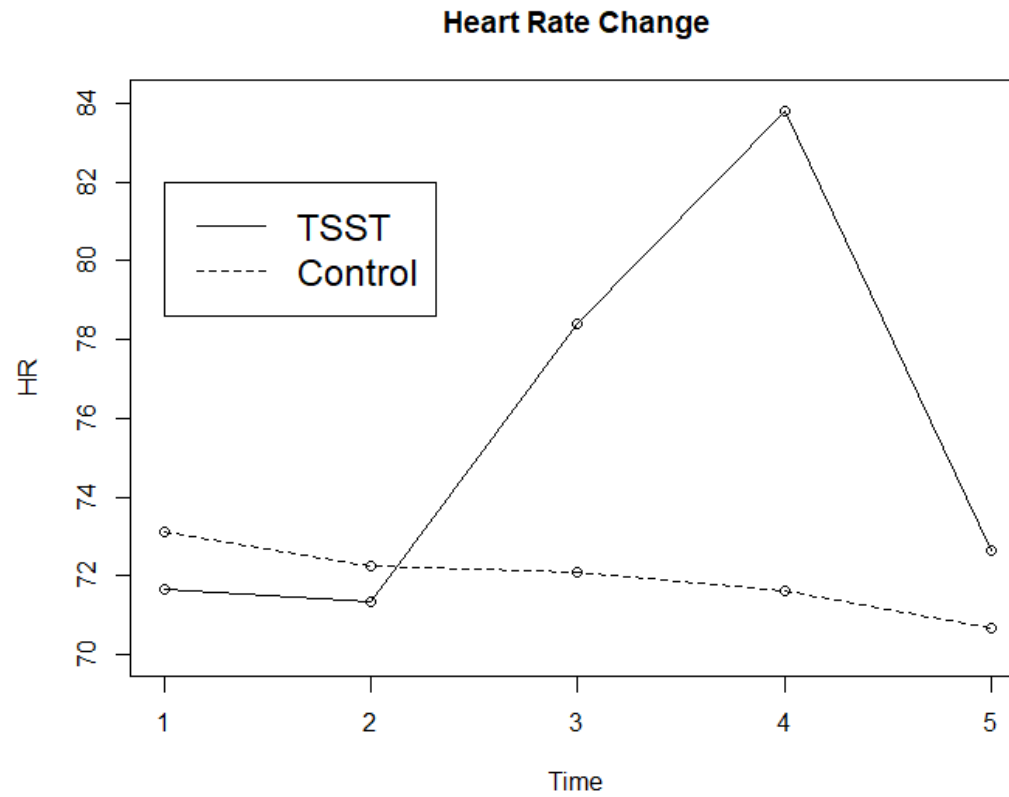


Figure 1b: Average change over time of Systolic Blood Pressure in the TSST and the c-TSST

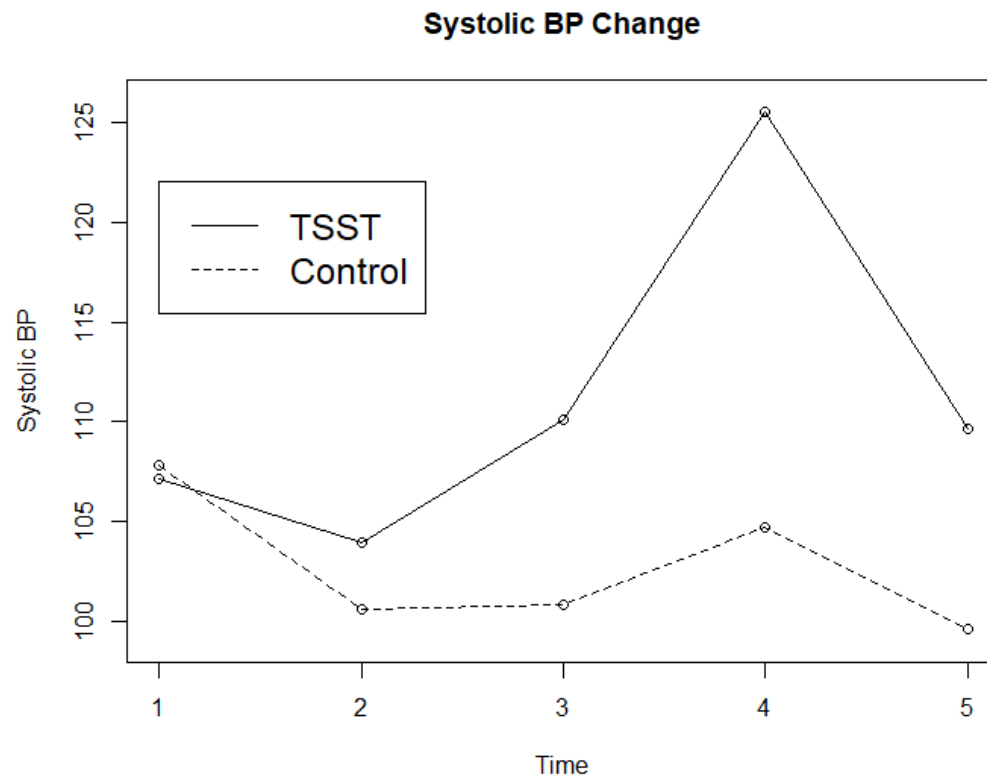


Figure 2b: Average change over time of Diastolic Blood Pressure in the TSST and the c-TSST

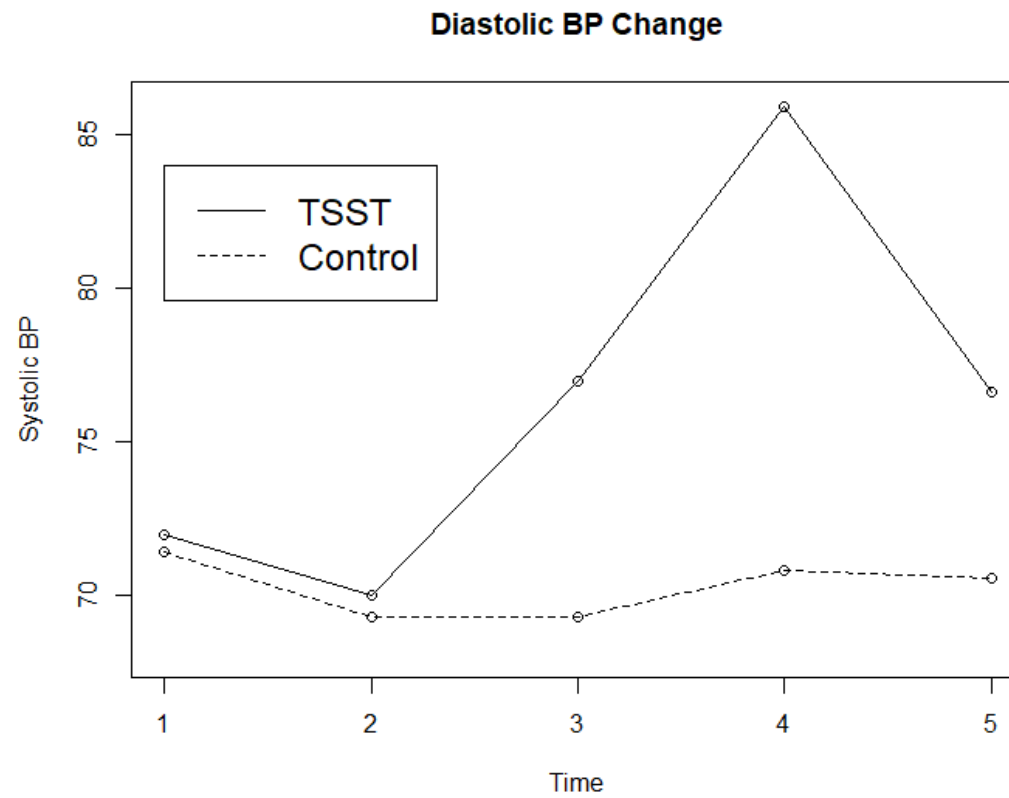




Figure 3b: Average change over time of Heart Rate in the TSST and the c-TSST

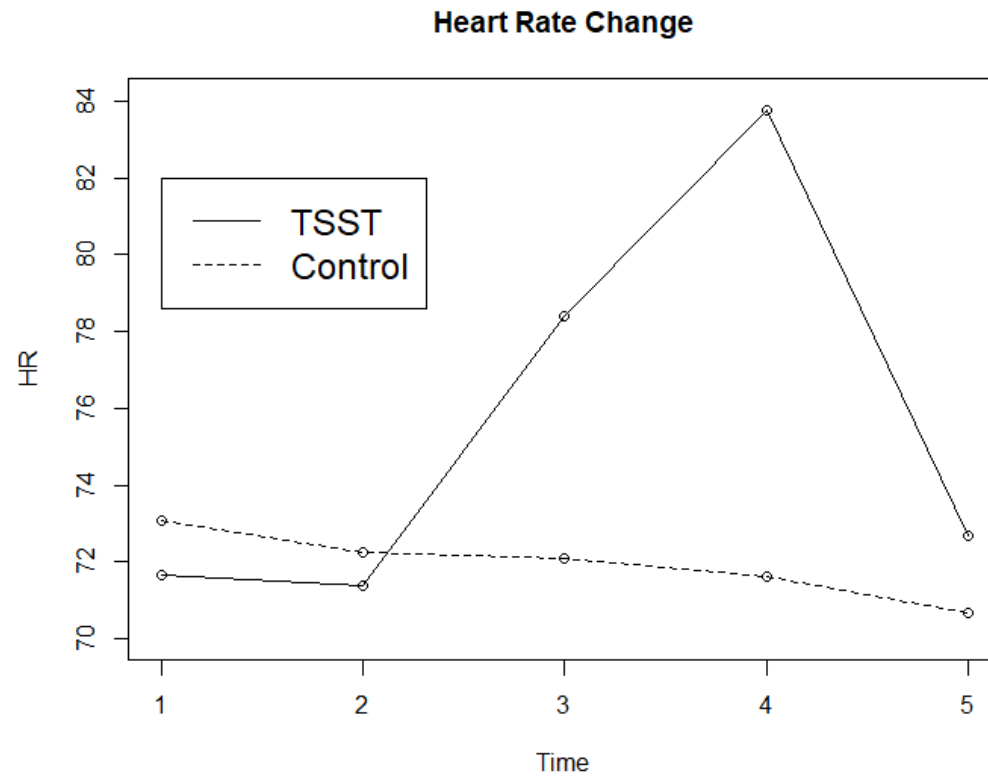


Figure 4b: Average change over time of Negative Affect in the TSST and the c-TSST

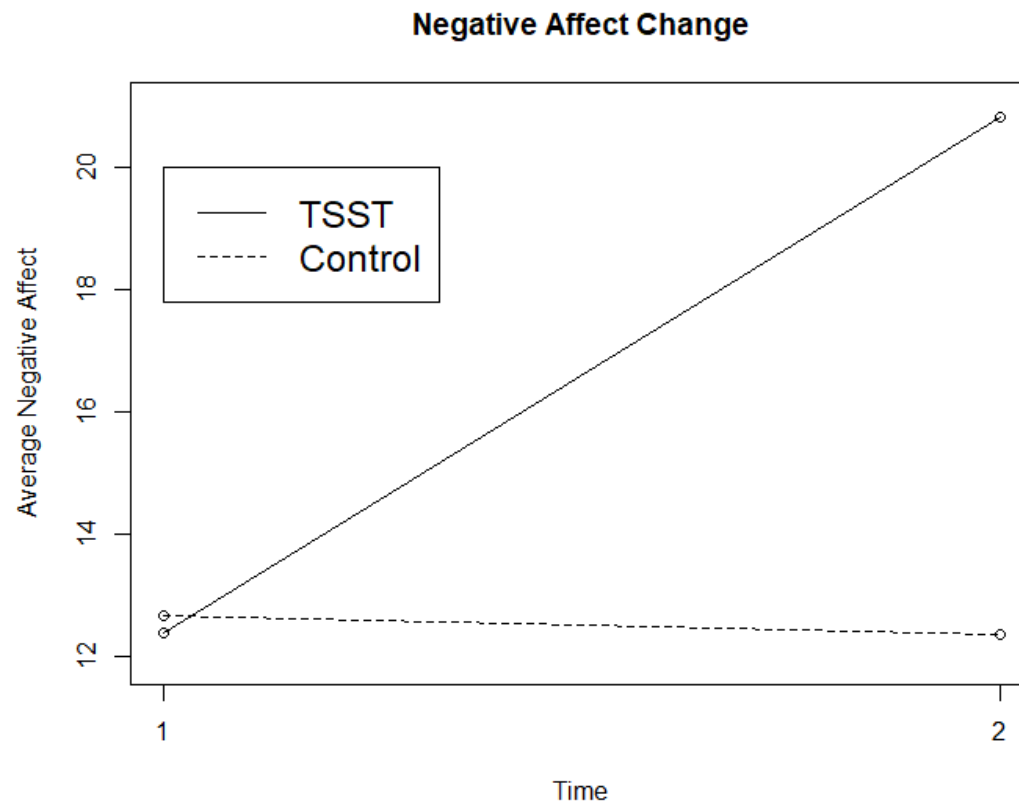
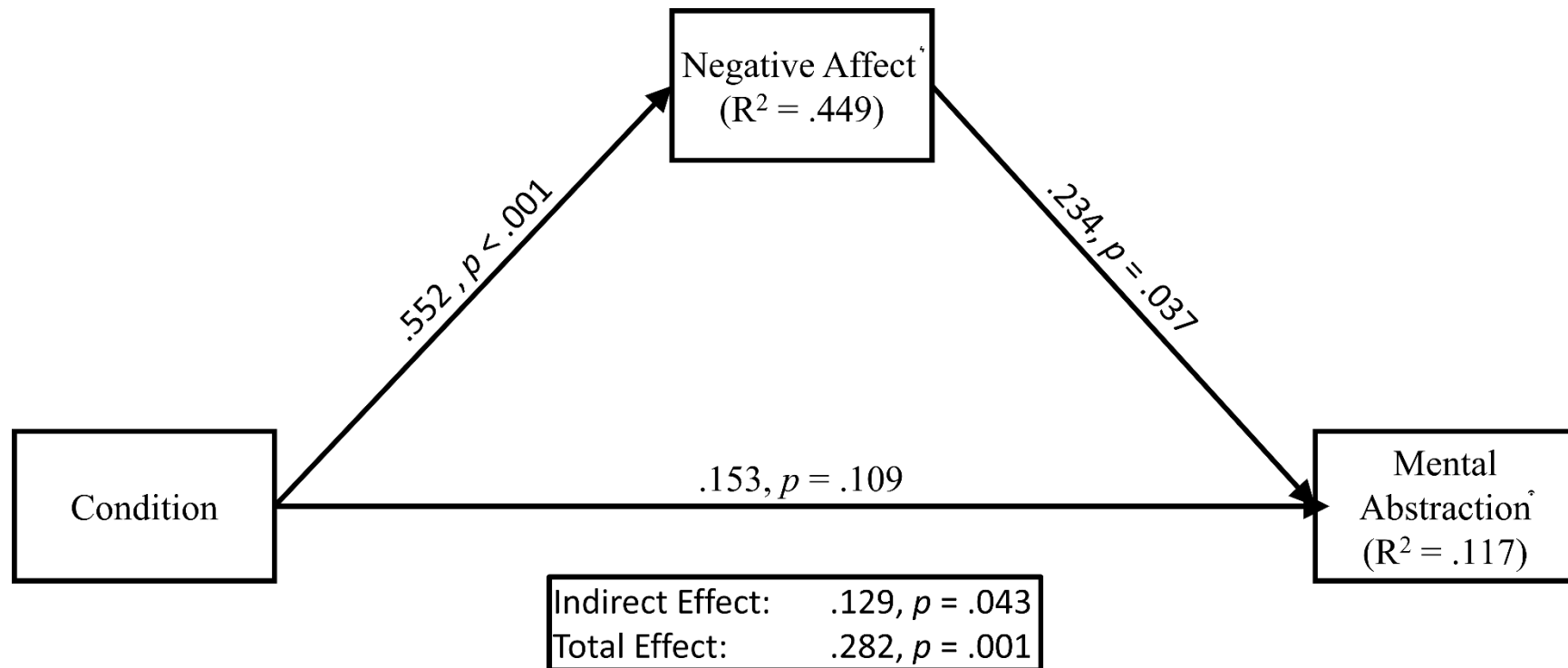


Figure 5b: Path model depicting relationships between exposure to a stressor, negative affect, and mental abstraction with standardized beta coefficients



Note:  $\hat{\cdot}$  Controlled for negative affect before the stressor and BMI.  $\hat{\cdot}$  Controlled for dispositional mental abstraction

Figure 1c: Number of each statistical method used to analyze cortisol or alpha-amylase in the journal *Health Psychology* from 2000-2017. Latent variable models have only been used in a single publication in this context dating back to 2010.

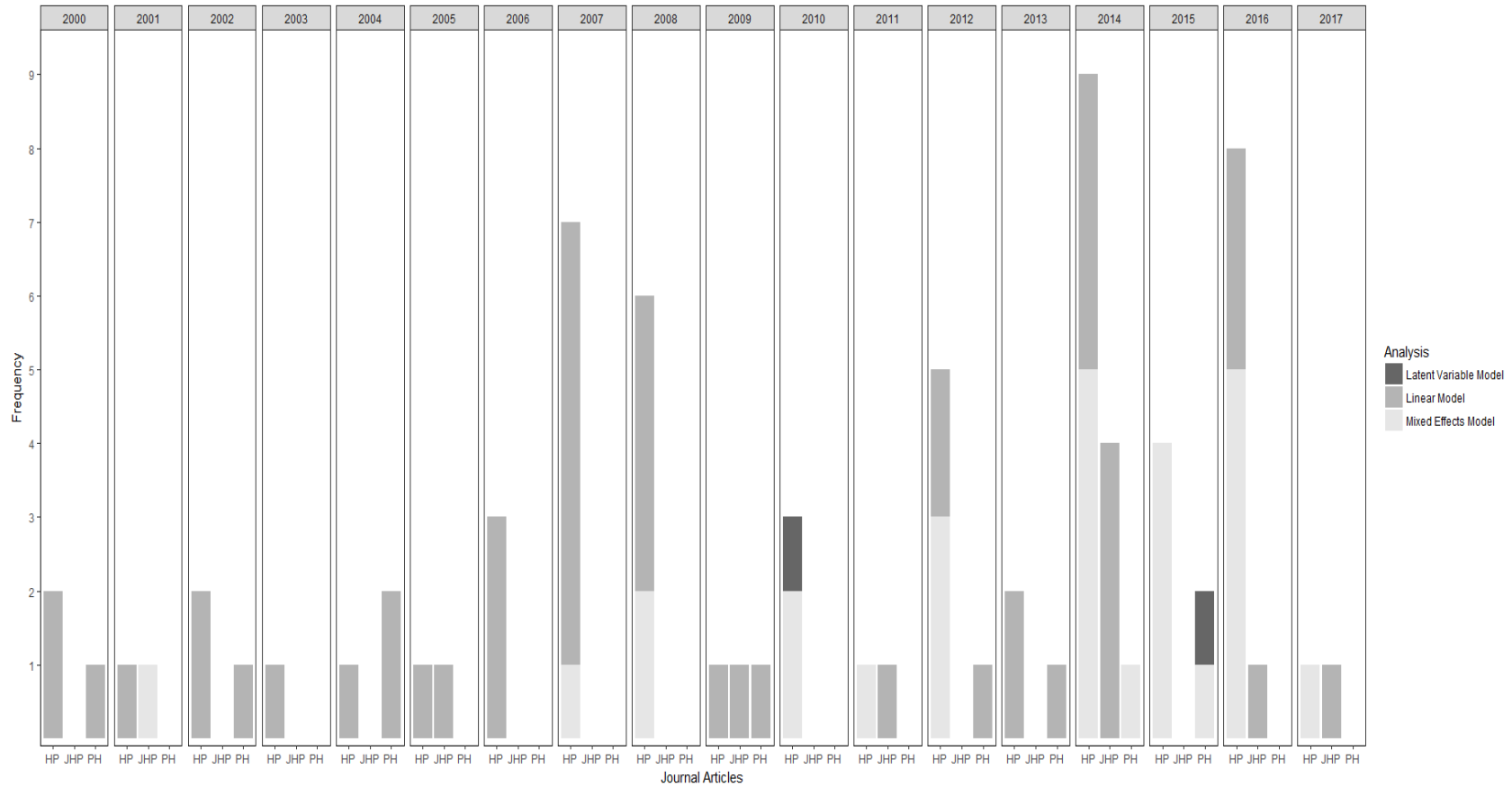


Figure 2c: Example trajectory plot for a Latent Growth Curve Model (LGCM). Each line (or trajectory) represents an individual persons growth trajectory across time. In the case of the example, this could be how the stress response (i.e., outcome measure) changes over-time across longitudinal measurements of data.

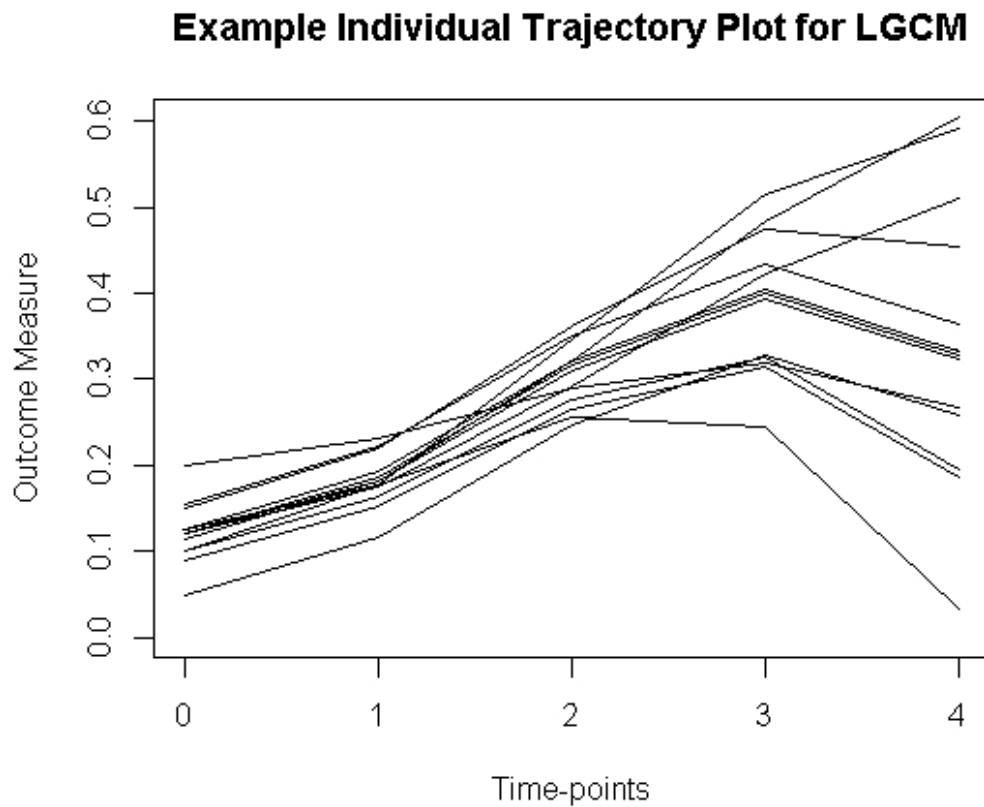
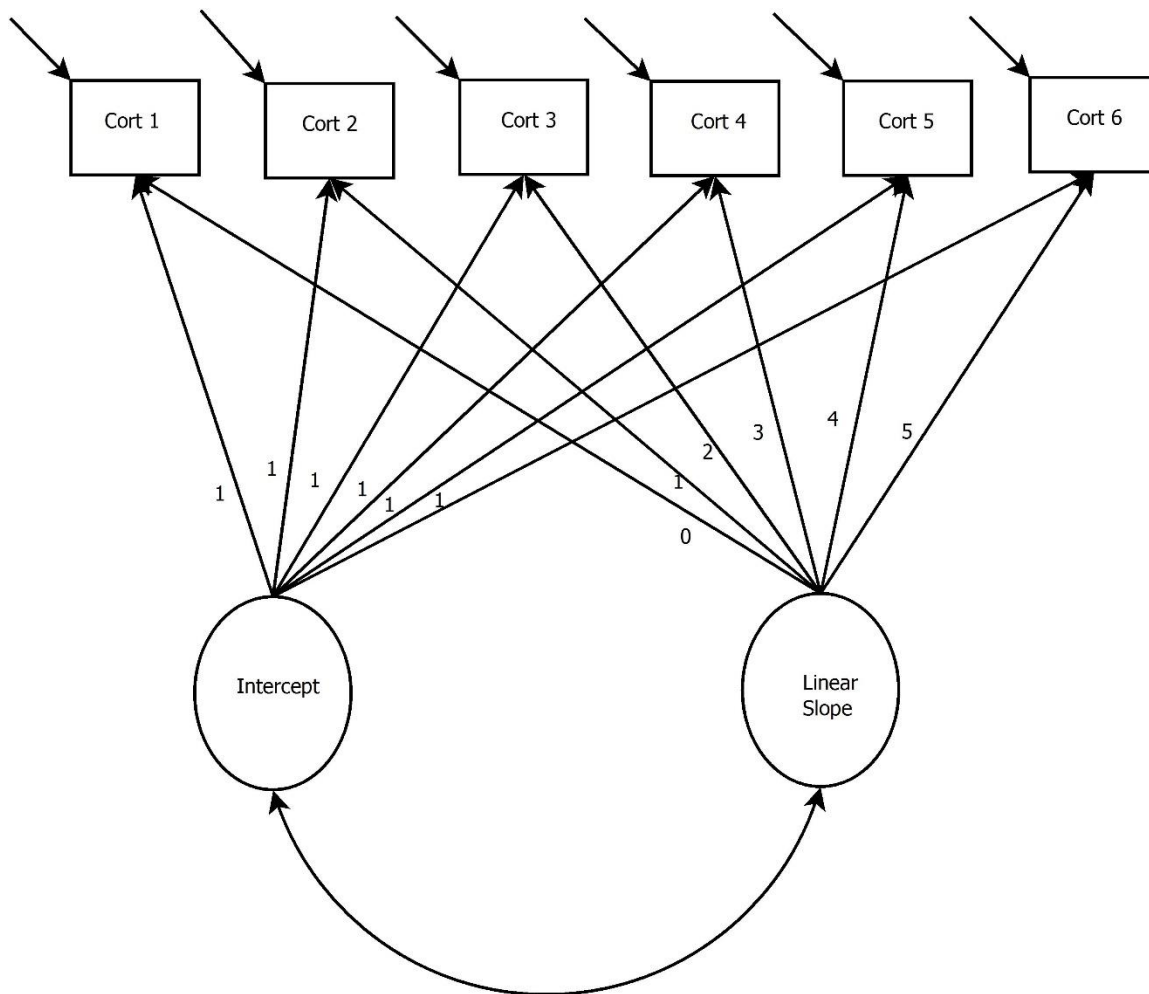
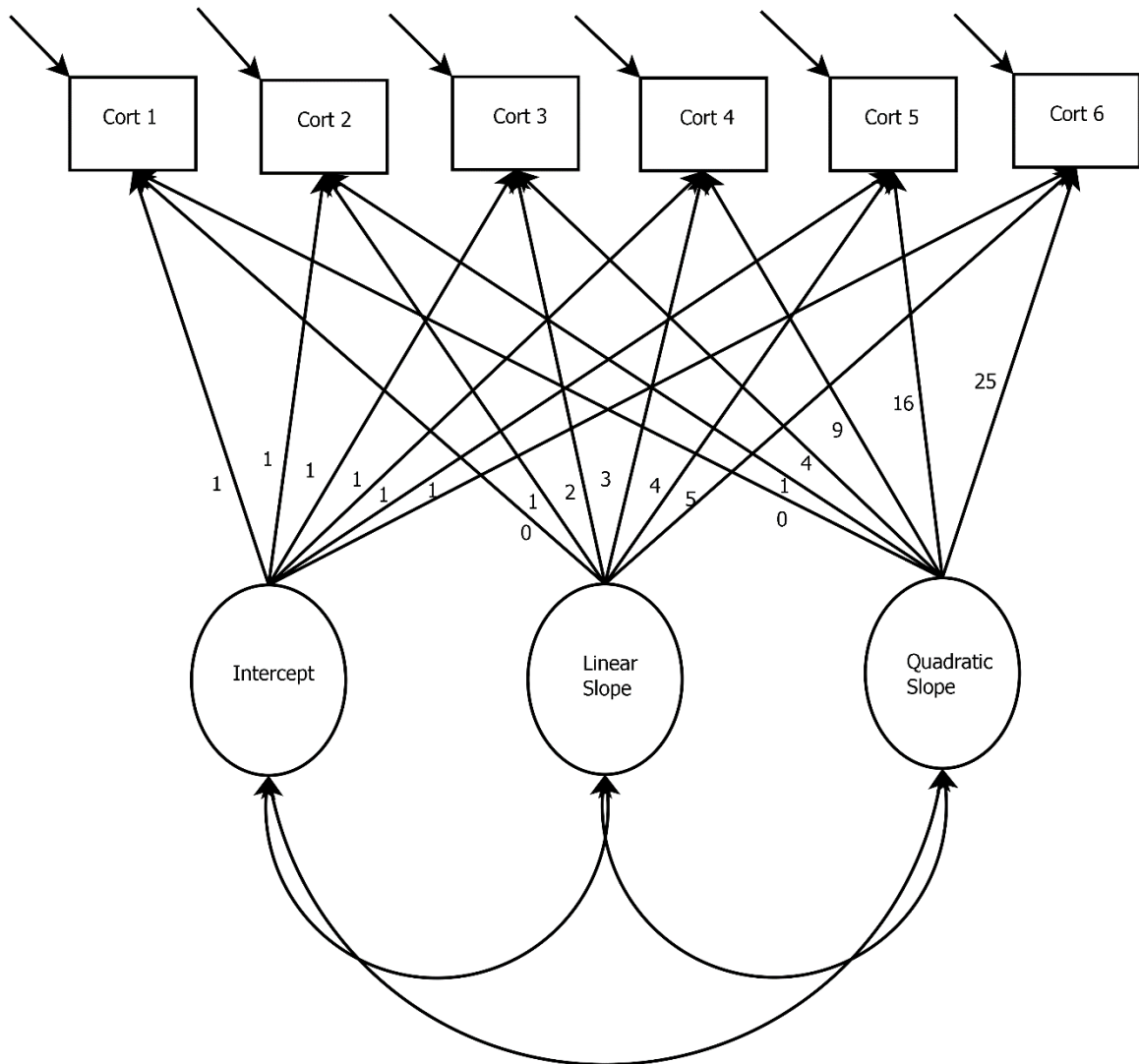


Figure 3c: Latent Growth Curve Model with a Linear Slopes



*Note: Cort = Cortisol measurement occasion*

Figure 4c: Latent Growth Curve Model with Linear and Quadratic Slopes



*Note: Cort = Cortisol measurement occasion; Alpha = Alpha-amylase measurement occasion.*

Figure 5c: Latent Growth Mixture Model: In this specification, there is a linear and a quadratic trend estimated, but the relationships can differ across latent groups (c). Note that groups can also be observed (e.g., gender) rather than latent.

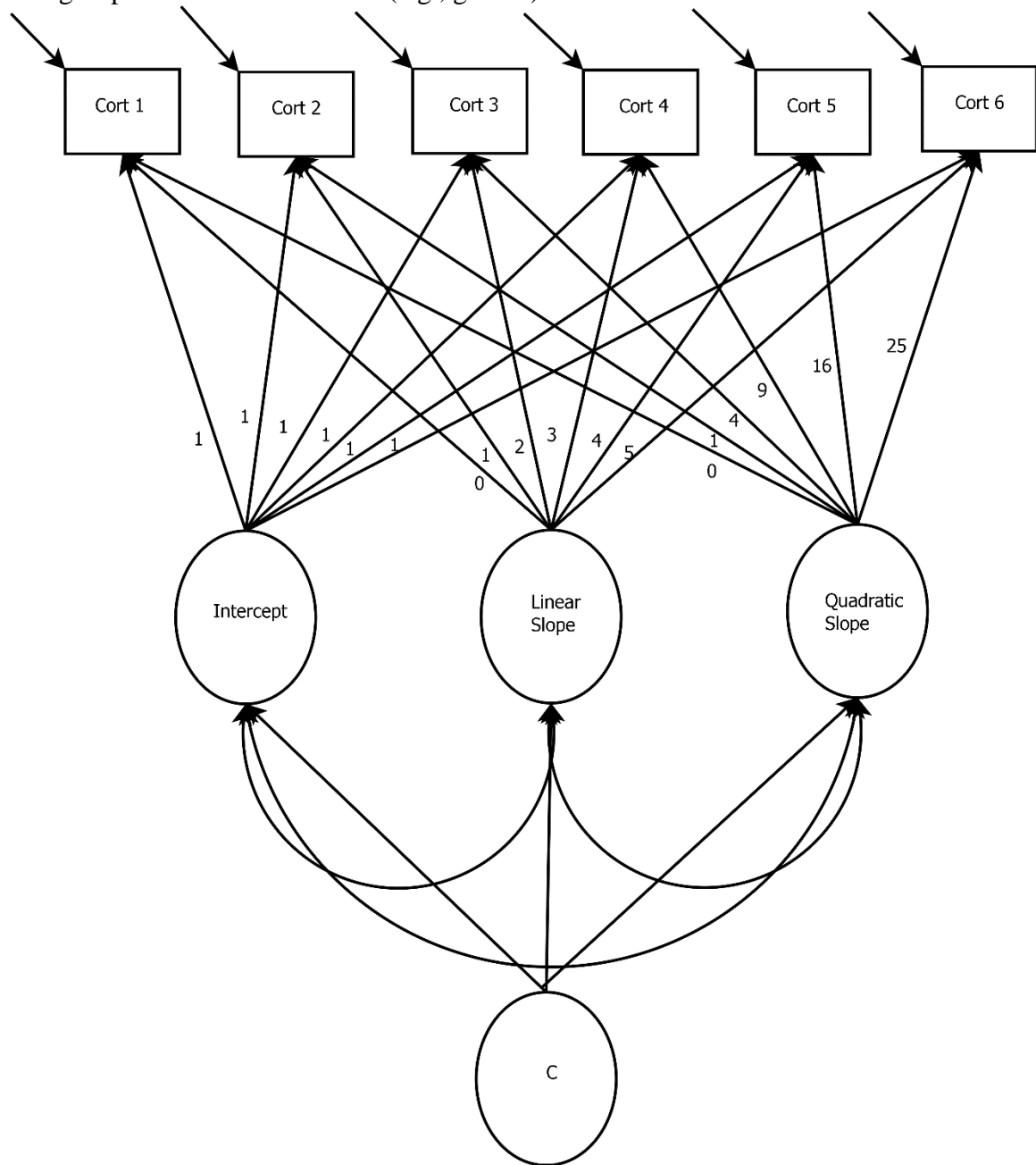




Figure 6c: Trajectories for multiple groups (observed or unobserved)

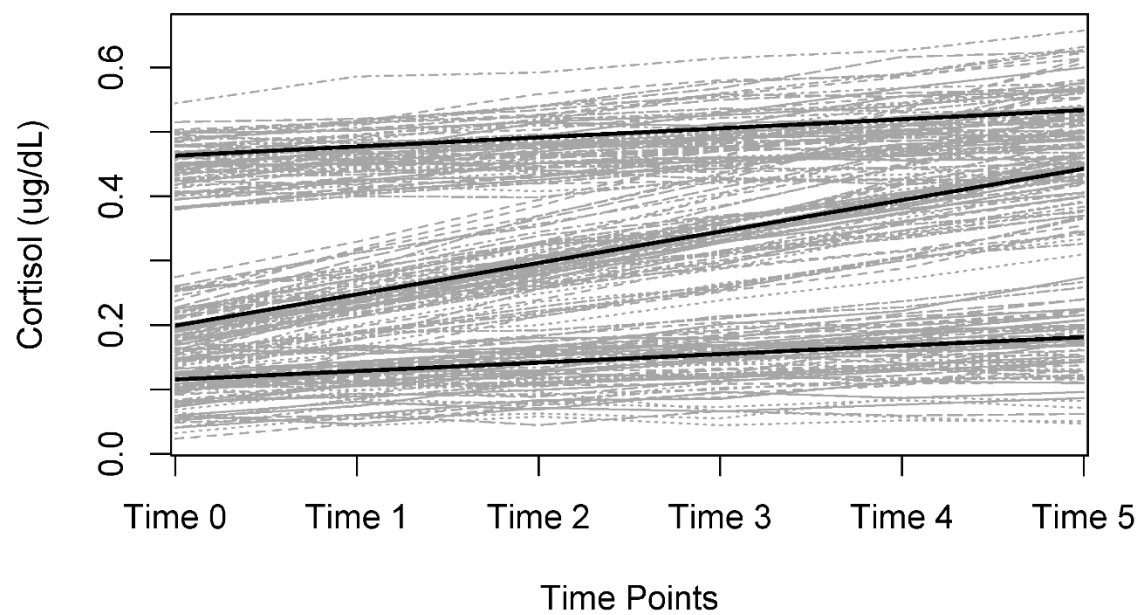
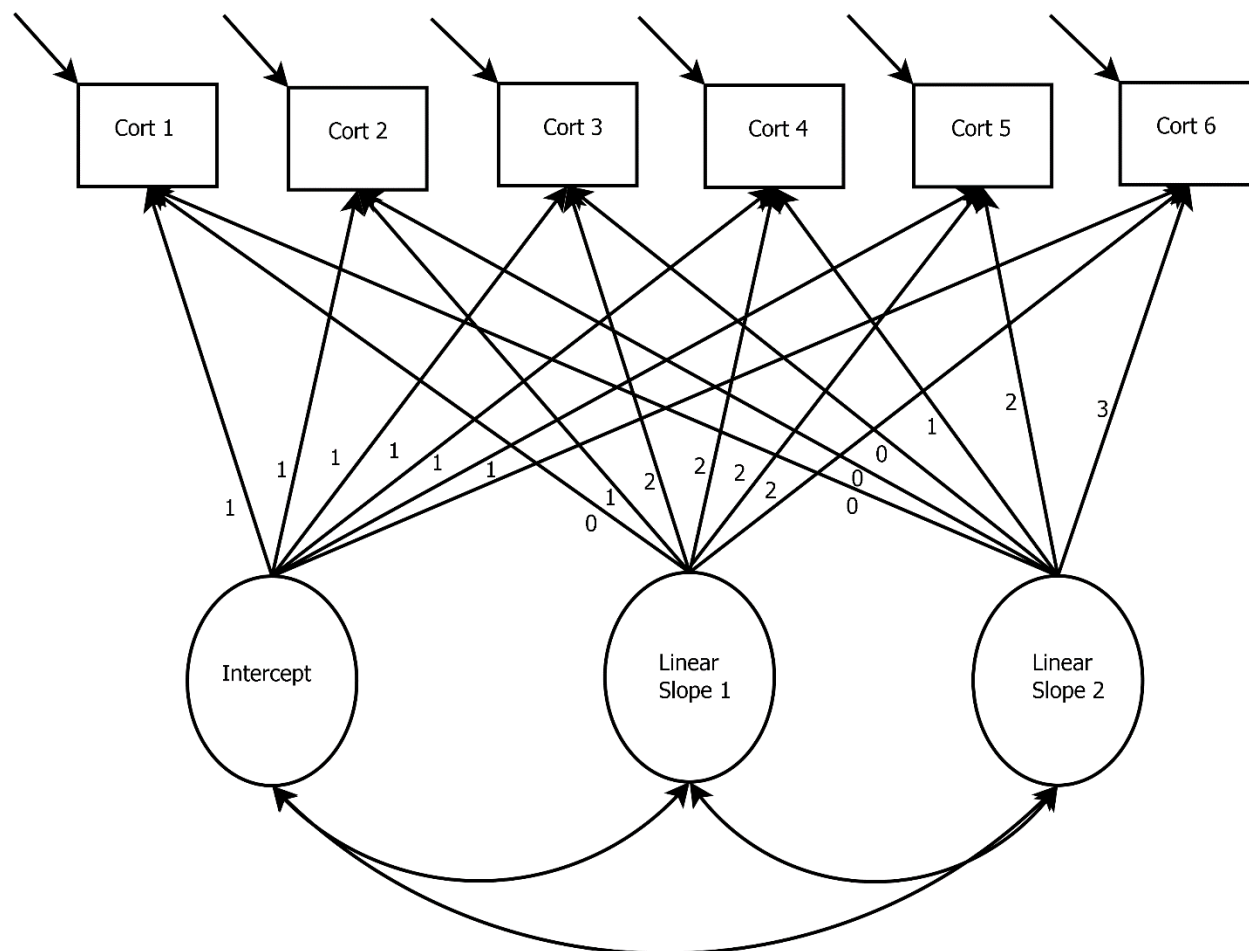
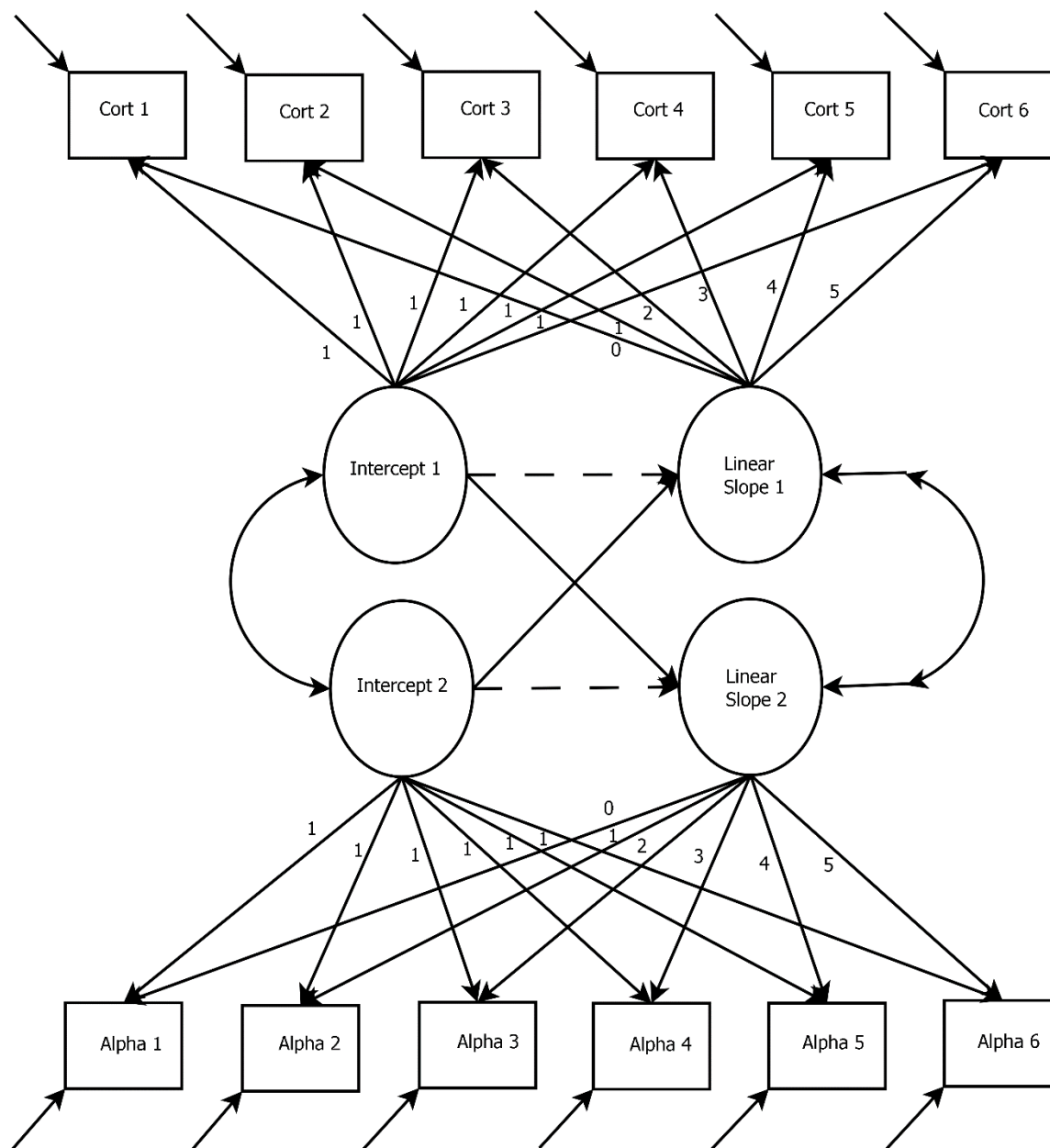


Figure 7c: Piecewise Latent Growth Curve Model. In this specification, there are two phases being modeled, Phase 1 (cort1, cort2, and cort3) and Phase 2 (cort 4, cort 5, and cort 6). This relationship is defined through the slope paths. Phase 1 represents the time-points before the onset of the TSST (i.e., the baseline period), whereas Phase 2 represents the time-points after the onset of the TSST (i.e., the recovery period).



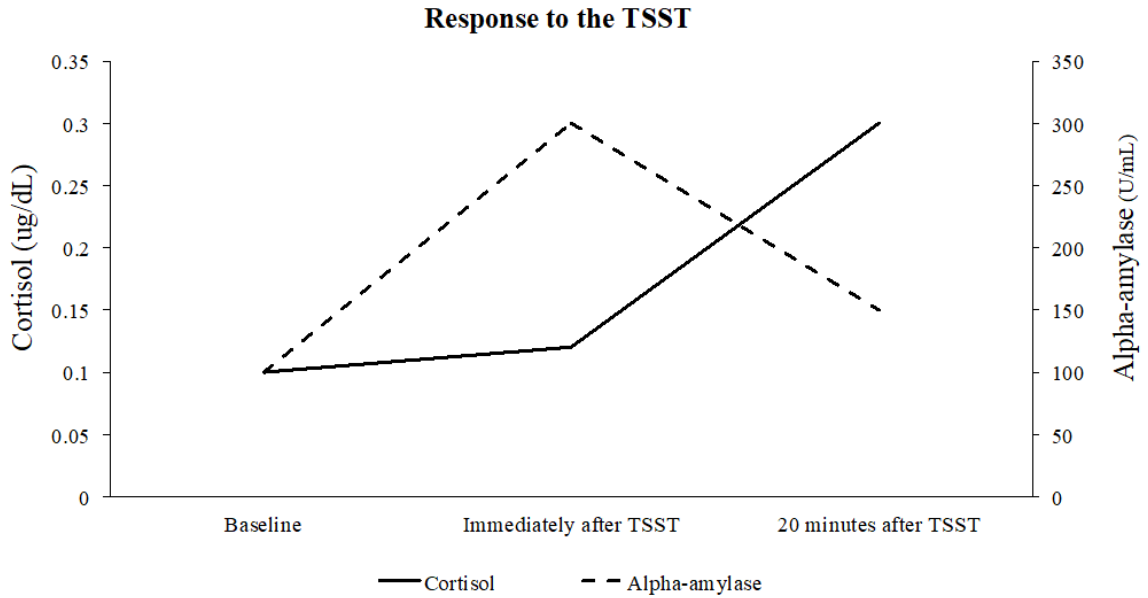
*Note: Cort = Cortisol measurement occasion; Alpha = Alpha-amylase measurement occasion.*

Figure 8c: Latent Growth Curve Modeling for Two Parallel Processes. The intercept and slope terms can be related in a variety of ways. For example, Intercept 1 can predict only Slope 1, only Slope 2, or both slope terms. Dashed lines have been included from the corresponding intercept and slope terms to show the choice of including this relationship or not within the model being estimated.



*Note: Cort = Cortisol measurement occasion; Alpha = Alpha-amylase measurement occasion.*

Figure 9c Trajectories for cortisol and alpha-amylase during the TSST. This figure shows that changes in alpha-amylase occur immediately after the stressor, whereas changes in cortisol occur about 20 minutes after the stressor.



## Appendix A

### Supplementary Results for Chapter 3 Primary Study: Results with Full Sample

The difference in average levels of mental abstraction between the stress group ( $M = 15.87$ ,  $SD = 4.80$ ,  $n = 97$ ) and the control group ( $M = 14.12$ ,  $SD = 3.86$ ,  $n = 68$ ) was statistically significant,  $t(159.84) = 2.62$ ,  $p = .0097$ ,  $d = .399$ , C.I.<sub>95%</sub> $d$ : [.714, .083].

The difference in average levels of negative affect after the stressor between the stress group ( $M = 20.35$ ,  $SD = 8.14$ ,  $n = 96$ ) and the control group ( $M = 12.70$ ,  $SD = 3.55$ ,  $n = 67$ ) was statistically significant,  $t(139.07) = 8.16$ ,  $p < .0001$ ,  $d = 1.15$ , C.I.<sub>95%</sub> $d$ : [1.49, .81].

Path analyses revealed that the relationship between exposure to a psychosocial stressor and mental abstraction was not statistically significant when negative affect was included in the model ( $\beta = 0.100$ ,  $p = .244$ ). The relationships between negative affect and mental abstraction ( $\beta = 0.213$ ,  $p = .034$ ), as well as between stress and negative affect ( $\beta = 0.526$ ,  $p < .001$ ), yielded statistical significance. The indirect effect ( $\beta = 0.112$ ,  $p = .034$ ) and the total effect ( $\beta = 0.212$ ,  $p = .004$ ) were both statistically significant. The model fit the data adequately ( $\chi^2(12) = 119.646$ ,  $p < .001$ ; CFI = 1; RMSEA = 0, C.I.<sub>90%</sub>: [0.00, .076],  $p = .876$ .) and explained 8% of the total variation in the BIF.

Model	Path	beta	p value	R <sup>2</sup>	X <sup>2</sup> (df = 9)	X <sup>2</sup> p-value	CFI	RMSEA
Model 3					100.004	< .001*	1	0*
	BIF ON			.041				
	Condition	.214	.035					
	SBP	.018	0.863					
	SBP ON			0.435				
	Condition	-0.651	<.001*					
	Indirect Effect	-0.012	0.863					
	Total Effect	0.202	0.006*					
Model 4					135.207	<.001*	1	0*
	BIF ON			0.056				
	Condition	0.072	0.663					
	DBP	-0.179	0.127					
	DBP ON			0.538				
	Condition	-0.719	<.001*					
	Indirect Effect	0.129	0.141					
	Total Effect	0.201	0.006*					
Model 5					28.237	.001*	1	0*
	BIF ON			0.054				
	Condition	0.163	0.037*					
	HR	-0.123	0.082					
	HR ON			0.107				
	Condition	-0.317	<.001*					
	Indirect Effect	0.039	0.078					
	Total Effect	0.202	0.007*					

Note: BIF = Behavioral identification form; SBP = Systolic blood pressure; DBP = Diastolic blood pressure; HR = Heart rate.  
\* indicates statistically significant effect at  $\alpha = .05$ .

### Appendix B: Correlations between stress measures

	SBP	DBP	HR	PS	NA
SBP	1				
DBP	<b>0.525</b>	1			
HR	0.127	<b>0.332</b>	1		
PS	-0.119	0.049	<b>0.331</b>	1	
NA	-0.044	-0.181	-0.131	<b>-0.545</b>	1

Note: **Bold** indicates statistically significant correlation

SBP = Systolic blood pressure

DBP = Diastolic blood pressure

HR = Heart rate

PS = Perceived stress

NA = Negative Affect

## Appendix C

### Chapter 3: Pilot Study

#### Pilot Study (Hobby Condition)

##### Before the participant arrives:

- Prepare the participant biomarker packet with participant number. Indicate Job or Hobby condition. Place on clipboard and put the clipboard on an empty committee chair
- Place experiment leader clipboard with a pen and session notes on empty committee chair
- Place the participant chair at the table facing the back wall
- Push the committee chairs back against the wall away from the table
- Place notepaper and pen for the participant to use on the standing desk
- Close the curtains to the rest of the lab
- Put on your fancy purple watch

##### On the table in the experiment room:

- Laptop closed but have the Qualtrics questionnaire open on the screen
- 2 copies of informed consent
- Pen

#### Part I

**Participant arrival:** At the scheduled time, greet the participant in the hallway and invite him/her into the experiment room.

*Hello, my name is [Say Your Name]. Are you here for the What Do You Think About It study?*

Let the participant answer, then say:

*I need to confirm your SONA ID number before we begin*

Make sure the SONA ID matches the SONA ID for the scheduled participant.

\*Make sure he/she is here for the “What do you think about it?” study.

Introduce yourself and ask him/her to place his/her belongings on the empty shelf in the cabinet. **MAKE SURE HIS/HER PHONE IS ON SILENT OR OFF.** Most of them will need to get their SONA number off their phone before putting it away. Once you are sitting at the table with the participant, read the following script:

*I am going to explain the study and then we will do informed consent and get started.  
OK?*



Write SONA ID on the Session Notes form, along with the ACTUAL START TIME (time from the purple watch), and the date. Read the following:

*We are interested understanding what you think about a variety of topics. During this study you will complete several questionnaires and tasks. We will be measuring blood pressure and heart rate using a pressure cuff placed around your upper arm at 3 time-points. Are you comfortable with all of this?*

While you are explaining, show the participant the blood pressure cuff. Make sure they acknowledge that they are comfortable with all the devices being used.

*The whole procedure should last about 30 minutes. Should you wish to stop at any point, you may do so.*

\*If the participant is wearing a long-sleeved shirt and the sleeves can't roll up, ask him/her to change into the lab tee-shirt in the cabinet.

**Informed consent:** Provide the participant with the informed consent and read the following:

*This is the informed consent. It is two copies of the exact same thing; one is for you to keep, and the other is for us. Please read through it, and if you still agree to participate, please print your name, sign, and date each copy.*

Allow adequate time to read it, ask questions, and sign both copies. Sign both copies under "person obtaining consent." Clip one to your clipboard and place the other with the participant's belongings in the cabinet.

**Baseline Questionnaires (~5 Minutes):** Provide participant with the laptop computer to complete baseline questionnaire.

*Now you are going to start on the first questionnaire. It's all online, so go ahead and follow the arrows through. You will eventually come to a page that says, "Please inform the researcher that you have completed this portion of the study" At this point, let me know, and we will go on to something else.*

**\*\*BIOMARKER MEASUREMENT\*\*-- Baseline**

Measure: Height, weight, and BMI  
 Blood pressure— arm cuff (non-dominant arm)  
 Heart rate— arm cuff  
 Page 1 of biomarker packet

Measure height and weight first. Read the following:

*We are now going to take some physical measurements. I need you to get on our scale.*

Ask the participant to remove their shoes. Follow instructions for scale posted on the wall. Once finished, allow participant to put his/her shoes back on. Once he/she is finished and sitting at the table, read the following:

*Now we are going to take the first blood pressure and heart rate measurements. I will place this cufflink around your arm. Please keep your feet planted on the ground and don't speak during the measurement. It is best if you keep the arm in the cufflink flat on the table and try to remain still. Which arm is your dominant arm?*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Record measures on page 1 of biomarker packet. Have the participant fill out the questionnaire on page 1 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. There are 7 feelings listed on here. Read each one, and mark with an X along the line whatever is appropriate.*

Place participant clipboard in cabinet

## **Part II**

After the first heart rate and blood pressure measurements, the participant will wait quietly for 15 minutes to acclimate to the lab setting. Provide the participant with the selection of magazines and tell them to relax until the next part of the study. Set the time inside the cabinet door for 15 minutes.

*Now I am going to need you to sit quietly and relax for the next 15 minutes. You may look through these magazines during this time if you would like.*

Once the participant begins the acclimation period, casually say:

*I will be back in 15 minutes.*

Go out into the lab and show the R.A.s the participant's name on the informed consent form. Make sure the R.A.s don't know the participant. Decide who will be President, Assistant I, and Assistant II. Fill this in on the session notes form. Return to the experiment room.

When the 15-minute time goes off...

**\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 2**

Mark time under “Bio 2 start” on the session notes form

\*\*Note that the participant doesn’t have to stop reading the magazines while you take this measure

Measure:

Blood pressure— arm cuff (non-dominant arm)

Heart rate— arm cuff

Page 2 of biomarker packet

Measure blood pressure and heart rate. Record blood pressure and heart rate on page 2 of biomarker packet. Read the following script:

*Now we are going to take the second blood pressure and heart rate measurements. Please keep your feet planted on the ground and don’t speak during the measurement.*

Have the participant fill out the questionnaire on page 2 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. There are 7 feelings listed on here. Read each one, and mark with an X along the line however is appropriate.*

Place participant clipboard in cabinet

Note: At this point, the table should be empty except for the blood pressure cuff and the tape recorder. Make sure all other materials are removed from the desk before moving on.

**Part III**

**Hobby writing:** Sit across from the participant and read the following script:

*We will start a new task now that consists of a writing task. Before we start, I would like to know what your favorite hobby is.*

Let the participant answer

*Your task now is to write about your favorite hobby. Don’t worry about spelling or grammar, just write anything you want about your favorite hobby. When you are done, you can put your paper in the envelope provided. While we will not be reading what you wrote, we will skim the document to make sure you wrote about your dream job. You will have five minutes to prepare, then you will stand behind this desk*

(point to the desk behind them)

*And write about your dream job.*

*You now have five minutes to prepare. You may use this time to create an outline or anything that may help you write your paper. You may use whatever preparation materials you make during this time for your final paper*

Experiment leader gives the participant a pen and piece of paper from the clipboard

*Any questions?*

Briefly answer any questions.

*I am going to leave now.*

Leave the room and shut the door.

Set the timer on the purple watch for five minutes. After five minutes, reenter the room

Then say:

*It is now time to begin writing about your favorite hobby. Please stand behind the desk. You may begin writing now. I will come back into the room after five minutes.*

Set the timer on the purple watch for five minutes.

After the timer goes off, immediately enter the room and ask the participant to sit at the desk for more measures

Wait by the door until the president says, "Stop!"

Immediately enter the room and ask the participant to sit for more measures

**\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 3**

While the stress committee is still present and watching the participant:

Mark time under "Bio 3 start" on the session notes form

Measure:

Blood pressure— arm cuff (non-dominant arm)

Heart rate— arm cuff

Page 3 of biomarker packet

*Now we are going to take the third blood pressure and heart rate measurements. I will place this cufflink around your arm. Please keep your feet planted on the ground and don't speak during the measurement. It is best if you keep the arm in the cufflink flat on the table and try to stay still.*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Make sure the participants feet are planted firmly on the ground (i.e., legs not crossed). Record measures on page 5 of biomarker packet. Have the participant fill out the questionnaire on page 5 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. There are 7 feelings listed on here. Read each question and respond however is appropriate.*

#### **PART IV**

**Main Outcomes:** Bring the computer onto the table and read the following:

*You will now complete the next portion of the study. This portion includes responding to a number of questionnaires. When you have completed the questionnaires, please let me know. I will stay in the room with you, but please pretend I am not here.*

When the participant indicates they are done with the questionnaires...

#### **PART VI**

**Debriefing:** Once follow-up questionnaires are completed, read the following script:

*Thank you for participating. The true purpose of this study was to look at the effects of writing on how you perceive the world. This study serves as a pilot test for a larger study. In order to do this, we randomly assigned participants into two conditions.*

Then say:

*You wrote about your hobby while standing in front of a standing desk. Your writing about your hobby was meant to determine whether writing in general affected how you perceive the world and was equivalent to something participants in the experimental condition completed.*

Ask participants the following questions:

*At any point in the study, did you suspect/know the true purpose of the study?*

After recording these responses, continue with:

*Half of our participants were randomly assigned to write about their dream job while the other half of participants were assigned to write about their hobby. We are trying to see if writing about your dream job, a future event, affects how you perceive the world. We are also trying to see if writing in general affects the way you perceive the world. Finally, we wanted to see if writing about either topic was stressful, which is why we collected heart rate and blood pressure, and why you filled out that same questionnaire 4 times. The ultimate goal of this study was to serve as a pilot test for an upcoming study. Because deception is a necessary part of this study, please do not disclose any details about your experience here to anyone else in case they end up participating in the future. Do you have any questions or comments?*

Allow the participant to disclose any thoughts or feelings. Should he or she express concern or distress, allow time for follow-up questions such as:

*What did you think of this experiment?*

*Did you feel stressed?*

*Would you like to talk about what happened?*

\*If the participant is distressed, remind the participant that the experiment leader (John Felt) and supervisor (Dr. Tiemensma) are always available through email, phone, or in person should he or she have questions or want to talk more about the experience. Also, that CAPS is available for consultation if necessary.

### **Pilot Study (Job Condition)**

#### **Before the participant arrives:**

- Prepare the participant biomarker packet with participant number. Indicate Job or Hobby condition. Place on clipboard and put the clipboard on an empty committee chair
- Place experiment leader clipboard with a pen and session notes on empty committee chair
- Place the participant chair at the table facing the back wall
- Push the committee chairs back against the wall away from the table
- Place notepaper and pen for the participant to use on the standing desk
- Close the curtains to the rest of the lab
- Put on your fancy purple watch

#### **On the table in the experiment room:**

- Laptop closed but have the Qualtrics questionnaire open on the screen
- 2 copies of informed consent
- Pen

### **Part I**

**Participant arrival:** At the scheduled time, greet the participant in the hallway and invite him/her into the experiment room.

*Hello, my name is [Say Your Name]. Are you here for the What Do You Think About It study?*

Let the participant answer, then say:

*I need to confirm your SONA ID number before we begin*

Make sure the SONA ID matches the SONA ID for the scheduled participant.

\*Make sure he/she is here for the “What do you think about it?” study.

Introduce yourself and ask him/her to place his/her belongings on the empty shelf in the cabinet. **MAKE SURE HIS/HER PHONE IS ON SILENT OR OFF.** Most of them will need to get their SONA number off their phone before putting it away. Once you are sitting at the table with the participant, read the following script:

*I am going to explain the study and then we will do informed consent and get started.  
OK?*

Write SONA ID on the Session Notes form, along with the ACTUAL START TIME (time from the purple watch), and the date. Read the following:

*We are interested understanding what you think about a variety of topics. During this study you will complete several questionnaires and tasks. We will be measuring blood pressure and heart rate using a pressure cuff placed around your upper arm at 3 time-points. Are you comfortable with all of this?*

While you are explaining, show the participant the blood pressure cuff. Make sure they acknowledge that they are comfortable with all the devices being used.

*The whole procedure should last about 30 minutes. Should you wish to stop at any point, you may do so.*

\*If the participant is wearing a long-sleeved shirt and the sleeves can't roll up, ask him/her to change into the lab tee-shirt in the cabinet.

**Informed consent:** Provide the participant with the informed consent and read the following:

*This is the informed consent. It is two copies of the exact same thing; one is for you to keep, and the other is for us. Please read through it, and if you still agree to participate, please print your name, sign, and date each copy.*

Allow adequate time to read it, ask questions, and sign both copies. Sign both copies under "person obtaining consent." Clip one to your clipboard and place the other with the participant's belongings in the cabinet.

**Baseline Questionnaires (~5 Minutes):** Provide participant with the laptop computer to complete baseline questionnaire.

*Now you are going to start on the first questionnaire. It's all online, so go ahead and follow the arrows through. You will eventually come to a page that says, "Please inform the researcher that you have completed this portion of the study" At this point, let me know, and we will go on to something else.*

**\*\*BIOMARKER MEASUREMENT\*\*-- Baseline**

Measure: Height, weight, and BMI  
 Blood pressure— arm cuff (non-dominant arm)  
 Heart rate— arm cuff  
 Page 1 of biomarker packet

Measure height and weight first. Read the following:



*We are now going to take some physical measurements. I need you to get on our scale.*

Ask the participant to remove their shoes. Follow instructions for scale posted on the wall. Once finished, allow participant to put his/her shoes back on. Once he/she is finished and sitting at the table, read the following:

*Now we are going to take the first blood pressure and heart rate measurements. I will place this cufflink around your arm. Please keep your feet planted on the ground and don't speak during the measurement. It is best if you keep the arm in the cufflink flat on the table and try to remain still. Which arm is your dominant arm?*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Record measures on page 1 of biomarker packet. Have the participant fill out the questionnaire on page 1 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. There are 7 feelings listed on here. Read each one, and mark with an X along the line whatever is appropriate.*

Place participant clipboard in cabinet

## **Part II**

After the first heart rate and blood pressure measurements, the participant will wait quietly for 15 minutes to acclimate to the lab setting. Provide the participant with the selection of magazines and tell them to relax until the next part of the study. Set the time inside the cabinet door for 15 minutes.

*Now I am going to need you to sit quietly and relax for the next 15 minutes. You may look through these magazines during this time if you would like.*

Once the participant begins the acclimation period, casually say:

*I will be back in 15 minutes.*

Go out into the lab and show the R.A.s the participant's name on the informed consent form. Make sure the R.A.s don't know the participant. Decide who will be President, Assistant I, and Assistant II. Fill this in on the session notes form. Return to the experiment room.

When the 15-minute time goes off...

**\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 2**

Mark time under “Bio 2 start” on the session notes form

\*\*Note that the participant doesn't have to stop reading the magazines while you take this measure

Measure:

Blood pressure— arm cuff (non-dominant arm)

Heart rate— arm cuff

Page 2 of biomarker packet

Measure blood pressure and heart rate. Record blood pressure and heart rate on page 2 of biomarker packet. Read the following script:

*Now we are going to take the second blood pressure and heart rate measurements. Please keep your feet planted on the ground and don't speak during the measurement.*

Have the participant fill out the questionnaire on page 2 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. There are 7 feelings listed on here. Read each one, and mark with an X along the line however is appropriate.*

Place participant clipboard in cabinet

Note: At this point, the table should be empty except for the blood pressure cuff and the tape recorder. Make sure all other materials are removed from the desk before moving on.

### **Part III**

**Job writing:** Sit across from the participant and read the following script:

*We will start a new task now that consists of a writing task. Before we start, I would like to know what your ideal job would be.*

Let the participant answer

*Your task now is to write about your dream job. Don't worry about spelling or grammar, just write anything you want about your dream job. When you are done, you can put your paper in the envelope provided. While we will not be reading what you wrote, we will skim the document to make sure you wrote about your dream job. You will have five minutes to prepare, then you will stand behind this desk*

(point to the desk behind them)

*And write about your dream job.*

*You now have five minutes to prepare. You may use this time to create an outline or anything that may help you write your paper. You may use whatever preparation materials you make during this time for your final paper*

Experiment leader gives the participant a pen and piece of paper from the clipboard

*Any questions?*

Briefly answer any questions.

*I am going to leave now.*

Leave the room and shut the door.

Set the timer on the purple watch for five minutes. After five minutes, reenter the room

Then say:

*It is now time to begin writing about your dream job. Please stand behind the desk. You may begin writing now. I will come back into the room after five minutes.*

Set the timer on the purple watch for five minutes.

After the timer goes off, immediately enter the room and ask the participant to sit at the desk for more measures

Wait by the door until the president says, "Stop!"

Immediately enter the room and ask the participant to sit for more measures

**\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 3**

While the stress committee is still present and watching the participant:

Mark time under "Bio 3 start" on the session notes form

Measure:

Blood pressure— arm cuff (non-dominant arm)

Heart rate— arm cuff

Page 3 of biomarker packet

*Now we are going to take the third blood pressure and heart rate measurements. I will place this cufflink around your arm. Please keep your feet planted on the ground and don't speak during the measurement. It is best if you keep the arm in the cufflink flat on the table and try to stay still.*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Make sure the participants feet are planted firmly on the ground (i.e., legs not crossed). Record measures on page 5 of biomarker packet. Have the participant fill out the questionnaire on page 5 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. There are 7 feelings listed on here. Read each question and respond however is appropriate.*

#### **PART IV**

**Main Outcomes:** Bring the computer onto the table and read the following:

*You will now complete the next portion of the study. This portion includes responding to a number of questionnaires. When you have completed the questionnaires, please let me know. I will stay in the room with you, but please pretend I am not here.*

When the participant indicates they are done with the questionnaires...

#### **PART VI**

**Debriefing:** Once follow-up questionnaires are completed, read the following script:

*Thank you for participating. The true purpose of this study was to look at the effects of writing on how you perceive the world. This study serves as a pilot test for a larger study. In order to do this, we randomly assigned participants into two conditions.*

Then say:

*You wrote about your dream job while standing in front of a standing desk. Your writings about your dream job was meant to determine whether writing about a future event, such as a dream job, affected the way you perceived the world.*

Ask participants the following questions:

*At any point in the study, did you suspect/know the true purpose of the study?*

After recording these responses, continue with:

*Half of our participants were randomly assigned to write about their dream job while the other half of participants were assigned to write about their hobby. We are trying to see if writing about your dream job, a future event, affects how you perceive the world. We are also trying to see if writing in general affects the way you perceive the world. Finally, we wanted to see if writing about either topic was stressful, which is why we collected heart rate and blood pressure, and why you filled out that same questionnaire 4 times. The ultimate goal of this study was to serve as a pilot test for an upcoming study. Because deception is a necessary part of this study, please do not disclose any details about your experience here to anyone else in case they end up participating in the future. Do you have any questions or comments?*

Allow the participant to disclose any thoughts or feelings. Should he or she express concern or distress, allow time for follow-up questions such as:

*What did you think of this experiment?*

*Did you feel stressed?*

*Would you like to talk about what happened?*

\*If the participant is distressed, remind the participant that the experiment leader (John Felt) and supervisor (Dr. Tiemensma) are always available through email, phone, or in person should he or she have questions or want to talk more about the experience. Also, that CAPS is available for consultation if necessary.

## Chapter 2 and Chapter 3 TSST and c-TSST Protocol

### Mental Abstraction and Stress Procedure (Stress Condition)

#### Before the participant arrives:

- Prepare the participant biomarker packet with participant number. condition. Place on clipboard and put the clipboard on an empty committee chair
- Place committee clipboards on the main lab table
- Place experiment leader clipboard with a pen and session notes on empty committee chair
- Turn on the baby monitors (one in experiment room, one on lab table)
- Place the participant chair at the table facing the back wall
- Push the committee chairs back against the wall away from the table
- Place notepaper and pen for the participant to use on empty committee chair
- Make a post it with the date and participant number. Stick it beneath the tape recorder
- Turn on the camera (just on, not recording) and cover it with the sheet
- Place standing desk on wall across from the scale
- Close the curtains to the rest of the lab
- Put on your fancy purple watch
- Place laptop 2 on standing desk

#### On the table in the experiment room:

- Laptop 1 closed but, have the Qualtrics questionnaire open on the screen
- 2 copies of informed consent
- Pen

### Part I

**Participant arrival:** At the scheduled time, greet the participant in the hallway and invite him/her into the experiment room.

*Hello, my name is [Say Your Name]. Are you here for the Well-being and Psychological Processes study?*

Let the participant answer, then say:

*Before we begin, I need to confirm your SONA ID number*

Make sure the SONA ID matches the SONA ID for the scheduled participant.

\*Make sure he/she is here for the “Well-being and Psychological Processes Study.”  
Introduce yourself and ask him/her to place his/her belongings on the empty shelf in the cabinet. **MAKE SURE HIS/HER PHONE IS ON SILENT OR OFF.** Most of them will need to get their

SONA number off their phone before putting it away. Once you are sitting at the table with the participant, read the following script:

*Come on in. You may put your belongings in this cabinet. Go ahead and take a seat*  
Place your hand on the chair

*I am going to explain the study and then we will do informed consent and get started.*  
OK?

Write the ACTUAL START TIME (time from the purple watch), and the date. Read the following:

*We are interested in psychological processes that affect well-being. During this study you will complete several tasks. We will also be measuring blood pressure and heart rate using a pressure cuff placed around your upper arm at five time-points. Are you comfortable with all of this?*

While you are explaining, show the participant the blood pressure cuff. Make sure they acknowledge that they are comfortable with all the devices being used.

*The whole procedure should last about 90 minutes. Should you wish to stop at any point, you may do so. Since this study is so long, you should use the restroom now if you need to.*

\*If the participant is wearing a long-sleeved shirt and the sleeves can't roll up, ask him/her to change into the lab tee-shirt in the cabinet.

**Informed consent:** Provide the participant with the informed consent and read the following:

*This is the informed consent. It is two copies of the exact same thing; one is for you to keep, and the other is for us. Please read through it, and if you still agree to participate, please print your name, sign, and date each copy. If you have any questions about anything in the informed consent, please let me know.*

Allow adequate time to read it, ask questions, and sign both copies. Sign both copies under "person obtaining consent." Clip one to your clipboard and place the other with the participant's belongings in the cabinet.

**Baseline Questionnaires (~15-20 Minutes):** Provide participant with the laptop computer to complete baseline questionnaire.

*Now you are going to start on the first questionnaire. It's all online, so go ahead and follow the arrows through. You will eventually come to a page that says, "Thank you for*

*completing this portion of the survey. Please inform the experiment leader that you have reached this page.” At this point, let me know, and we will go on to something else.*

Remain in the experiment room while the participant fills out the baseline questionnaire. As the participant is filling out the questionnaire, log into the lab Qualtrics account on your own computer/device. Use the standing desk to do this. Johnny’s Dissertation → Data & Analysis → Responses in Progress. Then, select the current participant. Note: Wait for them to complete the BDI before you check (it is the first questionnaire). It should take about 5-7 minutes to complete.

**If the participant expressed suicidal ideation, STOP THE STUDY. Read the following script:**

*Your responses indicate that we need to stop the study at this point for your safety. Remember that you consented to being escorted to CAPS if necessary. Because of the way you answered some of the items, I will now take you to see a counselor*

**Contact a study supervisor (Johnny, Jitske, or Sarah) and call CAPS at (209)- 228-4266 to inform them that a participant will be escorted to their office within the next 10 minutes. Return personal belongings to the participant before taking him/her to CAPS.**

**If a participant refused to go to CAPS, call UCM Police dispatch, (209) 228-2677, for immediate assistance in escorting the participant to CAPS.**

**If the participant did NOT express suicidal ideation, continue with the study.**

Once the participant says he/she has reached the stopping point within the questionnaire, read the following:

*We are going to go on to something else now. I am going to put this away now.*

Place the laptop into the cabinet. Click arrows until next part of the survey comes up.

### **\*\*BIOMARKER MEASUREMENT\*\*-- Baseline**

Measure: Height, weight, and BMI  
 Blood pressure— arm cuff (non-dominant arm)  
 Heart rate— arm cuff  
 Page 1 of biomarker packet

Measure height and weight first. Read the following:



*We are now going to take some physical measurements. I need you to get on our scale so that I can get your height and weight. Please remove your shoes first*

Ask the participant to remove their shoes. Follow instructions for scale posted on the wall. Once finished, allow participant to put his/her shoes back on. Once he/she is finished and sitting at the table, read the following:

*Now we are going to take the first blood pressure and heart rate measurements I will place this cufflink around your arm. Please keep your feet planted on the ground and don't speak during the measurement. It is best if you keep the arm in the cufflink flat on the table and try to remain still. Now, I need to place this on your non-dominant arm.*

Measure heart rate and blood pressure by placing the arm cuff around the participants non-dominant arm. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Also, make sure the participants are not crossing their legs or speaking. Record measures on page 1 of biomarker packet. Have the participant fill out the questionnaire on page 1 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. There are 8 feelings listed here. Read each one, and mark with an X along the line however is appropriate.*

Place participant clipboard in cabinet

## **Part II**

After the first heart rate and blood pressure measurements, the participant will wait quietly for 15 minutes to acclimate to the lab setting. Read the following script:

*Now I am going to need you to sit quietly and relax for the next 15 minutes. You may look through these magazines if you like during this time.*

Provide the participant with the selection of magazines and tell them to relax until the next part of the study.

Set the time on the purple wrist watch for 15 minutes.

Once the participant begins the acclimation period, casually say:

*I will be back in 15 minutes*

Go out into the lab and show the R.A.s the participant's name on the informed consent form. Make sure the R.A.s don't know the participant. Decide who will be President, Assistant I, and Assistant II. Fill this in on the session notes form. Return to the experiment room.

When the 15-minute time goes off...

**\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 2**

\*\*Note that the participant doesn't have to stop reading the magazines while you take this measure

Measure:

Blood pressure— arm cuff (non-dominant arm)

Heart rate— arm cuff

Page 2 of biomarker packet

Measure blood pressure and heart rate. Record blood pressure and heart rate on page 3 of biomarker packet.

Note: At this point, the table should be empty except for the blood pressure cuff and the tape recorder. Make sure all other materials are removed from the desk before moving on.

Read the following script:

*Now we are going to take the second blood pressure and heart rate measurements. Please keep your feet planted on the ground and don't speak during the measurement.*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Make sure the participants feet are planted firmly on the ground (i.e., legs not crossed). Record measures on page 1 of biomarker packet. Have the participant fill out the questionnaire on page 2 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. Read each question and answer however is appropriate. Notice that there are a few more questions at the bottom.*

**Part III**

**Stress induction (TSST Group ONLY):** Committee members are now waiting outside the experiment room door wearing their white coats (this is approximately 25 minutes after the participant arrived). Sit across from the participant and read the following script:

*We will start a new task now that consists of a speech task. It is important that you are well prepared. Before we start, I would like to know what your ideal job would be.*

Let the participant answer

*Now imagine the following: you have applied for your ideal job and have been asked for an interview. Your task now is to prepare a speech to convince a committee that you are the ideal candidate for that position. You must address both your good and bad qualities. You will have five minutes to prepare, then you will stand on this X*

(point to the X on the floor)

*And perform your speech in front of this committee*

Get up from the table and open the experiment room door to show the committee standing outside the door in their white coats. Shut the door, return to the table, and continue speaking:

*The committee members specialize in non-verbal communication and will be evaluating your performance on multiple criteria. You will also be video...*

(Pull sheet off camera and point to the camera)

*...And audio recorded...*

(Point to the recorder)

*...so we can perform voice analysis later. Your presentation should last five minutes, and your goal is to convince the committee that you are the ideal candidate for this job. It is important that you make a credible impression.*

### **\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 3**

Measure:

Blood pressure— arm cuff (non-dominant arm)

Heart rate— arm cuff

Page 3 of biomarker packet

Before measuring again, say the following:

*Now, before you begin, I need to take another heart rate and blood pressure measurement. Please keep your feet planted on the ground and don't speak during the measurement.*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Make sure the

participants feet are planted firmly on the ground (i.e., legs not crossed). Record measures on page 3 of biomarker packet. Have the participant fill out the questionnaire on page 3 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. Read each question and respond however is appropriate.*

*Then say:*

*You now have five minutes to prepare. You may make notes while you prepare, but you may not use them during your speech.*

Experiment leader gives the participant a pen and piece of paper from the clipboard

*Any questions?*

Briefly answer any questions.

*I am going to leave now. Good luck.*

Leave the room and shut the door. The committee president immediately starts the stopwatch for 5 minutes.

After 5 minutes, the committee silently enters the room in this order: Assistant I, President, Assistant II.

Listen outside the door for when Assistant II asks the participant to hold his/her arms out.

**Write the time stamp on the session notes form under, "R.A.s enter room"**

After Assistant I says: "Month, day, year. Participant number XXX. Please Speak clearly for recording purposes," set your stop watch for 5 minutes.

Listen to speech.

Wait by the door until the president says, "Stop!"

Immediately enter the room and ask the participant to sit for more measures

**\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 4**

While the stress committee is still present and watching the participant:

Measure:

Blood pressure— arm cuff (non-dominant arm)

Heart rate— arm cuff  
Page 4 of biomarker packet

Before measuring again, say the following:

*Now we are going to take the fourth blood pressure and heart rate measurements I will place this cufflink around your arm. Please keep your feet planted on the ground and don't speak during the measurement. It is best if you keep the arm in the cufflink flat on the table and try to stay still.*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Make sure the participants feet are planted firmly on the ground (i.e., legs not crossed). Record measures on page 4 of biomarker packet. Have the participant fill out the questionnaire on page 4 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. Read each question and respond however is appropriate.*

#### **PART IV**

**Main Outcomes:** Bring the computer onto the table and read the following:

*You will now complete the next portion of the study. This portion includes responding to a number of questionnaires. When you have completed the questionnaires, please let me know. I will stay in the room with you to take more measurements, but please pretend I am not here.*

When the participant indicates they are done with the questionnaires...

#### **\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 5**

Measure:  
Blood pressure— arm cuff (non-dominant arm)  
Heart rate— arm cuff  
Pages 5-6 of biomarker packet

Before taking measures, say the following:

*Now we are going to take the fifth blood pressure and heart rate measurements. I will place this cufflink around your arm. Please keep your feet planted on the ground and don't speak during the measurement. It is best if you keep the arm in the cufflink flat on the table and try to stay still.*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Make sure the participants feet are planted firmly on the ground (i.e., legs not crossed). Record measures on page 5 of biomarker packet. Have the participant fill out the questionnaires on page 5 and 6 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. Read each question and respond however is appropriate. On the second page, there is a word completion task for you to complete. Just follow the instructions on that page when you get there.*

#### **PART V**

**Demographic questions:** Once the participant completes the final biomarker measurements, open the laptop for the participants. Then say the following:

*Now you will complete the final questions on the computer. Please let me know when you have finished.*

#### **PART VI**

**Debriefing:** Once follow-up questionnaires are completed, read the following script:

*Thank you for participating. The true purpose of this study was to look at the effects of stress on how you perceive the world. In order to do this, we randomly assigned participants into two conditions.*

Then say:

*The panel judging you during your speech were just research assistants and not experts in non-verbal communication, and your recordings won't be used for anything. That task only served to make you experience temporary stress. That is actually called the Trier Social Stress Test, and is commonly used in psychological research to induce stress because it works. Most people don't like public speaking— especially when it is unexpected. (Assure them that it was supposed to be really difficult, but they did fine)*

Ask participants the following questions:

*Have you heard of the TSST before?*

*Have you experienced the TSST before?*

*Did you recognize anyone on the committee?*

*At any point in the study, did you suspect/know the true purpose of the study?*

After recording these responses, continue with:

*Half of our participants were randomly assigned to be in something stressful while the other half of participants were randomly assigned to a no stress control group. We are trying to see if stress affects the way that people perceive the world. We were also measuring how your heart rate and blood pressure changed over time. This study is one of the first studies to look at how physiological responses to stress may affect the way people perceive their environments, so you are part of something really important and unique. Because deception is a necessary part of this study, please do not disclose any details about your experience here to anyone else in case they end up participating in the future. Do you have any questions or comments?*

Allow the participant to disclose any thoughts or feelings. Should he or she express concern or distress, allow time for follow-up questions such as:

*What did you think of this experiment?*

*Did you feel stressed?*

*Would you like to talk about what happened?*

\*If the participant is distressed, remind the participant that the experiment leader (John Felt) and supervisor (Dr. Tiemensma) are always available through email, phone, or in person should he or she have questions or want to talk more about the experience. Also, that CAPS is available for consultation if necessary.

### **Mental Abstraction and Stress Procedure (Control Condition)**

#### **Before the participant arrives:**

- Prepare the participant biomarker packet with participant number. condition. Place on clipboard and put the clipboard on the standing desk
- Place experiment leader clipboard with a pen and session notes on empty committee chair
- Turn on the baby monitors (one in experiment room, one on lab table)
- Place the participant chair at the table facing the back wall
- Push the committee chairs back against the wall away from the table
- Place notepaper and pen for the participant to use on empty committee chair
- Turn on the camera (just on, not recording) and cover it with the sheet
- Place standing desk on wall across from the scale
- Close the curtains to the rest of the lab
- Put on your fancy purple watch
- Place laptop 2 on standing desk

#### **On the table in the experiment room:**

- Laptop 1 closed, but have the Qualtrics questionnaire open on the screen
- 2 copies of informed consent
- Pen

### **Part I**

**Participant arrival:** At the scheduled time, greet the participant in the hallway and invite him/her into the experiment room.

*Hello, my name is [Say Your Name]. Are you here for the Well-being and Psychological Processes study?*

Let the participant answer, then say:

*Before we begin, I need to confirm your SONA ID number*

Make sure the SONA ID matches the SONA ID for the scheduled participant.

\*Make sure he/she is here for the “Well-being and Psychological Processes Study.”

Introduce yourself and ask him/her to place his/her belongings on the empty shelf in the cabinet. **MAKE SURE HIS/HER PHONE IS ON SILENT OR OFF.** Most of them will need to get their SONA number off their phone before putting it away. Once you are sitting at the table with the participant, read the following script:



*Come on in. You may place your belongings in this cabinet. Go ahead and take a seat*

Place hand on chair

*I am going to explain the study and then we will do informed consent and get started.  
OK?*

Write the ACTUAL START TIME (time from the purple watch), and the date. Read the following:

*We are interested in psychological processes that affect well-being. During this study you will complete several tasks. We will also be measuring blood pressure and heart rate using a pressure cuff placed around your upper arm at five time-points. Are you comfortable with all of this?*

While you are explaining, show the participant the blood pressure cuff. Make sure they acknowledge that they are comfortable with all the devices being used.

*The whole procedure should last about 90 minutes. Should you wish to stop at any point, you may do so. Since this study is so long, you should use the restroom now if you need to.*

\*If the participant is wearing a long-sleeved shirt and the sleeves can't roll up, ask him/her to change into the lab tee-shirt in the cabinet.

**Informed consent:** Provide the participant with the informed consent and read the following:

*This is the informed consent. It is two copies of the exact same thing; one is for you to keep, and the other is for us. Please read through it, and if you still agree to participate, please print your name, sign, and date each copy. If you have any questions about anything in the informed consent, please let me know.*

Allow adequate time to read it, ask questions, and sign both copies. Sign both copies under "person obtaining consent." Clip one to your clipboard and place the other with the participant's belongings in the cabinet.

**Baseline Questionnaires (~15-20 Minutes):** Provide participant with the laptop computer to complete baseline questionnaire.

*Now you are going to start on the first questionnaire. It's all online, so go ahead and follow the arrows through. You will eventually come to a page that says, "Thank you for completing this portion of the survey. Please inform the experiment leader that you have reached this page." At this point, let me know, and we will go on to something else.*

Remain in the experiment room while the participant fills out the baseline questionnaire. As the participant is filling out the questionnaire, log into the lab Qualtrics account on your own computer/device. Use the standing desk for this. *Johnny's Dissertation → Data & Analysis → Responses in Progress. Then, select the current participant. Note: Wait for them to complete the BDI before you check (it is the first questionnaire). It should take about 5-7 minutes.*

**If the participant expressed suicidal ideation, STOP THE STUDY. Read the following script:**

*Your responses indicate that we need to stop the study at this point for your safety. Remember that you consented to being escorted to CAPS if necessary. Because of the way you answered some of the items, I will now take you to see a counselor*

**Contact a study supervisor (Johnny, Jitske, or Sarah) and call CAPS at (209)- 228-4266 to inform them that a participant will be escorted to their office within the next 10 minutes. Return personal belongings to the participant before taking him/her to CAPS.**

**If a participant refused to go to CAPS, call UCM Police dispatch, (209) 228-2677, for immediate assistance in escorting the participant to CAPS.**

**If the participant did NOT express suicidal ideation, continue with the study.**

Once the participant says he/she has reached the stopping point within the questionnaire, read the following:

*We are going to go on to something else now. I am just going to put this computer away now.*

Click arrows until next survey section comes up and then place the laptop into the cabinet.

**\*\*BIOMARKER MEASUREMENT\*\*-- Baseline**

Measure: Height, weight, and BMI  
 Blood pressure— arm cuff (non-dominant arm)  
 Heart rate— arm cuff  
 Page 1 of biomarker packet

Measure height and weight first. Read the following:

*We are now going to take some physical measurements. I need you to get on our scale so that I can get your height and weight. Please remove your shoes first.*

Ask the participant to remove their shoes. Follow instructions for scale posted on the wall. Once finished, allow participant to put his/her shoes back on. Once he/she is finished and sitting at the table, read the following:

*Now we are going to take the first blood pressure and heart rate measurements. I will place this cufflink around your arm. Please keep your feet planted on the ground and don't speak during the measurement. It is best if you keep the arm in the cufflink flat on the table and try to remain still. Now, I need to place this on your non-dominant arm.*

Measure heart rate and blood pressure by placing the arm cuff around the participants non-dominant arm. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Make sure the participants feet are planted firmly on the ground (i.e., legs not crossed). Record measures on page 1 of biomarker packet. Have the participant fill out the questionnaire on page 1 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. There are 8 feelings listed on here. Read each one, and mark with an X along the line however is appropriate.*

Place participant clipboard in cabinet

## **Part II**

After the first heart rate and blood pressure measurements, the participant will wait quietly for 15 minutes to acclimate to the lab setting. Read the following script:

*Now I am going to need you to sit quietly and relax for the next 15 minutes. You may look through these magazines if you like during this time.*

Provide the participant with the selection of magazines and tell them to relax until the next part of the study.

Set the time on the purpose watch for 15 minutes.

Once the participant begins the acclimation period, casually say:

*I will be back in 15 minutes*

When the 15-minute time goes off...

**\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 2**

**\*\*Note that the participant doesn't have to stop reading the magazines while you take this measure**

Measure:

Blood pressure— arm cuff (non-dominant arm)

Heart rate— arm cuff

Page 2 of biomarker packet

Measure blood pressure and heart rate. Record blood pressure and heart rate on page 2 of biomarker packet.

Note: At this point, the table should be empty except for the blood pressure cuff and the tape recorder. Make sure all other materials are removed from the desk before moving on.

Read the following script:

*Now we are going to take the second blood pressure and heart rate measurements. Please keep your feet planted on the ground*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Make sure the participants feet are planted firmly on the ground (i.e., legs not crossed). Record measures on page 2 of biomarker packet. Have the participant fill out the questionnaire on page 3 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. Read each item, and answer however is appropriate. Notice that there are a few more questions at the bottom.*

### **Part III**

**(Control Group ONLY):** Stand to the right of the participant and read the following script:

*We will start a new task now that consists of a writing task. Before we begin, I would like to know what your ideal job would be.*

Let the participant answer

*Now imagine the following: you have applied for you ideal job and have been asked for a letter of application. Your task now is to convince a hiring committee that you are the ideal candidate. You must address both your good and bad qualities. Don't worry about spelling or grammar, and don't worry about completing your letter. When you are done, you can put your paper in the envelope provided. You will have five minutes to prepare, then you will stand behind this desk*

(point to the desk behind them)

*And write about your ideal job. You will have five minutes and your goal is to convince the hiring committee that you are the ideal candidate for this job. It is important to note that nobody will actually read what you wrote. However, after the study, I will skim it to make sure that you wrote about your ideal job.*

**\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 3**

Measure:

Blood pressure— arm cuff (non-dominant arm)

Heart rate— arm cuff

Page 3 of biomarker packet

Before measuring again, say the following:

*Now, before you begin, I need to take another heart rate and blood pressure measurement. Please keep your feet planted on the ground and don't speak during the measurement.*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Make sure the participants feet are planted firmly on the ground (i.e., legs not crossed). Record measures on page 3 of biomarker packet. Have the participant fill out the questionnaire on page 3 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. Read each question and answer however is appropriate.*

Then say:

*You now have five minutes to prepare. You may use this time to create an outline or anything that may help you write your paper. You may use whatever preparation materials you make during this time for your final paper.*

Experiment leader gives the participant a pen and piece of paper from the clipboard

*Any questions?*

Briefly answer any questions.

*I am going to leave now. I will be back in 5 minutes.*

Leave the room and shut the door.

Set the timer on the purple watch for five minutes. After five minutes, reenter the room

**Write the time stamp on the session notes form under, "R.A.s enter room"**

Then say:

*It is now time to begin writing about your ideal job. Please stand behind the desk. You can bring your notes with you and you may begin writing now. I will come back into the room after five minutes.*

Set the timer on the purple watch for five minutes.

After the timer goes off, immediately enter the room and ask the participant to sit at the desk for more measures

**\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 4**

Measure:

Blood pressure— arm cuff (non-dominant arm)

Heart rate— arm cuff

Page 4 of biomarker packet

*Now we are going to take the fourth blood pressure and heart rate measurements. I will place this cufflink around your arm. Please keep your feet planted on the ground and don't speak during the measurement. It is best if you keep the arm in the cufflink flat on the table and try to stay still.*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Make sure the participants feet are planted firmly on the ground (i.e., legs not crossed). Record measures on page 4 of biomarker packet. Have the participant fill out the questionnaire on page 4 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. There are 8 feelings listed on here. Read each question and respond however is appropriate.*

#### **PART IV**

**Main Outcomes:** Bring the computer onto the table and read the following:

*You will now complete the next portion of the study. This portion includes responding to a number of questionnaires. When you have completed the questionnaires, please let me know. I will stay in the room with you to take more measurements afterwards, but please pretend I am not here.*

When the participant indicates they are done with the questionnaires take laptop, press arrows until you reach the next questionnaire, close the laptop and place on an empty committee chair.

**\*\*BIOMARKER MEASUREMENT\*\*-- Biomarker 5**

Measure:

Blood pressure— arm cuff (non-dominant arm)

Heart rate— arm cuff

Page 5-6 of biomarker packet

Before taking measures, say the following:

*Now we are going to take the fifth blood pressure and heart rate measurements. I will place this cufflink around your arm. Please keep your feet planted on the ground and don't speak during the measurement. It is best if you keep the arm in the cufflink flat on the table and try to stay still.*

Measure heart rate and blood pressure with the arm cuff. Make sure the participant's arm is relaxed on the table and the BP cuff cord is facing towards their hand. Make sure the participants feet are planted firmly on the ground (i.e., legs not crossed). Record measures on page 6 of biomarker packet. Have the participant fill out the questionnaire on page 5 and 6 of the biomarker packet. Read the following instructions:

*This is a questionnaire about how you are feeling right now. Read each question and respond however is appropriate. On the second page, there is a word completion task for you to complete. Just follow the instructions through.*

**PART V**

**Demographic questions:** Once the participant completes the final biomarker measurements, open the laptop for the participants. Then say the following:

*Now you will complete the final questions on the computer. Please let me know when you have finished.*

**PART VI**

**Debriefing:** Once follow-up questionnaires are completed, read the following script:

*Now I am going to debrief you. Thank you for participating. The true purpose of this study was to look at the effects of stress on how you perceive the world. In order to do this, we randomly assigned participants into two conditions.*

Then say

*You wrote about your ideal job while standing in front of a standing desk. Your writings about your dream job was meant to be a nonstressful task equivalent to something participants in the stress condition completed. Your writings will not be evaluated in anyway*

*At any point in the study, aside from this being about stress, did you suspect/know the true purpose of the study?*

After recording these responses, continue with:

*Half of our participants were randomly assigned to be in something stressful while the other half of participants were randomly assigned to a no stress control group. We are trying to see if stress affects the way that people perceive the world. We were also measuring how your heart rate and blood pressure changed over time. This study is one of the first studies to look at how physiological responses to stress may affect the way people perceive their environments, so you are part of something really important and unique. Because deception is a necessary part of this study, please do not disclose any details about your experience here to anyone else in case they end up participating in the future. Do you have any questions or comments?*

Allow the participant to disclose any thoughts or feelings. Should he or she express concern or distress, allow time for follow-up questions such as:

*What did you think of this experiment?*

*Did you feel stressed?*

*Would you like to talk about what happened?*

\*If the participant is distressed, remind the participant that the experiment leader (John Felt) and supervisor (Dr. Tiemensma) are always available through email, phone, or in person should he or she have questions or want to talk more about the experience. Also, that CAPS is available for consultation if necessary.



## Appendix D

### Chapter 3 Analysis R Code

```

responders <- read.csv("C:\\Users\\jfelt\\Documents\\Dissertation\\Dissertation Final\\Responders.csv",
header = TRUE, na.strings="NA")
responders$Condition <- as.factor(responders$Condition)
levels(responders$Condition)<- list("Control" = 0, "TSST" = 1)
install.packages("lavaan")
library(lavaan)
install.packages("effsize")
library(effsize)
##Hypothesis 1##
mod2 <- t.test(BIFTotal~Condition, data=responders)
mod2
cohen.d(responders$BIFTotal~responders$Condition)
##Hypothesis 2##
t.test(T2PANAS_NA~Condition, data=responders)
cohen.d(responders$T2PANAS_NA~responders$Condition)
model11 <- '
BIFTotal ~ c*Condition
T2PANAS_NA ~ a*Condition
BIFTotal ~ b*T2PANAS_NA
T2PANAS_NA ~ BDI + T1PANAS_NA
T1PANAS_NA~BDI
BIFTotal~TDQTotR
ab := a*b
total := c + (a*b)'

mod11 <- sem(model11, data=responders, estimator="ML", se="BOOTSTRAP", bootstrap=5000)
summary(mod11, fit.measures=TRUE, standardized=TRUE, rsquare=TRUE)
boot.fit11 <- parameterEstimates(mod11, boot.ci.type="bca.simple", standardized=TRUE)
##Hypothesis 3##
model13 <- '
BIFTotal ~ c*Condition
SYSReact ~ a*Condition
BIFTotal ~ b*SYSReact
SYSReact ~ BMI + BDI + PSRS_TOTAL
ab := a*b
total := c + (a*b)'

mod13 <- sem(model13, data=responders, estimator="ML", se="BOOTSTRAP", bootstrap=5000)
summary(mod13, fit.measures=TRUE, standardized=TRUE, rsquare=TRUE)
boot.fit13 <- parameterEstimates(mod13, boot.ci.type="bca.simple", standardized=TRUE)

model15 <- '
BIFTotal ~ c*Condition
DIARect ~ a*Condition
BIFTotal ~ b*DIARect
DIARect ~ BMI + BDI + PSRS_TOTAL
ab := a*b
total := c + (a*b)'

mod15 <- sem(model15, data=responders, estimator="ML", se="BOOTSTRAP", bootstrap=5000)
summary(mod15, fit.measures=TRUE, standardized=TRUE, rsquare=TRUE)
boot.fit15 <- parameterEstimates(mod15, boot.ci.type="bca.simple")

```

```

model17 <- '
BIFTotal ~ c*Condition
HRReact ~ a*Condition
BIFTotal ~ b*HRReact
HRReact ~ BMI + BDI + PSRS_TOTAL
ab := a*b
total := c + (a*b)'

mod17 <- sem(model17, data=responders, estimator="ML", se="BOOTSTRAP", bootstrap=5000)
summary(mod17, fit.measures=TRUE, standardized=TRUE, rsquare=TRUE)
boot.fit17 <- parameterEstimates(mod17, boot.ci.type="bca.simple")

```

## Chapter 4 Analysis Code

### R Code

#### LGCM

```

#This is how you add comments in r
#To download r, see https://www.r-project.org/
#To use this code, copy and paste everything into r

install.packages("lavaan")
#This is how you install packages in r
library(lavaan)
#Once the package is installed, you have to call the package from the library
#After the first time you install the package, you only have to use the library
#function each time you use r unless you want an updated version of the package

mydata <- read.table("C:\\Users\\ucmuser\\Desktop\\mydata.txt")
#read.table allows you to read a .dat or .txt file.
#You can also read in other data file types. Google is your friend when using r
#Here, I created an object called data so that the data can be easily accessed
#The arrow pointing to the object data means that everything to the left of that arrow will be held in the
object the arrow is pointing to

names(mydata) <- c("ID", "cort1", "cort2", "cort3", "cort4", "cort5", "cort6",
                  "medic", "alpha1", "alpha2", "alpha3", "alpha4", "alpha5",
                  "alpha6", "GenderR")
#Because I am using the same data set as in the Mplus example, the data file does not contain variable
names
#Using the names() command allows you to place names on an object
#Here, I named each column of my data set
#in r, you can read data files in that have the variable names by specifying header=TRUE within the
read.table command

model1 <-
#In Lavaan, you have to specify each part of the model.
#Here, we are placing the entire model being specified as model1
#You begin and end your model with an apostrophe

'i =~ 1*cort1 + 1*cort2 + 1*cort3 + 1*cort4 + 1*cort5 + 1*cort6
s =~ 0*cort1 + 1*cort2 + 2*cort3 + 3*cort4 + 4*cort5 + 5*cort6
q =~ 0*cort1 + 1*cort2 + 4*cort3 + 9*cort4 + 16*cort5 + 25*cort6

```

```
#This is where you specify the growth factors
#The =~ means that the growth factor to the left are a function of everything to the right
#The number with the asterick next to the variable name indicates a fixed path.
#So, for the intercept slope growth factor, all paths are fixed to 1
#In the linear slope growth factors, the first path is fixed to 0 while the subsequent paths increase by 1 for
each item
#The quadratic slope growth factor is just the squared values of the linear slope
#Higher order nonlinear trends can be specified in a similar way. Just add them below
#This example is for equidistant time points. If time points are unequally spaced, that coding can be
handled by placing different
#values for the slope growth factors that indicate the unequal spacing (i.e., 1, 4,5,6,8)
#Just make sure to square those values in a quadratic slope (or cube in a cubic slope)
```

```
cort1 ~ alpha1
cort2 ~ alpha2
cort3 ~ alpha3
cort4 ~ alpha4
cort5 ~ alpha5
cort6 ~ alpha6
```

```
#These are regression equations for time-varying covariates.
#Here, each measurement of alpha-amylase is predicting
#The corresponding measurement of cortisol
```

```
i ~ gender
s ~ gender
q ~ gender'
```

```
#These are regression equations for time-invariant covariates.
#Here, gender is predicting each of the latent growth factors
```

```
medic ~ i + s + q'
```

```
#This is a regression equation for the distal outcome measure
#Here, medical visits is predicted by the growth factors
#Since this is a linear model, if there are multiple predictors,
#They are added together in the equation
#Don't forget to end your model with the apostrophe
```

```
fit1 <- growth(model1, data=data, estimator = "MLR")
#This is how you estimate the latent growth curve model
#The growth command tells lavaan that this is an LGCM
#The first command in the parentheses is where you specify
#the model by placing the object that contains the model you built
#next you have to indicate what your data is by calling data=data
#(or whatever you called your data set)
#The next command is not necessary, but is useful. estimator can be
#used to change the estimator depending on the type of data you have
#See the Lavaan userguide for more information
```

```
summary(fit1)
#the summary command will provide you with parameter estimates and a description of
#your model (i.e., the model specified, estimator used, etc.)
```

```
absoluteFit <- fitmeasures(fit1, c("cfi", "tli", "rmsea", "rmsea.ci.lower", "rmsea.ci.upper",
```

```
"rmsea.pvalue", "srmr", "tli", "chisq", "df", "pvalue"))
relativefit <- fitmeasures(fit1, c("aic", "bic", "bic2", "logl"))
#fit measures calls all of the model fit statistics available to lavaan to evaluate
#If the command is fitmeasures(fit1), every fit statistic that lavaan has will be in the output
#Here, I specified some commonly used model fit indices to make the output more manageable
#I split the fit indices into absolute model fit and relative (comparative) model fit indices
#The absolute fit indices include the CFI, RMSEA, and Chi-Square (amongst others)
#The relative model fit indices include the AIC, BIC, adjusted BIC, and loglikelihood
#The relative model fit indices allow you to compare the performance of competing models
```

### Multigroup LGCM

```
#This is how you add comments in r
#To download r, see https://www.r-project.org/
#To use this code, copy and paste everything into r

install.packages("lavaan")
#This is how you install packages in r
library(lavaan)
#Once the package is installed, you have to call the package from the library
#After the first time you install the package, you only have to use the library
#function each time you use r unless you want an updated version of the package

mydata<- read.table("C:\\Users\\ucmuser\\Cloud Drive\\Candidacy Project (CP)\\Growth
Modeling\\Manuscript\\Manuscript\\Publication Version\\Statistical Code\\Mplus\\mydata.txt")
#read.table allows you to read a .dat or .txt file.
#You can also read in other data file types. Google is your friend when using r
#Here, I created an object called data so that the data can be easily accessed
#The arrow pointing to the object data means that everything to the left of that arrow will be held in the
object the arrow is pointing to

names(mydata) <- c("ID", "cort1", "cort2", "cort3", "cort4", "cort5", "cort6",
                 "medic", "alpha1", "alpha2", "alpha3", "alpha4", "alpha5",
                 "alpha6", "gender")
#Because I am using the same data set as in the Mplus example, the data file does not contain variable
names
#Using the names() command allows you to place names on an object
#Here, I named each column of my data set
#in r, you can read data files in that have the variable names by specifying header=TRUE within the
read.table command
mydata$gender[gender==0] <- "female"
mydata$gender[gender==1] <- "male"
#This code allows you to recode a numerical variable into a categorical one
#Here, I recoded gender so that all 0's in the data frame equals "female" and
#all 1's in the data frame equals "male"
#This is done because I am using the same data as Mplus. Mplus cannot read
#in string variables, so gender was coded binary 0,1.

modelMG<-
#In Lavaan, you have to specify each part of the model.
#Here, we are placing the entire model being specified as model1
#You begin and end your model with an apostrophe
'i =~ 1*cort1 + 1*cort2 + 1*cort3 + 1*cort4 + 1*cort5 + 1*cort6
s =~ 0*cort1 + 1*cort2 + 2*cort3 + 3*cort4 + 4*cort5 + 5*cort6
q =~ 0*cort1 + 1*cort2 + 4*cort3 + 9*cort4 + 16*cort5 + 25*cort6'
```

```
#This is where you specify the growth factors
#The =~ means that the growth factor to the left are a function of everything to the right
#The number with the asterick next to the variable name indicates a fixed path.
#So, for the intercept slope growth factor, all paths are fixed to 1
#In the linear slope growth factors, the first path is fixed to 0 while the subsequent paths increase by 1 for
each item
#The quadratic slope growth factor is just the squared values of the linear slope
#Higher order nonlinear trends can be specified in a similar way. Just add them below
#This example is for equidistant time points. If time points are unequally spaced, that coding can be
handled by placing different
#values for the slope growth factors that indicate the unequal spacing (i.e., 1, 4,5,6,8)
#Just make sure to square those values in a quadratic slope (or cube in a cubic slope)
```

```
fitMG <- growth(modelMG, data=mydata, estimator = "MLR", group = "gender")
#This is how you estimate the latent growth curve model
#The growth command tells lavaan that this is an LGCM
#The first command in the parentheses is where you specify
#the model by placing the object the contains the model you built
#next you have to indicate what your data is by calling data=data
#(or whatever you called your data set)
#The next command is not necessary, but is useful. estimator can be
#used to change the estimator depending on the type of data you have
#See the Lavaan userguide for more information
```

```
fitMG
```

```
summary(fitMG)
```

```
#the summary command will provide you with parameter estimates and a description of
#your model (i.e., the model specified, estimator used, etc.)
```

```
AbsolutefitMG <- fitmeasures(fitMG, c("cfi", "tli", "rmsea", "rmsea.ci.lower", "rmsea.ci.upper",
"rmsea.pvalue", "srmr", "tli", "chisq", "df", "pvalue"))
```

```
RelativefitMG <- fitmeasures(fitMG, c("aic", "bic", "bic2", "logl"))
```

```
#fit measures calls all of the model fit statistics available to lavaan to evaluate
```

```
#If the command is fitmeasures(fit1), every fit statistic that lavaan has will be in the output
```

```
#Here, I specified some commonly used model fit indices to make the output more manageable
```

```
#I split the fit indices into absolute model fit and relative (comparative) model fit indices
```

```
#The absolute fit indices include the CFI, RMSEA, and Chi-Square (amongst others)
```

```
#The relative model fit indices include the AIC, BIC, adjusted BIC, and loglikelihood
```

```
#The relative model fit indices allow you to compare the performance of competing models
```

### Latent Basis Model

```
#This is how you add comments in r
```

```
#To download r, see https://www.r-project.org/
```

```
#To use this code, copy and paste everything into r
```

```
install.packages("lavaan")
```

```
#This is how you install packages in r
```

```
library(lavaan)
```

```
#Once the package is installed, you have to call the package from the library
```

```
#After the first time you install the package, you only have to use the library
```

```

#function each time you use r unless you want an updated version of the package

#Here, I created an object called data so that the data can be easily accessed
#The arrow pointing to the object data means that everything to the left of that arrow will be held in that
object.
data <- read.table("C:/Users/ucmuser/Cloud Drive/Candidacy Project (CP)/Growth
Modeling/Manuscript/Manuscript/Publication Version/Statistical Code/Examples/Lavaan/data.dat",
quote="\")
#read.table allows you to read a .dat or .txt file.
#You can also read in other data file types. Google is your friend when using r
#Here, I created an object called data so that the data can be easily accessed
#The arrow pointing to the object data means that everything to the left of that arrow will be held in the
object the arrow is pointing to

names(data) <- c("ID", "cort1", "cort2", "cort3", "cort4", "cort5", "cort6",
               "medic", "alpha1", "alpha2", "alpha3", "alpha4", "alpha5",
               "alpha6", "gender")
#Because I am using the same data set as in the Mplus example, the data file does not contain variable
names
#Using the names() command allows you to place names on an object
#Here, I named each column of my data set
#in r, you can read data files in that have the variable names by specifying header=TRUE within the
read.table command

modelLB<-
  'i =~ 1*cort1 + 1*cort2 + 1*cort3 + 1*cort4 + 1*cort5 + 1*cort6
  c =~ 0*cort1 + cort2 + cort3 + cort4 + cort5 + 1*cort6'
#This is where you specify the growth factors
#The =~ means that the growth factor to the left are a function of everything to the right
#The number with the asterick next to the variable name indicates a fixed path.
#variables without an asterick and number attached are freely estimated.
#So, for the intercept slope growth factor, all paths are fixed to 1.
#Because this is a latent basis model, the pattern of change is estimated, rather than fixed
#Instead of fixing the slope values as is done in the intercept, only the first and final time point
#are fixed values. This keeps the estimate of the slope bound between 0 and 1.

fitLB <- growth(modelLB, data=data, estimator = "MLR")
#This is how you estimate the latent growth curve model
#The growth command tells lavaan that this is an LGCM
#The first command in the parentheses is where you specify
#the model by placing the object the contains the model you built
#next you have to indicate what your data is by calling data=data
#(or whatever you called your data set)
#The next command is not necessary, but is useful. estimator can be
#used to change the estimator depending on the type of data you have
#See the Lavaan userguide for more information

summary(fitLB)
#the summary command will provide you with parameter estimates and a description of
#your model (i.e., the model specified, estimator used, etc.)

abosultefitLB <- fitmeasures(fitLB, c("cfi", "tli", "rmsea", "rmsea.ci.lower", "rmsea.ci.upper",
"rmsea.pvalue", "srmr", "tli", "chisq", "df", "pvalue"))

```

```
relativefitLB <- fitmeasures(fitLB, c("aic", "bic", "bic2", "logl"))
#fit measures calls all of the model fit statistics available to lavaan to evaluate
#If the command is fitmeasures(fit1), every fit statistic that lavaan has will be in the output
#Here, I specified some commonly used model fit indices to make the output more manageable
#I split the fit indices into absolute model fit and relative (comparative) model fit indices
#The absolute fit indices include the CFI, RMSEA, and Chi-Square (amongst others)
#The relative model fit indices include the AIC, BIC, adjusted BIC, and loglikelihood
#The relative model fit indices allow you to compare the performance of competing models
```

### Piecewise LGCM

```
#This is how you add comments in r
#To download r, see https://www.r-project.org/
#To use this code, copy and paste everything into r
```

```
install.packages("lavaan")
#This is how you install packages in r
library(lavaan)
#Once the package is installed, you have to call the package from the library
#After the first time you install the package, you only have to use the library
#function each time you use r unless you want an updated version of the package
```

```
mydata <- read.table("C:/Users/ucmuser/Cloud Drive/Candidacy Project (CP)/Growth
Modeling/Manuscript/Publication Version/Statistical Code/Examples/Lavaan/mydata.dat",
quote="\")
#read.table allows you to read a .dat or .txt file.
#You can also read in other data file types. Google is your friend when using r
#Here, I created an object called data so that the data can be easily accessed
#The arrow pointing to the object data means that everything to the left of that arrow will be held in the
object the arrow is pointing to
```

```
names(mydata) <- c("ID", "cort1", "cort2", "cort3", "cort4", "cort5", "cort6",
"medic", "alpha1", "alpha2", "alpha3", "alpha4", "alpha5",
"alpha6", "gender")
#Because I am using the same data set as in the Mplus example, the data file does not contain variable
names
#Using the names() command allows you to place names on an object
#Here, I named each column of my data set
#in r, you can read data files in that have the variable names by specifying header=TRUE within the
read.table command
```

```
modelPW<-
#In Lavaan, you have to specify each part of the model.
#Here, we are placing the entire model being specified as model1
#You begin and end your model with an apostrophe
```

```
'i =~ 1*cort1 + 1*cort2 + 1*cort3 + 1*cort4 + 1*cort5 + 1*cort6
s1 =~ 0*cort1 + 1*cort2 + 2*cort3 + 2*cort4 + 2*cort5 + 2*cort6
s2 =~ 0*cort1 + 0*cort2 + 0*cort3 + 1*cort4 + 2*cort5 + 3*cort6'
```

```
#This is where you specify the growth factors
#The =~ means that the growth factor to the left are a function of everything to the right
#The number with the asterick next to the variable name indicates a fixed path.
#So, for the intercept slope growth factor, all paths are fixed to 1
#For the intercept, the path between each cortisol measurement and the intercept is fixed to 1
#The first linear slope is specified to evaluate a linear trend in time-points 1, 2, and 3 (i.e., baseline)
```

```
#The second linear slope is specified to evaluate a linear trend in time-points 4, 5, and 6 (i.e., recovery)
#The first and second slope can be specified to capture the bend in the trajectory
#any way that matches your research design
#You can also specify other models than linear-linear (e.g., linear-quadratic)
```

```
fit2 <- growth(modelPW, data=mydata, estimator = "MLR")
#This is how you estimate the latent growth curve model
#The growth command tells lavaan that this is an LGCM
#The first command in the parentheses is where you specify
#the model by placing the object that contains the model you built
#next you have to indicate what your data is by calling data=data
#(or whatever you called your data set)
#The next command is not necessary, but is useful. estimator can be
#used to change the estimator depending on the type of data you have
#See the Lavaan userguide for more information
```

```
summary(fit2)
#the summary command will provide you with parameter estimates and a description of
#your model (i.e., the model specified, estimator used, etc.)
```

```
absolutefit <- fitmeasures(fit2, c("cfi", "tli", "rmsea", "rmsea.ci.lower", "rmsea.ci.upper",
                                "rmsea.pvalue", "srmr", "tli", "chisq", "df", "pvalue"))
relativefit <- fitmeasures(fit2, c("aic", "bic", "bic2", "logl"))
#fit measures calls all of the model fit statistics available to lavaan to evaluate
#If the command is fitmeasures(fit2), every fit statistic that lavaan has will be in the output
#Here, I specified some commonly used model fit indices to make the output more manageable
#I split the fit indices into absolute model fit and relative (comparative) model fit indices
#The absolute fit indices include the CFI, RMSEA, and Chi-Square (amongst others)
#The relative model fit indices include the AIC, BIC, adjusted BIC, and loglikelihood
#The relative model fit indices allow you to compare the performance of competing models
```

## Mplus Code

### LGCM

```
!This is how you add comments to your code in Mplus. Lines with a ! will be commented out
!To use this code, copy and past everything into the Mplus editor window
!When a line of code is finished, you must end it with a semi-colon (;)
!Lines of code or text should be fewer than 90 characters
!You can begin comments or code on the next line if to keep
!below 90 characters
```

```
TITLE: Latent Growth Curve Model with linear and quadratic slope growth factors
time-varying and time-invariant covariates and a distal outcome measure;
!With the 'TITLE' command, you can specify a descriptive title to help you
!recall what the analysis was
```

```
DATA: FILE IS mydata.txt;
!The DATA command is where you call in the data set
!If the Mplus file and the data file are saved in the same folder, you can
!call the data in with just the file name
!Here, I called in the data set as if the Mplus file and the data file are
!saved in the same folder
!If the Mplus and the data files are NOT saved in the same folder, you have
!to call the data in with the full path to the file
```



**VARIABLE:**

!The 'VARIABLE' command is where you define your variables

NAMES ARE ID cort1-cort6 medic alpha1-alpha6 gender;

!Mplus data files cannot contain the variable names. Instead, you specify the variable names with the 'NAMES ARE' command. Make sure you list your variable names by the order they appear in your data set

USEVARIABLES ARE cort1-cort6 medic alpha1-alpha6 gender;

!The 'USEVARIABLES' command is where you specify which variables in your data set will be part of the current analysis

!CATEGORICAL ARE

!BINARY ARE

!COUNT ARE

!If you have any outcome variables that are not continuous, you can specify that here

!For instance, if gender were used as an outcome variable, we would specify it as

!BINARY ARE gender

!Specifying the variable type will change the default estimator to one appropriate for the type of data

!For instance, with categorical data, the estimator will default to WLSMV unless otherwise

!specified

MISSING ARE ALL (-999);

!If there is missing data present in your data set, you can specify that here.

!When all missing data are coded the same way, the command 'MISSING ARE ALL' can be used

!This will implement Full-information maximum likelihood for missing data

!Missing data can also be handled using multiple imputation (See Mplus userguide)

!Here, I have all missing data coded as -999, but any value can be inserted

**ANALYSIS:**

ESTIMATOR = MLR;

!Can specify the estimator here. With continuous variables, will default to ML. Here, MLR

!(ML with robust standard errors) was specified

!Can specify Bayesian estimation here with 'ESTIMATOR = BAYES'

!See user guide for full list of estimators that can be specified

!DISTRIBUTION = SKEWT;

!If your variables are non-normal, you can specify a skewed distribution instead of

!transforming your variables using the command 'DISTRIBUTION'

!Distribution options include SKEWNORMAL (when skewness is below the absolute value of 1)

!or SKEWT regardless of skewness values

!Other distribution options are described in the Mplus usermanual

**MODEL:**

!The model command is where you build, or specify, your model

i s q | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5;

!i s and q represent intercept, linear slope, and quadratic slope growth factors

!The | indicates that i s and q are random effects constructed from the cortisol

!measurements

!Here, time was assumed to be equidistant. Mplus will automatically specify all paths

!between the items and the latent growth factors accordingly (e.g., paths between items and

!intercept will all be 1; paths between items and quadratic slope will be the squared

!values of what was specified in the command line)  
 !Higher order nonlinear trends can be specified by adding more before the |  
 !For instance, if you would like a cubic trend, you could specify  
 li s q c | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5; to estimate a  
 !cubic trend

```
i s q ON gender;
```

!This is a time-invariant covariate. Gender is predicted by the latent growth factors

```
cort1 ON alpha1;  
cort2 ON alpha2;  
cort3 ON alpha3;  
cort4 ON alpha4;  
cort5 ON alpha5;  
cort6 ON alpha6;
```

!This is how you specify time-varying covariates. Each measurement of alpha-amylase  
 !predicts the corresponding cortisol measurement

```
medic ON i s q;
```

!This is how you specify a distal outcome measure. Here, the latent growth factors are  
 !predicting the number of medical visits

!OUTPUT:

!The OUTPUT command is not necessary, but can call useful information.  
 !In this command, you can call technical outputs to help diagnosis modelling issues  
 !such as multicollinearity, you can request standardized results, and you can  
 !request sample statistics.

PLOT:

!The 'PLOT' command is where you can request plots

```
TYPE = PLOT3;
```

!Specify 'TYPE = PLOT3' for plots will generate trajectory plots (among other plots)

```
SERIES= cort1(0) cort2(1) cort3(2) cort4(3) cort5(4) cort6(5);
```

!Specifying 'SERIES=cort1-cort6' tells Mplus to makes the trajectory plots  
 !with the six cortisol measurements

!The parentheses specify the x-axis values

!This can be specified in many different ways. See Mplus userguide for more information

## LGCM for 2 Parallel Processes

#This is how you add comments in r

#To download r, see <https://www.r-project.org/>

#To use this code, copy and paste everything into r

```
install.packages("lavaan")
```

#This is how you install packages in r

```
library(lavaan)
```

#Once the package is installed, you have to call the package from the library

#After the first time you install the package, you only have to use the library

#function each time you use r unless you want an updated version of the package

```
mydata <- read.table("C:/Users/ucmuser/Cloud Drive/Candidacy Project (CP)/Growth  
Modeling/Manuscript/Manuscript/Publication Version/Statistical Code/Examples/Lavaan/mydata.dat",  
quote="\")
```

#read.table allows you to read a .dat or .txt file.  
 #You can also read in other data file types. Google is your friend when using r  
 #Here, I created an object called data so that the data can be easily accessed  
 #The arrow pointing to the object data means that everything to the left of that arrow will be held in the object the arrow is pointing to

```
names(mydata) <- c("ID", "cort1", "cort2", "cort3", "cort4", "cort5", "cort6",
                  "medic", "alpha1", "alpha2", "alpha3", "alpha4", "alpha5",
                  "alpha6", "gender")
```

#Because I am using the same data set as in the Mplus example, the data file does not contain variable names

#Using the names() command allows you to place names on an object

#Here, I named each column of my data set

#in r, you can read data files in that have the variable names by specifying header=TRUE within the read.table command

```
modelPP<-
```

#In Lavaan, you have to specify each part of the model.

#Here, we are placing the entire model being specified as model3

#You begin and end your model with an apostrophe

```
'#cortisol growth
```

```
  i1 =~ 1*cort1 + 1*cort2 + 1*cort3 + 1*cort4 + 1*cort5 + 1*cort6
  s1 =~ 0*cort1 + 1*cort2 + 2*cort3 + 3*cort4 + 4*cort5 + 5*cort6
  q1 =~ 0*cort1 + 1*cort2 + 4*cort3 + 9*cort4 + 16*cort5 + 25*cort6
```

#This is where you specify the growth factors for cortisol

#The =~ means that the growth factor to the left are a function of everything to the right

#The number with the asterick next to the variable name indicates a fixed path.

#So, for the intercept slope growth factor, all paths are fixed to 1

#In the linear slope growth factors, the first path is fixed to 0 while the subsequent paths increase by 1 for each item

#The quadratic slope growth factor is just the squared values of the linear slope

#Higher order nonlinear trends can be specified in a similar way. Just add them below

#This example is for equidistant time points. If time points are unequally spaced, that coding can be handled by placing different

#values for the slope growth factors that indicate the unequal spacing (i.e., 1, 4,5,6,8)

#Just make sure to square those values in a quadratic slope (or cube in a cubic slope)

```
  '#alpha-amylase growth
```

```
  i2 =~ 1*alpha1 + 1*alpha2 + 1*alpha3 + 1*alpha4 + 1*alpha5 + 1*alpha6
  s2 =~ 0*alpha1 + 1*alpha2 + 2*alpha3 + 3*alpha4 + 4*alpha5 + 5*alpha6
  q2 =~ 0*alpha1 + 1*alpha2 + 4*alpha3 + 9*alpha4 + 16*alpha5 + 25*alpha6
```

#This is where you specify the growth factors for alpha-amylase

#See above comments for cortisol growth factors for additional information here

#The equal tilda (==) means the latent variable is constructed from the equation on the right

```
  '#intercepts predicting slopes
```

```
  s1 ~ i2
```

```
  s2 ~ i1
```

```
  q1 ~ s2
```

```
  q2 ~ s1
```

#These lines of code specify regression paths between the

#latent growth factors of each process

#This is an example of one configuration. This can be specified differently to accomodate

#different research questions

#The single tilde (~) means the variable on the left is being predicted by the variable on the right

```
#correlating intercepts with intercepts and slopes with slopes
q1 ~~ q2
i1 ~~ i2'
```

#this is where you specify the correlations between two variables, manifest or latent

#The double tilde (~~) means correlate with

```
fit3 <- growth(modelPP, data=mydata, estimator = "MLR")
#This is how you estimate the latent growth curve model
#The growth command tells lavaan that this is an LGCM
#The first command in the parentheses is where you specify
#the model by placing the object the contains the model you built
#next you have to indicate what your data is by calling data=data
#(or whatever you called your data set)
#The next command is not necessary, but is useful. estimator can be
#used to change the estimator depending on the type of data you have
#See the Lavaan userguide for more information
```

```
summary(fit3)
```

#the summary command will provide you with parameter estimates and a description of  
#your model (i.e., the model specified, estimator used, etc.)

```
absolutefit <- fitmeasures(fit3, c("cfi", "tli", "rmsea", "rmsea.ci.lower", "rmsea.ci.upper",
                                "rmsea.pvalue", "srmr", "tli", "chisq", "df", "pvalue"))
```

```
relativefit <- fitmeasures(fit3, c("aic", "bic", "bic2", "logl"))
```

#fit measures calls all of the model fit statistics available to lavaan to evaluate

#If the command is fitmeasures(fit3), every fit statistic that lavaan has will be in the output

#Here, I specified some commonly used model fit indices to make the output more manageable

#I split the fit indices into absolute model fit and relative (comparative) model fit indices

#The absolute fit indices include the CFI, RMSEA, and Chi-Square (amongst others)

#The relative model fit indices include the AIC, BIC, adjusted BIC, and loglikelihood

#The relative model fit indices allow you to compare the performance of competing models

## LGMM

!This is how you add comments to your code in Mplus. Lines with a ! will be commented out

!To use this code, copy and past everything into the Mplus editor window

!When a line of code is finished, you must end it with a semi-colon (;)

!Lines of code or text should be fewer than 90 characters

!You can begin comments or code on the next line if to keep

!below 90 characters

TITLE: Latent Growth Mixture Model with linear and quadratic slope growth factors;

!With the 'TITLE' command, you can specify a descriptive title to help you

!recall what the analysis was

DATA: FILE IS mydata.txt;

!The DATA command is where you call in the data set

!If the Mplus file and the data file are saved in the same folder, you can

!call the data in with just the file name

!Here, I called in the data set as if the Mplus file and the data file are

!saved in the same folder

!If the Mplus and the data files are NOT saved in the same folder, you have

!to call the data in with the full path to the file

**VARIABLE:**

!The 'VARIABLE' command is where you define your variables

NAMES ARE ID cort1-cort6 medic alpha1-alpha6 gender;

!Mplus data files cannot contain the variable names. Instead, you specify the variable names with the 'NAMES ARE' command. Make sure you list your variable names by the order they appear in your data set

USEVARIABLES ARE cort1-cort6 medic alpha1-alpha6 gender;

!The 'USEVARIABLES' command is where you specify which variables in your data set will be part of the current analysis

!CATEGORICAL ARE

!BINARY ARE

!COUNT ARE

!If you have any outcome variables that are not continuous, you can specify that here

!For instance, if gender were used as an outcome variable, we would specify it as

!BINARY ARE gender

!Specifying the variable type will change the default estimator to one appropriate for the type of data

!For instance, with categorical data, the estimator will default to WLSMV unless otherwise specified

MISSING ARE ALL (-999);

!If there is missing data present in your data set, you can specify that here.

!When all missing data are coded the same way, the command 'MISSING ARE ALL' can be used

!This will implement Full-information maximum likelihood for missing data

!Missing data can also be handled using multiple imputation (See Mplus userguide)

!Here, I have all missing data coded as -999, but any value can be inserted

CLASSES = c (3);

!With the classes command, you can specify the number of latent (unobserved) groups exists in your data set. In this example, we have specified 3 latent groups. In practice, you would want to estimate a series of models with different latent group solutions and compare them.

**ANALYSIS:**

ESTIMATOR = MLR;

!Can specify the estimator here. With continuous variables, will default to ML. Here, MLR

!(ML with robust standard errors) was specified

!Can specify Bayesian estimation here with 'ESTIMATOR = BAYES'

!See user guide for full list of estimators that can be specified

!DISTRIBUTION = SKEWT;

!If your variables are non-normal, you can specify a skewed distribution instead of

!transforming your variables using the command 'DISTRIBUTION'

!Distribution options include SKEWNORMAL (when skewness is below the absolute value of 1)

!or SKEWT regardless of skewness values

!Other distribution options are described in the Mplus usermanual

TYPE = MIXTURE;

!By selecting TYPE = MIXTURE, a mixture model will be estimated.

STARTS = 40 8;

!With the STARTS command, random starting values can be specified.

!With this specification, 40 initial stage random sets of starting values are used  
!and 8 final stage optimizations are carried out.

#### MODEL:

!The model command is where you build, or specify, your model

```
%OVERALL%
```

```
i s q | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5;
```

!The %OVERALL% command specifies the model that is consistent across all latent  
!groups.

!i s and q represent intercept, linear slope, and quadratic slope growth factors

!The | indicates that i s and q are random effects constructed from the cortisol  
!measurements

!Here, time was assumed to be equidistant. Mplus will automatically specify all paths  
!between the items and the latent growth factors accordingly (e.g., paths between items and  
!intercept will all be 1; paths between items and quadratic slope will be the squared  
!values of what was specified in the command line)

!Higher order nonlinear trends can be specified by adding more before the |

!For instance, if you would like a cubic trend, you could specify

```
i s q c | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5; to estimate a  
!cubic trend
```

```
%c#1%
```

```
i s q | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5;
```

```
%c#2%
```

```
i s q | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5;
```

```
%c#3%
```

```
i s q | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5;
```

!Using the %c# % command allows you to specify different models for each latent class.

!If the models are hypothesized to be the same across each latent group, you only need  
!to specify the model for the %OVERALL% command. For this example, we manually specified

!the same model across all three latent groups to demonstrate where changes could be made

!As a note, if there are fewer or more latent groups estimated, the %c# % values will change.

!For example, with four latent groups, you would add %c#4% to specify a model for the fourth

!latent group. Likewise, if you were to estimate two latent classes, you would delete the code

!for %c#3%.

#### !OUTPUT:

!The OUTPUT command is not necessary, but can call useful information.

!In this command, you can call technical outputs to help diagnosis modelling issues

!such as multicollinearity, you can request standardized results, and you can

!request sample statistics.

```
TECH11 TECH14;
```

!TECH11 and TECH14 can be specified in the OUTPUT: command to obtain comparative model fit  
!statistics

!For mixture models. TECH11 provides the Lo-Mendell-Ruben test and TECH14 provides the  
!bootstrapped

!likelihood ratio test. Both of these model fit indices have been demonstrated to outperform traditional

!comparative model fit indices (see web notes from Asprouhov & Muthen, 2012 at statmodel.com).

#### PLOT:

!The 'PLOT' command is where you can request plots

```

TYPE = PLOT3;
!Specify 'TYPE = PLOT3' for plots will generate trajectory plots (among other plots)
SERIES= cort1(0) cort2(1) cort3(2) cort4(3) cort5(4) cort6(5);
!Specifying 'SERIES=cort1-cort6' tells Mplus to makes the trajectory plots
!with the six cortisol measurements
!The parentheses specify the x-axis values
!This can be specified in many different ways. See Mplus userguide for more information

```

### Multigroup LGCM

```

!This is how you add comments to your code in Mplus. Lines with a ! will be commented out
!To use this code, copy and past everything into the Mplus editor window
!When a line of code is finished, you must end it with a semi-colon (;)
!Lines of code or text should be fewer than 90 characters
!You can begin comments or code on the next line if to keep
!below 90 characters

```

```

TITLE: Multiple-group Latent Growth Curve Model with linear and quadratic slope growth factors;
!With the 'TITLE' command, you can specify a descriptive title to help you
!recall what the analysis was

```

```

DATA: FILE IS mydata.txt;
!The DATA command is where you call in the data set
!If the Mplus file and the data file are saved in the same folder, you can
!call the data in with just the file name
!Here, I called in the data set as if the Mplus file and the data file are
!saved in the same folder
!If the Mplus and the data files are NOT saved in the same folder, you have
!to call the data in with the full path to the file

```

```

VARIABLE:
!The 'VARIABLE' command is where you define your variables

```

```

NAMES ARE ID cort1-cort6 medic alpha1-alpha6 gender;
!Mplus data files cannot contain the variable names. Instead, you specify the variable
!names with the 'NAMES ARE' command. Make sure you list your variable names by the order
!they appear in you data set

```

```

USEVARIABLES ARE cort1-cort6 gender;
!The 'USEVARIABLES' commands is where you specify which variables in your data set will be
!part of the current analysis

```

```

!CATEGORICAL ARE
!BINARY ARE
!COUNT ARE
!If you have any outcome variables that are not continuous, you can specify that here
!For instance, if gender were used as an outcome variable, we would specify it as
!BINRARY ARE gender
!Specifying the variable type will change the default estimator to one appropriate for the
!type of data
!For instance, with categorical data, the estimator will default to WLSMV unless otherwise
!specified

```

```

MISSING ARE ALL (-999);

```

!If there is missing data present in your data set, you can specify that here.  
 !When all missing data are coded the same way, the command 'MISSING ARE ALL' can be used  
 !This will implement Full-information maximum likelihood for missing data  
 !Missing data can also be handled using multiple imputation (See Mplus userguide)  
 !Here, I have all missing data coded as -999, but any value can be inserted

GROUPING IS = gender (1 = male 0 = female);

!With the GROUPING command, you can specify grouping variable. In this example, we are going  
 !to compare the LGCM parameter estimates across gender.

ANALYSIS:

ESTIMATOR = MLR;

!Can specify the estimator here. With continuous variables, will default to ML. Here, MLR

!(ML with robust standard errors) was specified

!Can specify Bayesian estimation here with 'ESTIMATOR = BAYES'

!See user guide for full list of estimators that can be specified

!DISTRIBUTION = SKEWT;

!If your variables are non-normal, you can specify a skewed distribution instead of

!transforming your variables using the command 'DISTRIBUTION'

!Distribution options include SKEWNORMAL (when skewness is below the absolute value of 1)

!or SKEWT regardless of skewness values

!Other distribution options are described in the Mplus usermanual

MODEL:

!The model command is where you build, or specify, your model

i s q | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5;

!i s and q represent intercept, linear slope, and quadratic slope growth factors

!The | indicates that i s and q are random effects constructed from the cortisol

!measurements

!Here, time was assumed to be equidistant. Mplus will automatically specify all paths

!between the items and the latent growth factors accordingly (e.g., paths between items and

!intercept will all be 1; paths between items and quadratic slope will be the squared

!values of what was specified in the command line)

!Higher order nonlinear trends can be specified by adding more before the |

!For instance, if you would like a cubic trend, you could specify

!i s q c | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5; to estimate a

!cubic trend

MODEL female:

i s q | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5;

!Using the MODEL female command allows you to specify different models for the reference group.

!In this case, the reference group is the female group. We specified the same model for both groups,

!but in practice, the models can be different (e.g., constraining covariances, etc).

!OUTPUT:

!The OUTPUT command is not necessary, but can call useful information.

!In this command, you can call technical outputs to help diagnosis modelling issues

!such as multicollinearity, you can request standardized results, and you can

!request sample statistics.



**PLOT:**

!The 'PLOT' command is where you can request plots

```
TYPE = PLOT3;
```

!Specify 'TYPE = PLOT3' for plots will generate trajectory plots (among other plots)

```
SERIES= cort1(0) cort2(1) cort3(2) cort4(3) cort5(4) cort6(5);
```

!Specifying 'SERIES=cort1-cort6' tells Mplus to makes the trajectory plots

!with the six cortisol measurements

!The parentheses specify the x-axis values

!This can be specified in many different ways. See Mplus userguide for more information

**Piecewise LGCM**

!This is how you add comments to your code in Mplus. Lines with a ! will be commented out

!To use this code, copy and past everything into the Mplus editor window

!When a line of code is finished, you must end it with a semi-colon (;)

!Lines of code or text should be fewer than 90 characters

!You can begin comments or code on the next line if to keep

!below 90 characters

```
TITLE: Linear-Linear Piecewise Latent Growth Curve Model;
```

!With the 'TITLE' command, you can specify a descriptive title to help you

!recall what the analysis was

```
DATA: FILE IS mydata.txt;
```

!The DATA command is where you call in the data set

!If the Mplus file and the data file are saved in the same folder, you can

!call the data in with just the file name

!Here, I called in the data set as if the Mplus file and the data file are

!saved in the same folder

!If the Mplus and the data files are NOT saved in the same folder, you have

!to call the data in with the full path to the file

**VARIABLE:**

!The 'VARIABLE' command is where you define your variables

```
NAMES ARE ID cort1-cort6 medic alpha1-alpha6 gender;
```

!Mplus data files cannot contain the variable names. Instead, you specify the variable

!names with the 'NAMES ARE' command. Make sure you list your variable names by the order

!they appear in you data set

```
USEVARIABLES ARE cort1-cort6;
```

!The 'USEVARIABLES' commands is where you specify which variables in your data set will be

!part of the current analysis

!In this example, the analysis will only include 'cort1-cort6' and none of the other

!variables

```
!CONTINUOUS ARE
```

```
!CATEGORICAL ARE
```

```
!BINARY ARE
```

```
!COUNT ARE
```

!If you have any outcome variables that are not continuous, you can specify that here

!For instance, if gender were used as an outcome variable, we would specify it as  
 !BINRARY ARE gender  
 !Specifying the variable type will change the default estimator to one appropriate for the  
 !type of data  
 !For instance, with categorical data, the estimator will default to WLSMV unless otherwise  
 !specified

MISSING ARE ALL (-999);

!If there is missing data present in your data set, you can specify that here.  
 !When all missing data are coded the same way, the command 'MISSING ARE ALL' can be used  
 !This will implement Full-information maximum likelihood for missing data  
 !Missing data can also be handled using multiple imputation (See Mplus userguide)  
 !Here, I have all missing data coded as -999, but any value can be inserted

ANALYSIS:

ESTIMATOR = MLR;

!Can specify the estimator here. With continuous variables, will default to ML. Here, MLR  
 !(ML with robust standard errors) was specified  
 !Can specify Bayesian estimation here with 'ESTIMATOR = BAYES'  
 !See useguide for full list of estimators that can be specified

!DISTRIBUTION = SKEWT;

!If you variables are non-normal, you can specify a skewed distribution instead of  
 !transforming your variables using the command 'DISTRIBUTION'\*!  
 !Distribution options include SKEWNORMAL (when skewness is below the absolute value of 1)  
 !or SKEWT regardless of skewness values\*!  
 !Other distribution options are described in the Mplus usermanual

MODEL:

!The model command is where you build, or specify, your model

i s1 | cort1@0 cort2@1 cort3@2 cort4@2 cort5@2 cort6@2;

!This line specifies a linear trend before the intervention consisting of cort1-cort3  
 !The baseline phase

i s2 | cort1@0 cort2@0 cort3@0 cort4@1 cort5@2 cort6@3;

!This line specifies a linear trend after the intervention consisting of cort4-cort6  
 !The recovery phase

!The first and second slope can be specified to capture the bend in the trajectory  
 !any way that matches your research design

OUTPUT:

!The OUTPUT command is not necessary, but can call useful information.  
 !In this command, you can call technical outputs to help diagnosis modelling issues  
 !such as multicollinearity, or you can request standardized results.

PLOT:

!The 'PLOT' command is where you can request plots

TYPE IS PLOT3;

!Specify 'TYPE IS PLOT3' for plots will generate trajectory plots (among other plots)

SERIES=cort1(0) cort2(1) cort3(2) cort4(4) cort5(4) cort6(5);

!Specifying the series this way tells Mplus to makes the trajectory plots

!with the six cortisol measurements  
 !The parentheses specify the x-axis values  
 !This can be specified in many different ways. See Mplus userguide for more information

### LGCM for 2 Parallel Processes

!\*This is how you add comments to your code in Mplus. Lines with an  
 explanation point will be commented out\*!  
 !To use this code, copy and past everything into the Mplus editor window  
 !When a line of code is finished, you must end it with a semi-colon  
 !Lines of code or text should be fewer than 90 characters  
 !You can begin comments or code on the next line if to keep  
 !below 90 characters

TITLE: Latent Growth Curve Model for 2 parallel processes with linear slopes;  
 !With the 'TITLE' command, you can specify a descriptive title to help you  
 !recall what the analysis was

DATA: FILE IS mydata.txt;  
 !The DATA command is where you call in the data set  
 !If the Mplus file and the data file are saved in the same folder, you can  
 !call the data in with just the file name  
 !Here, I called in the data set as if the Mplus file and the data file are  
 !saved in the same folder  
 !If the Mplus and the data files are NOT saved in the same folder, you have  
 !to call the data in with the full path to the file

VARIABLE:  
 !The 'VARIABLE' command is where you define your variables

NAMES ARE ID cort1-cort6 medic alpha1-alpha6 gender;  
 !Mplus data files cannot contain the variable names. Instead, you specify the variable  
 !names with the 'NAMES ARE' command. Make sure you list your variable names by the order  
 !they appear in your data set

USEVARIABLES ARE cort1-cort6 alpha1-alpha6;  
 !The 'USEVARIABLES' command is where you specify which variables in  
 !your data set will be part of the current analysis

!CATEGORICAL ARE  
 !BINARY ARE  
 !COUNT ARE

!If you have any outcome variables that are not continuous, you can specify that here  
 !For instance, if gender were used as an outcome variable, we would specify it as  
 !BINARY ARE gender  
 !Specifying the variable type will change the default estimator to one appropriate for the  
 !type of data  
 !For instance, with categorical data, the estimator will default to WLSMV unless  
 !otherwise specified

MISSING ARE ALL (-999);  
 !If there is missing data present in your data set, you can specify that here.  
 !When all missing data are coded the same way, the command 'MISSING ARE ALL' can be used  
 !This will implement Full-information maximum likelihood for missing data

!Missing data can also be handled using multiple imputation (See Mplus userguide)  
!Here, I have all missing data coded as -999, but any value can be inserted

#### ANALYSIS:

ESTIMATOR = MLR;

!\*Can specify the estimator here. With continuous variables, will default to ML. Here, MLR (ML with robust standard errors) was specified\*!

!Can specify Bayesian estimation here with 'ESTIMATOR = BAYES'

!See useguide for full list of estimators that can be specified

!DISTRIBUTION = SKEWT;

!If your variables are non-normal, you can specify a skewed distribution instead of

!transforming your variables using the command 'DISTRIBUTION'

!Distribution options include SKEWNORMAL (when skewness is below the absolute value of 1)

!or SKEWT regardless of skewness values

!Other distribution options are described in the Mplus usermanual

#### MODEL:

!The model command is where you build, or specify, your model

i1 s1 q1 | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5;

!i1 s1 and q1 represent intercept, linear slope, and quadratic slope growth factors  
!for cortisol

!The | indicates that i1 s1 and q1 are random effects constructed from the cortisol  
!measurements

!Here, time was assumed to be equidistant. Mplus will automatically specify all paths

!between the items and the latent growth factors accordingly (e.g., paths between items and

!intercept will all be 1; paths between items and quadratic slope will be the squared

!values of what was specified in the command line)

!Higher order nonlinear trends can be specified by adding more before the |

!For instance, if you would like a cubic trend, you could specify

!i1 s1 q1 c1 | cort1@0 cort2@1 cort3@2 cort4@3 cort5@4 cort6@5; to estimate a

!cubic trend

i2 s2 q2 | alpha1@0 alpha2@1 alpha3@2 alpha4@3 alpha5@4 alpha6@5;

!i2 s2 and q2 represent intercept, linear slope, and quadratic slope growth factors

!for alpha-amylase

!The above comments for cortisol also apply here

s1 ON i2;

s2 ON i1;

q1 ON s2;

q2 ON s1;

!These lines of code specify regression paths between the

!latent growth factors of each process

!This is an example of one configuration. This can be specified differently to accommodate

!different research questions

#### !OUTPUT:

!The OUTPUT command is not necessary, but can call useful information.

!In this command, you can call technical outputs to help diagnosis modelling issues

!such as multicollinearity, you can request standardized results, and you can

!request sample statistics

#### PLOT:

!The 'PLOT' command is where you can request plots

```
TYPE = PLOT3;
```

!Specify 'TYPE = PLOT3' for plots will generate trajectory plots (among other plots)

```
SERIES= cort1(0) cort2(1) cort3(2) cort4(3) cort5(4) cort6(5)|  
alpha1(0) alpha2(1) alpha3(2) alpha4(3) alpha5(4) alpha6(5);
```

!Specifying 'SERIES=cort1-cort6' tells Mplus to makes the trajectory plots

!with the six cortisol measurements

### Appendix E

Choose one statement from among the groups of four statements in each question that best describes how you have been feeling during the PAST FEW DAYS.

1. .
  - a. I do not feel sad
  - b. I feel sad
  - c. I am sad all the time and can't snap out of it
  - d. I am so sad or unhappy that I cannot stand it
2. .
  - a. I am not particularly discouraged about the future
  - b. I feel discouraged about the future
  - c. I feel I have nothing to look forward to
  - d. I feel that the future is hopeless and that things cannot improve
3. .
  - a. I do not feel like a failure
  - b. I feel I have failed more than the average person
  - c. As I look back on my life, all I can see is a lot of failures
  - d. I feel I am a complete failure as a person
4. .
  - a. I get as much satisfaction out of things as I used to
  - b. I don't enjoy things the way I used to
  - c. I don't get real satisfaction out of anything anymore
  - d. I am dissatisfied or bored with everything
5. .
  - a. I don't feel particularly guilty
  - b. I feel guilty a good part of the time
  - c. I feel quite guilty most of the time
  - d. I feel guilty all of the time
6. .
  - a. I don't feel I am being punished
  - b. I feel I may be punished
  - c. I expect to be punished
  - d. I feel I am being punished
7. .
  - a. I don't feel disappointed in myself
  - b. I am disappointed in myself
  - c. I am disgusted in myself
  - d. I hate myself
8. .
  - a. I don't feel I am any worse than anybody else
  - b. I am critical of myself for my weaknesses or mistakes
  - c. I blame myself all the time for my faults
  - d. I blame myself for everything bad that happens
9. .
  - a. I don't have any thoughts of killing myself
  - b. I have thoughts of killing myself, but I would not carry them out
  - c. I would like to kill myself
  - d. I would kill myself if I had the chance

10. .
- I don't cry any more than usual
  - I cry more now than I used to
  - I cry all the time now
  - I used to be able to cry, but now I can't cry even though I want to
11. .
- I am no more irritated by things than I ever was
  - I am slightly more irritated now than usual
  - I am quite annoyed or irritated a good deal of the time
  - I feel irritated all the time
12. .
- I have not lost interest in other people
  - I am less interested in other people than I used to be
  - I have lost most of my interest in other people
  - I have lost all of my interest in other people
13. .
- I make decisions about as well as I ever could
  - I put off making decisions more than I used to
  - I have greater difficulty in making decisions more than I used to
  - I can't make decisions at all anymore
14. .
- I don't feel that I look any worse than I used to
  - I am worried that I am looking old or unattractive
  - I feel there are permanent changes in my appearance that make me look unattractive
  - I believe that I look ugly
15. .
- I can work about as well as before
  - It takes an extra effort to get started at doing something
  - I have to push myself very hard to do anything
  - I can't do any work at all
16. .
- I can sleep as well as usual
  - I don't sleep as well as I used to
  - I wake up 1-2 hours earlier than usual and find it hard to get back to sleep
  - I wake up several hours earlier than I used to and cannot get back to sleep
17. .
- I don't get more tired than usual
  - I get tired more easily than I used to
  - I get tired from doing almost anything
  - I am too tired to do anything
18. .
- My appetite is no worse than usual
  - My appetite is not as good as it used to be
  - My appetite is much worse now
  - I have no appetite at all anymore
19. .
- I haven't lost much weight, if any, lately
  - I have lost more than five pounds
  - I have lost more than ten pounds
  - I have lost more than fifteen pounds

20. .
- a. I am no more worried about my health than usual
  - b. I am worried about physical problems like aches, pains, upset stomach, or constipation
  - c. I am very worried about physical problems and it's hard to think of much else
  - d. I am so worried about my physical problems that I cannot think of anything else
21. .
- a. I have not noticed any recent change in my interest in sex
  - b. I am less interested in sex than I used to be
  - c. I have almost no interest in sex
  - d. I have lost interest in sex completely



### Perceived stress reactivity scale

Instructions: This questionnaire asks about your reactions to situations which you may have experienced in the past. Three answers are suggested. Please indicate the answer that most closely describes your own reaction in general. Please don't skip any item, even if it may be hard to find the best answer.

---

01	When tasks and duties build up to the extent that they are hard to manage...	I am generally untroubled I usually feel a little uneasy I normally get quite nervous
02	When I want to relax after a hard day at work...	This is usually quite difficult for me I usually succeed I generally have no problem at all
03	When I have conflicts with others that may not be immediately resolved ...	I generally shrug it off It usually affects me a little It usually affects me a lot
04	When I make a mistake ...	In general, I remain confident I sometimes feel unsure about my abilities I often have doubts about my abilities
05	When I'm wrongly criticized by others ...	I am normally annoyed for a long time I am annoyed for just a short time In general, I am hardly annoyed at all
06	When I argue with other people ...	I usually calm down quickly I usually stay upset for some time It usually takes me a long time until I calm down
07	When I have little time for a job to be done ...	I usually stay calm I usually feel uneasy I usually get quite agitated
08	When I make a mistake ...	I am normally annoyed for a long time I am normally annoyed for a while I generally get over it easily
09	When I am unsure what to do or say in a social situation ...	I generally stay cool I often feel warm I often begin to sweat
10	When I have space time after working hard ...	It often is difficult for me to unwind and relax I usually need some time to unwind properly I am usually able to unwind effectively and forget about the problems of the day
11	When I am criticized by others...	

---

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		Important arguments usually come to mind when it is too late to still make my point I often have difficulty finding a good reply I usually think of a reply to defend myself
12	When something does not go the way I expected ...	I usually stay calm I often get uneasy I usually get very agitated
13	When I do not attain a goal ...	I usually remain annoyed for a long time I am usually disappointed, but recover soon In general, I am hardly concerned at all
14	When others criticize me ...	I generally don't lose confidence at all I generally lose a little confidence I generally feel very unconfident
15	When I fail at something ...	I usually find it hard to accept I usually accept it to some degree In general, I hardly think about it
16	When there are too many demands on me at the same time ...	I generally stay calm and do one thing after the other I usually get uneasy Usually, even minor interruptions irritate me
17	When others say something incorrect about me ...	I usually get quite upset I normally get a little bit upset In general, I shrug it off
18	When I fail at a task	I usually feel very uncomfortable I usually feel somewhat uncomfortable In general, I don't mind
19	When I argue with others ...	I usually get very upset I usually get a little bit upset I usually don't get upset
20	When I am under stress ...	I usually can't enjoy my leisure time at all I usually have difficulty enjoying my leisure time I usually enjoy my leisure time
21	When tasks and duties accumulate to the extent that they are hard to cope with ...	My sleep is unaffected My sleep is slightly disturbed My sleep is very disturbed
22	When I have to speak in front of other people...	I often get very nervous I often get somewhat nervous In general, I stay calm

---

23 When I have many tasks and duties to fulfill...

In general, I stay calm  
I usually get impatient  
I often get irritable

### Biomarker Packet

Measurement: 1 2 3 4 5 Date: \_\_\_\_\_ Weight: \_\_\_\_\_

Participant ID: \_\_\_\_\_ T/C \_\_\_\_\_ Height: \_\_\_\_\_

BP: \_\_\_\_/\_\_\_\_ HR: \_\_\_\_\_ Start Time: \_\_\_\_\_ BMI: \_\_\_\_\_

Sex: M/F

How stressed do you feel right now? X----- -----X Not at all stressed Extremely Calm
How tense do you feel right now? X----- -----X Not at all tense Extremely tense
How anxious do you feel right now? X----- -----X Not at all anxious Extremely anxious
What is your overall sense of well-being right now? X----- -----X Not at all well Extremely well
How irritated do you feel right now? X----- -----X Not at all irritated Extremely irritated
How nervous do you feel right now? X----- -----X Not at all nervous Extremely nervous
How afraid do you feel right now? X----- -----X

Not at all afraid afraid	Extremely
What is your overall mood right now?	
X-----	
-----X	
Extremely unhappy	
Extremely happy	

## Biomarker Packet

Measurement: 1 2 3 4 5

BP: \_\_\_\_/\_\_\_\_ HR: \_\_\_\_ Start Time: \_\_\_\_\_

How stressed do you feel right now? X----- -----X Not at all stressed Extremely Calm
How tense do you feel right now? X----- -----X Not at all tense Extremely tense
How anxious do you feel right now? X----- -----X Not at all anxious Extremely anxious
What is your overall sense of well-being right now? X----- -----X Not at all well Extremely well
How irritated do you feel right now? X----- -----X Not at all irritated Extremely irritated
How nervous do you feel right now? X----- -----X Not at all nervous Extremely nervous
How afraid do you feel right now? X----- -----X Not at all afraid Extremely afraid
What is your overall mood right now? X----- -----X Extremely unhappy Extremely happy

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. **Indicate to what extent you feel this way right now, that is, at the present moment.** Using the following scale to record your answers.

1 2 3 4 5

Very slightly or  
not at all

A little

Moderately

Quite a bit

Extremely

\_\_\_\_\_interested

\_\_\_\_\_distressed

\_\_\_\_\_excited

\_\_\_\_\_upset

\_\_\_\_\_strong

\_\_\_\_\_guilty

\_\_\_\_\_scared

\_\_\_\_\_hostile

\_\_\_\_\_enthusiastic

\_\_\_\_\_proud

\_\_\_\_\_irritable

\_\_\_\_\_alert

\_\_\_\_\_ashamed

\_\_\_\_\_inspired

\_\_\_\_\_nervous

\_\_\_\_\_determined

\_\_\_\_\_attentive

\_\_\_\_\_jittery

\_\_\_\_\_active

\_\_\_\_\_afraid

**Biomarker Packet**

Measurement: 1 2 3 4 5

BP: \_\_\_\_/\_\_\_\_ HR: \_\_\_\_

Start Time: \_\_\_\_\_

How stressed do you feel right now? X----- -----X Not at all stressed Extremely Calm	
How tense do you feel right now? X----- -----X Not at all tense tense	Extremely
How anxious do you feel right now? X----- -----X Not at all anxious Extremely anxious	
What is your overall sense of well-being right now? X----- -----X Not at all well Extremely well	
How irritated do you feel right now? X----- -----X Not at all irritated Extremely irritated	
How nervous do you feel right now? X----- -----X Not at all nervous Extremely nervous	
How afraid do you feel right now? X----- -----X Not at all afraid afraid	Extremely
What is your overall mood right now? X----- -----X Extremely unhappy Extremely happy	

**Biomarker Packet**

Measurement: 1 2 3 4 5

BP: \_\_\_\_/\_\_\_\_ HR: \_\_\_\_ Start Time: \_\_\_\_\_

How stressed do you feel right now? X----- -----X Not at all stressed Extremely Calm
How tense do you feel right now? X----- -----X Not at all tense Extremely tense
How anxious do you feel right now? X----- -----X Not at all anxious Extremely anxious
What is your overall sense of well-being right now? X----- -----X Not at all well Extremely well
How irritated do you feel right now? X----- -----X Not at all irritated Extremely irritated
How nervous do you feel right now? X----- -----X Not at all nervous Extremely nervous
How afraid do you feel right now? X----- -----X Not at all afraid Extremely afraid
What is your overall mood right now? X----- -----X Extremely unhappy Extremely happy

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. **Indicate to what extent you feel this way right now, that is, at the present moment.** Using the following scale to record your answers.

1 2 3 4 5



Very slightly or  
not at all

A little

Moderately

Quite a bit

Extremely

\_\_\_\_\_interested

\_\_\_\_\_distressed

\_\_\_\_\_excited

\_\_\_\_\_upset

\_\_\_\_\_strong

\_\_\_\_\_guilty

\_\_\_\_\_scared

\_\_\_\_\_hostile

\_\_\_\_\_enthusiastic

\_\_\_\_\_proud

\_\_\_\_\_irritable

\_\_\_\_\_alert

\_\_\_\_\_ashamed

\_\_\_\_\_inspired

\_\_\_\_\_nervous

\_\_\_\_\_determined

\_\_\_\_\_attentive

\_\_\_\_\_jittery

\_\_\_\_\_active

\_\_\_\_\_afraid

**Biomarker Packet**

Measurement: 1 2 3 4 5

BP: \_\_\_\_/\_\_\_\_ HR: \_\_\_\_

Start Time: \_\_\_\_\_

How stressed do you feel right now? X----- -----X Not at all stressed Extremely Calm	
How tense do you feel right now? X----- -----X Not at all tense tense	Extremely
How anxious do you feel right now? X----- -----X Not at all anxious Extremely anxious	
What is your overall sense of well-being right now? X----- -----X Not at all well Extremely well	
How irritated do you feel right now? X----- -----X Not at all irritated Extremely irritated	
How nervous do you feel right now? X----- -----X Not at all nervous Extremely nervous	
How afraid do you feel right now? X----- -----X Not at all afraid afraid	Extremely
What is your overall mood right now? X----- -----X Extremely unhappy Extremely happy	

### SAMPLE WORD COMPLETION TASK

We are simply pre-testing this questionnaire for future studies. Please complete the following by filling letters in the blanks to create words. Please fill in the blanks with the first word that comes to mind. Write one letter per blank. Some words may be plural. Thank you.

1. BUR \_\_ D

14. CHA \_\_

2. PLA \_\_

15. KI \_\_ ED

3. \_\_ OK

16. CL \_\_ K

4. WAT \_\_

17. TAB \_\_

5. DE \_\_

18. W \_\_ DOW

6. MU \_\_

19. SK \_\_ L

7. \_\_ NG

20. TR \_\_

8. B \_ T \_ LE

21. P \_ P \_ R

9. M \_ J \_ R

22. COFF \_\_

10. P \_\_ TURE

23. \_ O \_ SE

11. FL \_ W \_ R

24. POST \_\_

12. GRA \_\_

25. R \_ DI \_

13. K \_\_ GS

**Session Notes**

SONA ID	
Date	
Start Time	
End Time	
Total Time	
President	
Assistant 1	
Assistant 2	

**Notes**

	Yes	No
Have you heard of the TSST before?		
Have you experienced the TSST before?		
Did you recognize anyone in the committee?		
At any point did you suspect/know the true purpose of the study?		

## Behavioral Identification Form

Any behavior can be described in many ways. For example, one person might describe a behavior as "writing a paper," while another person might describe the same behavior as "pushing keys on the keyboard." Yet another person might describe it as "expressing thoughts." This form focuses on your personal preferences for how a number of different behaviors should be described. Below you will find several behaviors listed. After each behavior will be two different ways in which the behavior might be identified.

For example:

1. Attending class
  - sitting in a chair
  - looking at a teacher

Your task is to choose the identification, a or b, that best describes the behavior for you. Simply place a checkmark next to the option you prefer. Be sure to respond to every item. Please mark only one alternative for each pair. Remember, mark the description that you personally believe is more appropriate for each pair.

1. Making a list
  - Getting organized\*
  - Writing things down
2. Reading
  - Following lines of print
  - Gaining knowledge\*
3. Joining the Army
  - Helping the Nation's defense\*
  - Signing up
4. Washing clothes
  - Removing odors from clothes\*
  - Putting clothes into the machine
5. Picking an apple
  - Getting something to eat\*
  - Pulling an apple off a branch
6. Chopping down a tree
  - Wielding an axe
  - Getting firewood\*

7. Measuring a room for carpeting
  - Getting ready to remodel\*
  - Using a yard stick
8. Cleaning the house
  - Showing one's cleanliness\*
  - Vacuuming the floor
9. Painting a room
  - Applying brush strokes
  - Making the room look fresh\*
10. Paying the rent
  - Maintaining a place to live\*
  - Writing a check
11. Caring for houseplants
  - Watering plants
  - Making the room look nice\*
12. Locking a door
  - Putting a key in the lock
  - Securing the house\*
13. Voting
  - Influencing the election\*
  - Marking a ballot
14. Climbing a tree
  - Getting a good view\*
  - Holding on to branches
15. Filling out a personality test
  - Answering questions
  - Revealing what you're like\*
16. Toothbrushing
  - Preventing tooth decay\*
  - Moving a brush around in one's mouth
17. Taking a test
  - Answering questions
  - Showing one's knowledge\*
18. Greeting someone
  - Saying hello

- Showing friendliness\*
- 19. Resisting temptation
  - Saying "no"
  - Showing moral courage\*
- 20. Eating
  - Getting nutrition\*
  - Chewing and swallowing
- 21. Growing a garden
  - Planting seeds
  - Getting fresh vegetables\*
- 22. Traveling by car
  - Following a map
  - Seeing countryside\*
- 23. Having a cavity filled
  - Protecting your teeth\*
  - Going to the dentist
- 24. Talking to a child
  - Teaching a child something\*
  - Using simple words
- 25. Pushing a doorbell
  - Moving a finger
  - Seeing if someone's home\*

## Demographics

Gender:

- Male
- Female
- Other
- Choose not to answer

Date of birth

- MM/DD/YYYY

Year in School

- Freshman
- Sophomore
- Junior
- Senior
- Senior+

Are you a first-generation college student? (i.e., neither of your parents graduated from a 4-year institution)

- Yes
- No

Race/Ethnicity

- Caucasian/White
- Hispanic/Latino
- African-American/Black
- Native American/American Indian
- Asian/Pacific Islander
- Bi-racial \_\_\_\_\_
- Other \_\_\_\_\_

Choose the appropriate number (0 to 7) which best describes your general activity level for the previous month.

0. DO NOT PARTICIPATE IN PROGRAMMED RECREATION, SPORT, OR HEAVY PHYSICAL ACTIVITY. Avoid walking or exertion, e.g., always use the elevator, drive whenever possible instead of walking.
1. DO NOT PARTICIPATE IN PROGRAMMED RECREATION, SPORT, OR HEAVY PHYSICAL ACTIVITY. Walk for pleasure, routinely use stairs, occasionally exercise sufficiently to cause heavy breathing perspiration.
2. PARTICIPATED REGULARLY IN RECREATION OR WORK REQUIING MODEST PHYSICAL ACTIVITY, SUCH AS GOLF, HORSEBACK RIDING, CALISTHENICS, GYMNASTICS, TABLE TENNIS, BOWLING, WEIGHT LIFTING, YARD WORK. 10 to 60 minutes per week.
3. PARTICIPATED REGULARLY IN RECREATION OR WORK REQUIING MODEST PHYSICAL ACTIVITY, SUCH AS GOLF, HORSEBACK RIDING, CALISTHENICS, GYMNASTICS, TABLE TENNIS, BOWLING, WEIGHT LIFTING, YARD WORK. Over one hour per week.



4. PARTICIPATED REGULARLY IN HEAVY PHYSICAL EXERCISE SUCH AS RUNNING OR JOGGING, SWIMMING, CYCLING, ROWING, SKIPPING ROPE, RUNNING IN PLACE, OR ENGAGING IN VIGOROUS AEROBIC ACTIVITY TYPE EXERCISE SUCH AS TENNIS, BASKETBALL, OR HANDBALL. Run less than one mile per week or spend fewer than 30 minutes per week in comparable physical activity.
5. PARTICIPATED REGULARLY IN HEAVY PHYSICAL EXERCISE SUCH AS RUNNING OR JOGGING, SWIMMING, CYCLING, ROWING, SKIPPING ROPE, RUNNING IN PLACE, OR ENGAGING IN VIGOROUS AEROBIC ACTIVITY TYPE EXERCISE SUCH AS TENNIS, BASKETBALL, OR HANDBALL. Run 1 to 5 miles per week or spend 1 to 3 hours per week in comparable physical activity.
6. PARTICIPATED REGULARLY IN HEAVY PHYSICAL EXERCISE SUCH AS RUNNING OR JOGGING, SWIMMING, CYCLING, ROWING, SKIPPING ROPE, RUNNING IN PLACE, OR ENGAGING IN VIGOROUS AEROBIC ACTIVITY TYPE EXERCISE SUCH AS TENNIS, BASKETBALL, OR HANDBALL. Run 5 to 10 miles per week or spend 1 to 3 hours per week in comparable physical activity.
7. PARTICIPATED REGULARLY IN HEAVY PHYSICAL EXERCISE SUCH AS RUNNING OR JOGGING, SWIMMING, CYCLING, ROWING, SKIPPING ROPE, RUNNING IN PLACE, OR ENGAGING IN VIGOROUS AEROBIC ACTIVITY TYPE EXERCISE SUCH AS TENNIS, BASKETBALL, OR HANDBALL. Run over 10 miles per week or spend over 3 hours per week in comparable physical activity.

Are you currently using hormonal contraceptives?

- Yes
- No

Do you currently smoke cigarettes or use other tobacco products?

- Yes
- No

Have you ever smoked cigarettes or used other tobacco products?

- Yes
- No

Do you currently use recreational drugs?

- Yes
- No

Have you ever used recreational drugs?

- Yes
- No

On average, how much alcohol do you consume per week? (One drink = 1.5 oz hard liquor, or 5 oz. wine, or 12 oz. beer)

- None
- 1-2 drinks
- 3-4 drinks

- 5 drinks
- 6+ drinks

Do you currently use prescription medication that contains cortisol, cortisone, or hydrocortisone?

- Yes
- No

Do you currently use anti-depressant medication?

- Yes
- No

Have you ever used anti-depressant medication?

- Yes
- No

Are you currently diagnosed with an anxiety disorder?

- Yes
- No

Have you ever been diagnosed with an anxiety disorder?

- Yes
- No

Do you currently take anti-anxiety medication?

- Yes
- No

Have you ever taken anti-anxiety medication?

- Yes
- No

Do you currently use any anabolic/androgenic steroids?

- Yes
- No

Have you ever used anabolic/androgenic steroids?

- Yes
- No

Are you currently diagnosed with post-traumatic stress disorder (PTSD)?

- Yes
- No

Have you ever been diagnosed with post-traumatic stress disorder (PTSD)?

- Yes
- No