IDIOGRAPHIC TEMPORAL DYNAMICS OF POSTTRAUMATIC STRESS DISORDER (PTSD) SYMPTOM DIMENSIONS IN DAILY LIFE

Keke Schuler

Dissertation Prepared for the Degree of

DOCTOR OF PHILOSOPHY

UNIVERSITY OF NORTH TEXAS

December 2017

APPROVED:

Camilo Ruggero, Major Professor
Adriel Boals, Committee Member
Craig Neumann, Committee Member
Vicki Campbell, Chair of the Department of Psychology
David Holderman, Dean of the College of Liberal Arts and Social Sciences
Victor Prybutok, Dean of the Toulouse Graduate School

Schuler, Keke. *Idiographic Temporal Dynamics of Posttraumatic Stress Disorder (PTSD) Symptom Dimensions in Daily Life*. Doctor of Philosophy (Behavioral Science), December 2017, 52 pp., 3 tables, 2 figures, references, 105 titles.

Understanding temporal relations among posttraumatic stress disorder (PTSD) symptom dimensions has received increasing attention in research. However, current findings in this area are limited by group-level approaches, which are based on inter-individual variation. PTSD is a heterogeneous syndrome and symptoms are likely to vary across individuals and time. Thus, it is important to examine temporal relations among PTSD symptom dimensions as dynamic processes and at the level of intra-individual variation. The aim of the present study was to capture temporal dynamics among PTSD symptom dimensions at an individual level using unified structural equation modeling (uSEM). World Trade Center (WTC) 9/11 responders (N = 202) oversampled for current PTSD (18.3% met criteria in past month) were recruited from the Long Island site of the WTC health program. Using ecological momentary assessment (EMA), PTSD symptoms were assessed three times a day over seven consecutive days. The person-specific temporal relations among PTSD symptom dimensions were estimated with individual-level uSEM. For the sample as a whole, hyperarousal played a key role in driving the other three symptom dimensions longitudinally, with the strongest effect in intrusive symptoms. However, daily temporal relations among PTSD symptoms were idiosyncratic. Although hyperarousal was a strong predictor of subsequent symptom severity, only 33.95% of the sample showed this predictive effect while others showed more evident temporal relations between intrusion and avoidance. Implications for personalized health care and recommendations for future research using individual-level uSEM in psychopathology are discussed.

ACKNOWLEDGEMENTS

Studying trauma and becoming a trauma psychologist is a dream I have since 2008, in 2017, this dream finally will come true. Many people have helped and supported me during this journey. I wish to thank my committee members, Dr. Adriel Boals and Dr. Craig Neumann, who were always willing to help and provide suggestions. I would like to thank Dr. Heidemarie Blumenthal and Dr. Jennifer Callahan for their wonderful collaboration on several projects.

I would like to express my deepest appreciation to two important individuals who have supported me tremendously. I would like to gratefully and sincerely thank my mentor, Dr. Camilo Ruggero, for his valuable guidance, understanding, patience, and most importantly, his mentorship during my doctoral training at the University of North Texas. His mentorship was paramount in getting my graduate career started on the right foot, showing confidence in my work, and providing extensive research experience consistent with my career goals. He encouraged me to not only grow as a psychologist but also as a critical and independent thinker. For everything you've done for me, Dr. Ruggero, I thank you. The second person I would like to express my appreciation to is Dr. Roman Kotov at the Stony Brook University. I would like to thank Dr. Kotov for the opportunities that allowed me to work with extraordinary psychologists and scientists, and gain unique research experience as a graduate student.

Finally, I would like to thank my husband, Eric Schuler. He is the first person I met when I landed in the United States and the person I want to spend the rest of my life with. He provided and continues to provide unending support, encouragement, and love. I thank my parents for believing in me and allowing me to be ambitious. I also would like to thank my friends, Jessica Dietch, Allison Dornbach-Bender, and Shana Southard-Dobbs. We supported each other by deliberating over problems and frustrations, and talking about things other than manuscripts.

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS iii

CHAPTER 1. INTRODUCTION 1
The Structure of PTSD Symptoms 1
The Emotional Numbing Model 3
The Dysphoria Model 5
Temporal Relations among PTSD Symptoms 6
Empirical Evidence 8
Limitations 10
Statistical Modeling of Dynamic Relations 12
Path Analysis 13
Vector Autoregression 15
Unified Structural Equation Modeling 16
Idiographic Analysis 17
Summary and Conclusions 21
The Present Study 21

CHAPTER 2. METHOD 23
Participants 23
Measures 23
PTSD Diagnosis 23
Momentary PTSD Symptoms 23
Daily Stress 24
Procedure 24
Analytic Plan 25

CHAPTER 3. RESULTS 27
Exemplar Temporal Relations among PTSD Symptom Dimensions 27
Group Temporal Relations among PTSD Symptom Dimensions 30
Temporal Relations between Daily Stress and PTSD Symptom Dimensions 31

CHAPTER 4. DISCUSSION 34

REFERENCES 44

CHAPTER 1

INTRODUCTION

Posttraumatic stress disorder (PTSD) is a trauma- and stress-related psychiatric disorder that develops in response to traumatic events (*DSM-5*; American Psychiatric Association, 2013). Lifetime prevalence of PTSD in US adults is 6.8% (Kessler et al., 2005). Traditionally, studies of underlying dimensions of PTSD and temporal relations among these dimensions have used group-level analytic approaches, which may fail to capture individual differences in the relations. In the present study, we demonstrated an analytic method that models temporal relations among PTSD symptom dimensions individually. The present introduction is structured as follows: First, a brief review was provided on different structural models of PTSD, with an emphasis on four-factor models. Second, theoretical models and empirical evidence regarding temporal relations among PTSD symptom dimensions was reviewed. Third, an alternative to traditional analysis of these issues – an idiographic approach using unified structure equation modeling (uSEM) was introduced with discussion of empirical applications in psychology. Finally, the present study used this approach to investigate temporal relations of PTSD symptoms in a trauma-exposed sample, World Trade Center (WTC) responders.

The Structure of PTSD Symptoms

There has been a long-standing debate on the underlying dimensionality of PTSD symptoms in the literature (Armour, Contractor, Palmieri, & Elhai 2014; Armour et al., 2015; Elhai & Palmieri, 2011; Elhai et al., 2009a; 2011b; Yufik & Simms, 2010; Zoellner, Pruitt, Farach, & Jun, 2014). In *DSM-IV*, PTSD symptom dimensions were represented as reflecting three broad factors, namely symptoms of intrusion, avoidance and numbing, and hyperarousal

(*DSM-IV*; APA, 2000). This three-factor model was primarily developed on the basis of expert consensus (Asmundson, Stapleton, & Taylor, 2004) and had little empirical support (Armour, Contractor, Shea, Elhai, & Pietrzak, 2016; Elhai & Palmieri, 2011; Yufik & Simms, 2010). Across 25 studies, little support for this structure emerged (Asnumdson et al., 2000; Baschnagel, O'Connor, Colder, & Hawk, 2005; Cordova, Studts, Hann, Jacobsen, & Andrykowski, 2000; DuHamel et al., 2004; Elhai, Ford, Ruggiero, & Frueh, 2009b; Elhai, Gray, Docherty, Kashdan, & Kose, 2007; Elhai, Grubaugh, Kashdan, & Frueh, 2008; Elklit & Shevlin, 2007; Elklit, Armour, & Shevlin, 2010; Ford, Elhai, Ruggiero, & Frueh, 2009; Foy, Wood, King, King, & Resnick, 1997; Hoyt & Yeater, 2010; Kassam-Adams, Marsac, & Cirilli, 2010; Mansfield, Williams, Hourani, & Babeu, 2010; McDonald et al., 2008; McWilliams, Cox, & Asmundson, 2005; Naifeh, Elhai, Kashdan, & Grubaugh, 2008; Naifeh, Richardson, Del Ben, & Elhai, 2010; Palmieri & Fitzgerald, 2005; Palmieri, Marshall, & Schell, 2007; Palmieri, Weathers, Difede, & King, 2007; Rasmussen, Smith, & Keller, 2007; Saul, Grant, & Carter, 2008; Schinka, Brown, Borenstein, & Mortimer, 2007; Shelby, Golden-Kreutz, & Andersen, 2005), with only one confirmatory factor analysis (CFA) in a sample of breast cancer survivors supporting its fit to the data (Cordova et al., 2000).

Consequently, alternative structural models of PTSD have been put forward, including two four-factor models (King, Leskin, King, & Weathers, 1998; Simms, Watson, & Doebbeling, 2002), a five-factor model (Elhai et al., 2011b), two six-factor models (Liu et al., 2014; Tsai et al., 2014), and a hybrid seven-factor model (Armour et al., 2015; 2016; Pietrzak et al., 2015). The majority of work in this area has supported one of two four-factor models (for review, see Elhai & Palmieri, 2011; Yufik & Simms, 2010). Both have received numerous empirical support over the past decades and each is reviewed in more detail.

The Emotional Numbing Model

The first four-factor model - the emotional numbing model - was proposed by King and colleagues in 1998. The model is composed of reexperiencing, effortful avoidance, emotional numbing, and hyperarousal. Reexperiencing is measured by five symptoms in *DSM-IV* (Criterion B1-B5), including intrusive recollections, recurrent dreams, event reoccurring, psychological, and physiological reactions. Effortful avoidance is measured by the first two symptoms in avoidance and numbing cluster in *DSM-IV* (Criterion C1-C2); they are efforts to avoid thoughts and efforts to avoid activities related to trauma. Emotional numbing is measured by the remaining five symptoms in avoidance and numbing cluster of *DSM-IV* (Criterion C3-C7). These symptoms are memory impairment, diminished interest in activities, feelings of detachment from others, restricted range of effect, and sense of foreshortened future. Five arousal symptoms in *DSM-IV* (i.e., sleeping difficulties, irritability, difficulty concentrating, hypervigilance, and exaggerated startle response; Criterion D1-D5) are retained to measure hyperarousal in the emotional numbing model. The emotional numbing model retained similar symptom dimensions in *DSM-IV* but separated avoidance and numbing into two factors: effortful avoidance and emotional numbing (Asmundson et al., 2004; King et al., 1998).

King and colleagues (1998) first examined this model in 524 treatment-seeking male military veterans. PTSD symptoms were assessed by the Clinician-Administered PTSD Scale (CAPS; Blake et al., 1990). CFA results suggested that the four-factor model yielded the best model fit relative to the other three models tested. Since the publication, this model has been supported by a large number of empirical studies using different samples, including cancer survivors (DuHamel et al., 2004; Shelby et al., 2005; Shevlin, McBride, Armour, & Adamson, 2009), trauma-exposed samples of the general population (Asmundson et al., 2000; Cox, Mota, Clara, & Asmundson, 2008; Elhai et al., 2008; Marshall, 2004; Naifeh et al., 2008; Palmieri & Fitzgerald, 2005; Scher, McCreary, Asmundson, & Resick, 2008), World Trade Center (WTC) responders (Palmieri et al., 2007), military samples (Asmundson, Wright, McCreary, & Pedlar, 2003; Grubaugh, Long, Elhai, Frueh, & Magruder, 2010; Mansfield et al., 2010; McDonald et al., 2008), refugees (Palmieri et al., 2007; Rasmussen et al., 2007), adolescents (Ford et al., 2009; Kassam-Adams et al., 2010; Saul et al., 2008), elderly samples (Schinka et al., 2007), and college students (Elhai et al., 2007; Hoyt & Yeater, 2010).

In *DSM-5*, a four-factor model that is similar to the emotional numbing model was proposed. The *DSM-5* model includes intrusion (i.e., re-experiencing), effortful avoidance, negative alterations in mood and cognition (NAMC; replacing emotional numbing), and altered arousal and reactivity (APA, 2013). The key differences from the emotional numbing model are new symptoms added to NAMC and hyperarousal factors. In NAMC factor, two new symptoms - perceived trauma-related blame and a pervasive negative emotional state – were added. In addition, the symptom of sense of foreshortened future was replaced with persistent exaggerated negative perceptions of oneself, others or the world. In hyperarousal factor, a new symptom, reckless or self-destructive behavior, was added.

Several studies have compared the *DSM-5* model to the emotional numbing model in different trauma samples, but the results are mixed. For example, Elhai and colleagues (2012) assessed PTSD symptoms using PTSD symptom scale (Foa et al., 1993) in 585 undergraduates who had a history of trauma exposure. Their results indicated the *DSM-5* model fit the data better than the emotional numbing model (Elhai et al., 2012). Similar findings were reported in studies using individuals with a history of trauma exposure (Armour et al., 2014; Biehn et al., 2013; Forbes et al., 2015) and military veterans (Miller et al., 2013). However, other empirical data did not support the four-factor model implied by the *DSM-5* (Armour et al., 2016; Pietrzak et al., 2015).

The Dysphoria Model

The second four-factor model was proposed by Simms and colleagues in 2002. They found support for a slightly different model from the emotional numbing one, consisting of intrusions, avoidance, hyperarousal, and dysphoria (Simms et al., 2002). The key difference from King's model is the movement of three symptoms (i.e., sleep problems, irritability, and concentration problems) from the hyperarousal factor to the numbing one, and it being relabeled as dysphoria. This dysphoria factor was conceptualized as a general distress factor underlying many depressive and anxiety disorders and one not specific to PTSD (for review, see Watson, 2005; 2009).

In their initial study, PTSD symptoms were assessed via the PCL-Military version (Weathers, Huska, & Keane, 1993) in a sample of 3,695 deployed and nondeployed veterans. Their results indicated the dysphoria model provided the best fit to the data. Since the publication of the dysphoria model, this model has received support from numerous studies using different samples, including trauma-exposed individuals of the general population (Armour & Shevlin, 2010; Baschnagel et al., 2005; Boelen, van den Hout, & van den Bout, 2008; Carragher, Mills, Slade, Teesson, & Silove, 2010; Elhai, Biehn, Naifeh, & Frueh, 2011a; Elhai et al., 2009a; 2011b; Elklit & Shevlin, 2007; Krause, Kaltman, Goodman, & Dutton, 2007; Milanak & Berenbaum, 2009; Olff, Sijbrandij, Opmeer, Carlier, & Gersons, 2009), WTC responders (Ruggero et al., 2013), refugees (Elklit et al., 2010), adolescents (Elhai et al., 2009b), and military veterans (Engdahl, Elhai, Richardson, & Frueh, 2011; Naifeh et al., 2010; Pietrzak, Goldstein, Malley, Rivers, & Southwick, 2010).

A meta-analysis of 40 studies conducted by YufiK and Simms (2010) directly compared the emotional numbing model with the dysphoria one. The study revealed two important findings. First, in comparison to models involving higher order factors and bifactor models, the inter-correlated without higher order factor models fit the data better. Second, although both four-factor models provided good model fit, the dysphoria model fit the data better across the studies examined in the meta-analysis. This meta-analysis provided further empirical support for the four-factor dysphoria model.

Overall, there is no clear evidence to conclude either the emotional numbing model or the dysphoria model offers consistently superior fit to the data. However, results from the previous studies indicated that PTSD symptoms are best explained by a four-factor model and the four symptom dimensions represented in the model are correlated.

Temporal Relations among PTSD Symptoms

Factor models imply that the dimensions of PTSD reflect an underlying, static disorder. A number of theories, however, have argued that dimensions may influence one another, which can only be gleaned by tracking dimensions across time. Two in particular outline potential sequences.

Creamer and colleagues (1992) proposed a cognitive processing model of PTSD in which intrusion symptoms precede avoidance symptoms after experiencing a traumatic event (Creamer, Burgess, & Pattison, 1992). Specifically, the presence of avoidance symptoms is a consequence of the discomfort resulting from the intrusive memories of the trauma over time, rather than a direct consequence of trauma itself. After trauma, it is common for individuals to experience intrusive memories of the trauma for days or even years. In addition, these traumatic memories can be activated by numerous environmental stimuli. Consequently, these intrusive memories lead to high levels of psychological distress in individuals. To cope with and reduce this psychological distress, avoidance (or escape) symptoms are developed or further accelerated.

In contrast, Horowitz (2001) proposed a model by summarizing a series of observations regarding individuals' responses to trauma. His model suggests that after trauma exposure, avoidance symptoms precede intrusive symptoms. Specifically, avoidance symptoms represent individuals' initial responses to the trauma and intrusive symptoms follow later. In the model, intrusive and avoidance symptoms developed in response to traumatic events often come in a temporal sequence, specifically in three phases. In the initial phase, individuals have a basic realization that a trauma has occurred and they are often overwhelmed by heightened emotion, such as fear. Then, they enter a phase of denial, in which individuals try to cope with the overwhelming emotion. The denial in this phase is often expressed as ideational denial, emotional numbness, and behavioral denial. In the final phase, intrusive repetition in thought and emotion occur as a defensive mechanism to further help cope with the overwhelming emotion. In addition to the three phases, Horowitz (2001) also emphasized the individual variability in this temporal sequence. It is possible that the sequence of the three phases and the duration of each phase may vary from one person to another. How individuals function and express denial or intrusive thoughts and behavior also varies across individuals. For some individuals, certain phases may overlap. For example, an individual may have both denial and intrusive thoughts at the same time. Thus, it is important to consider individual variation when examining temporal relations among symptoms developed after trauma.

Empirical Evidence

Early studies have investigated the specific relationship between intrusive and avoidance symptom dimensions over time. Two studies revealed inconsistent results (Lawrence, Fauerbach, & Munster, 1996; McFarlane, 1992). McFarlane (1992) examined the role of intrusive symptoms in the etiology of PTSD in a sample of 290 firefighters and found that intrusion predicted avoidance The intrusive and avoidance symptoms were assessed 4, 11, and 29 months after exposure to a natural disaster. Using cross-lagged correlations, results suggested that intrusive symptoms were the direct result of trauma exposure and caused great psychological distress. Avoidance symptoms were not associated with the trauma experienced in the sample but served as a defensive mechanism to reduce the psychological distress associated with intrusive symptoms. These findings provided empirical support for the cognitive process model of PTSD (Creamer et al., 1992).

However, another study using a sample of 23 survivors from a burn injury reported opposite findings that were in the line with Horowitz (2001)'s model (Lawrence et al., 1996). In this study, intrusive and avoidance symptoms were assessed twice: upon discharge from the hospital and at 4 months after the discharge. Results suggested that avoidance was a significant predictor to intrusive symptoms over time. Importantly, this predictive effect of avoidance symptoms was stronger than the effect of intrusive symptoms at discharge. Together, Lawrence and colleagues (1996) concluded that avoidance plays a critical role in the maintenance of intrusive symptoms.

More informative findings came from longitudinal studies that have assessed temporal relations among PTSD symptom dimensions beyond just intrusion and avoidance (Doron-LaMarca et al., 2015; Marshall, Schell, Glynn, & Shetty, 2006; Pietrzak et al., 2013; Schell et al., 2004; Solomon, Horesh, & Ein-Dor, 2009). In these studies, all of four symptom dimensions of PTSD were examined. However, their results contradicted previous findings, suggesting that hyperarousal emerges as the best predictor to subsequent symptom dimensions.

In the initial study, Schell and colleagues (2004) examined the temporal relations among PTSD symptom dimensions over the course of 12 months in a sample of 413 victims of community violence using PCL-C (Weathers et al., 1993). The symptoms were assessed three times during this 12-month period: at baseline, at 3-month, and at 12-month. Using cross-lagged panel analyses, the study revealed that PTSD symptom dimensions over time were largely determined by hyperarousal. Specifically, hyperarousal at baseline significantly predicted hyperarousal, intrusive, avoidance, and emotional numbing symptoms three months later. Similarly, hyperarousal at 3-month predicted all of four symptom dimensions at 12-month. However, the generalizability of this initial study was limited by a homogeneous sample consisting of young Hispanic participants.

To address this limitation and replicate the initial findings, the same researchers examined temporal relations among PTSD symptom dimensions in a sample of 264 individuals with a history of trauma exposure (Marshall et al., 2006). In this replication study, PTSD symptoms were assessed three times: at 1-month, at 6-month, and at 12-month after trauma. Results from the replication study supported the initial findings that hyperarousal was the strongest predictor of other symptom dimensions in later assessments and was not influenced by other symptom dimensions from the previous assessments. Similar patterns were later found in a sample of 369 Israeli veterans (Solomon et al., 2009), and a sample of 10,835 WTC responders (Pietrzak et al., 2013).

Recently, the same findings were replicated in a study using an intensive sampling method (Doron-LaMarca et al., 2015). In this study, PTSD symptom dimensions were assessed in a sample of 34 combat veterans with chronic PTSD biweekly over two years. Using cross-lagged autoregressive approach, results suggested that hyperarousal was the only PTSD symptom dimension predicted subsequent intrusion, avoidance, and emotional numbing over two-week intervals. In addition, the study also revealed a bidirectional relationship between hyperarousal and intrusion. That is, intrusive symptoms predicted later hypersoual symptoms, and hypersoual symptoms predicted later intrusive symptoms. This bidirectional relationship was only found in these two symptom dimensions.

Limitations

Findings from the longitudinal studies reviewed above are suggestive regarding temporal relations among PTSD symptom dimensions over time. Hyperarousal played a key role in driving other symptom dimensions over time (Doron-LaMarca et al., 2015; Marshall et al., 2006; Pietrzak et al., 2013; Schell et al., 2004; Solomon et al., 2009). However, these studies had three methodological limitations.

First, previous studies were limited in the assessments of PTSD symptom dimensions across a long period of time. Individuals were often asked to report PTSD symptoms in the past months, or even years (e.g., Solomon et al., 2009). Thus, these findings cannot directly address the day-to-day associations of PTSD symptom dimensions, which may follow a different pattern (Marshall et al., 2006). Assessment approaches with long time interval works under an assumption that PTSD symptom dimensions remain stable during the reference period (i.e., in the past month). This assumption is problematic given that PTSD symptoms are easily triggered by environmental stimuli and symptoms are context dependent (Naragon-Gainey, Simpson, Moore, Varra, & Kaysen, 2012).

In addition, empirical findings support that there are significant variations in different symptom dimensions over time (Black et al., 2016; McFarlane, 2000; Solomon et al., 2009). For example, Solomon and colleagues (2009) reported that among four symptom dimensions, only avoidance was found stable over years. However, in an early review, McFarlane (2000) found that intrusive symptoms typically decreased, whereas avoidance symptoms increased over time. Using ecological momentary assessment (EMA; Stone & Shiffman, 1994), Black and colleagues (2016) were able to capture the variability of PTSD symptom dimensions on a daily basis. They reported substantial within-person variability in PTSD symptoms on a given day in a sample of veterans. Specifically, PTSD symptoms varied 28 points or more (on an 80-point scale) across intervals (i.e., two hours) within a day. Importantly, such variations in the symptom dimensions were not related to symptom severity or daily events (Black et al., 2016). As such, to capture the symptom changes and variabilities in a more accurate manner, it is important to assess PTSD symptom dimensions with short time intervals (e.g., on a daily basis).

Second, none of the longitudinal studies reviewed so far have examined the impacts of potential covariates on temporal relations among PTSD symptom dimensions. Understanding how potential covariates (e.g., stress levels) influence temporal relations of PTSD symptom dimensions may provide insights regarding the heterogeneity in PTSD symptomatology. One of the implications from the aforementioned studies is that each symptom dimension of PTSD is influenced by other symptom dimensions in a different way. For example, hyperarousal was only predicted by previous hyperarousal, but intrusion was predicted by both hyperarousal and intrusion symptoms from previous assessments (Doron-LaMarca et al., 2015; Marshall et al., 2006; Soloman et al., 2009). The underlying mechanisms of why and how hyperarousal may influence other symptoms remain inconclusive. It is possible that individual differences in potential covariates may form unique trigger(s) to each symptom dimension of PTSD and therefore contribute to the heterogeneity in the symptomatology.

Third, all of the longitudinal studies reviewed so far primarily used path analysis (i.e., cross-lagged panel analysis), which assumes the same linear relationships among variables measured across time (de Marco, Devauchelle, & Berquin, 2009; Gates, Molenaar, Hillary, & Slobounov, 2011). In other words, path analysis typically estimates one path coefficient for how one variable at time 1 is related to the other variable at time 2 (de Marco et al., 2009). This limitation is closely related to the research design often used with path analysis. Studies using path analysis assess variables of interest at least at two time points but with a long period of time in between (e.g., three months). Because of this design, what has happened between the two time points is unknown. It is possible that relationships among these variables may change or fluctuate at some points between the two time points. However, path analysis does not have the ability to capture these changes or fluctuations. Consequently, it may lead to estimation bias or false interpretations of phenomena implied in the data. Therefore, it is important to use a study design that allows one to capture PTSD symptoms more frequently and consider temporal relations among PTSD symptom dimensions as dynamic processes, rather than simple longitudinal correlations.

Statistical Modeling of Dynamic Relations

Longitudinal time series design has been increasingly used in understanding interrelationships among PTSD symptom dimensions over time. Such research design has an advantage of capturing underlying patterns of how each symptom dimension relates to other symptom dimensions over multiple time points. This research design is often achieved by using intensive sampling methods, such as EMA, daily diary, or naturalistic observations. Therefore, longitudinal time series design typically constitutes multisubject, multivariate time series data (Kim, Zhu, Chang, Bentler, & Ernst, 2007). Unfortunately, the information collected through this research design is rarely used at its fullest capacity (Beltz, Beekman, Molenaar, & Buss, 2013). Often times, a simple score is calculated by averaging across the entire sample, losing information about time and individuals (Beltz et al., 2013). When PTSD symptom dimensions are assessed via intensive sampling methods, temporal relations among PTSD symptom dimensions should be viewed as dynamic processes. Aggregating across individuals and time produces group-level results (e.g., sex differences in temporal relations) but fails to describe any individual differences within the sample (i.e., how one individual may differ from the other; Beltz et al., 2013). Thus, it is important to employ an analytic technique that can fully exploit the wealth of information collected in longitudinal time series design (Beltz et al., 2013). The following section will first review two traditional analytic approaches and then introduce a new approach to model dynamic processes, as well as the utility of this new approach in analyzing dynamic processes at the individual level.

Path Analysis

Structural equation modeling (SEM) is one of the traditional approaches to analyze longitudinal data. It is a family of related procedures developed to examine associations in a set of variables (Kline, 2010). Typically, two classes of variables are examined in SEM, the manifest variables (or observed variables) and the latent variables (Kline, 2010). SEM is a hypothesisdriven analytic approach that involves two principle analysis methods: factor analysis and multiple regression (de Marco et al., 2009). Therefore, SEM allows examining influences of multiple independent variables on one or more dependent variables (de Marco et al., 2009; Kline, 2010). Path analysis is the oldest member of SEM family and it is the most straightforward and common application in assessing associations among a set of manifest variables (Gates, Molenaar, Hillary, Ram, & Rovine, 2010). In path analysis, associations among variables are typically represented by path coefficients (i.e., beta weights), indicating how much a dependent variable changes when an independent variable changes in a unit (de Marco et al., 2009; Kline, 2010).

Despite the common use of path analysis in the literature, a major shortcoming of this analytic approach is that it is a group-level analysis based on inter-individual variation (Molenaar, 2013) and is often not conducted at the individual level. As such, this analysis cannot capture individual differences in temporal relations among PTSD symptom dimensions. Traditional path analysis often aggregates data across all the participants within the sample and it has a tendency of regressing towards the mean (Beltz et al., 2013; Molenaar, Sinclair, Rovine, Ram, & Corneal, 2009; Nesselroade & Molenaar, 1999). This traditional analytic approach is a problem when considering substantial fluctuations of each PTSD symptom dimension over time and the severity of symptom dimensions varies across individuals (Black et al., 2016; Zoellner et al., 2014). For example, it is possible that in a sample of individuals with PTSD, there is a subgroup of individuals whose symptoms are quantitatively different from others (e.g., more severe). The traditional aggregating across the sample approach fails to distinguish this subgroup from others in the data. In addition, given the fluctuations in symptom dimensions, when PTSD symptoms are measured repeatedly, how PTSD symptom dimensions relate to each other may change over time and across individuals in nontrivial ways. Therefore, it is important to model temporal relations among PTSD symptoms at the individual level, which will unveil results of individual differences in temporal relations among PTSD symptom dimensions.

Vector Autoregression

Vector (or multivariate) autoregression (VAR) is a valuable approach to analyze longitudinal time series data (Beltz & Molenaar, 2016). It is originally proposed by Sims (1980) and has been primarily used in studying structural econometrics (for review, see Beltz & Molenaar, 2016). More recently, VAR has been used in understanding the connection among different brain regions, neural activities, and psychological processes (Beltz et al., 2013; Gates & Molenaar, 2012; Penny & Harrison, 2006).

VAR is an extension of traditional univariate time series modeling (Penny & Harrison, 2006). In a univariate time series, measures are administrated at each consecutive time point. In order to model the underlying process in this time series, the current value is typically regressed as a linear function of its previous values. VAR extends this approach to multivariate time series. In a VAR model, instead of one current value, a vector of current values is modeled as a linear function of previous activities. In other words, VAR modeling regresses each current (or future) variable in the model on other variables that are lagged for a certain number of time points (Gates et al., 2010; Penny & Harrison, 2006).

VAR modeling has three advantages for the analysis of time series data. The first advantage of this method is its ability to capture dependencies within the data, especially the influence of one variable on another (Penny & Harrison, 2006). This advantage allows VAR to quantify instantaneous correlations among different variables (Penny & Harrison, 2007). The second advantage is its ability to analyze lagged relationships in variables collected repeatedly over the course of a certain time interval (Gates et al., 2010; Goebel, Roebroeck, Kim, & Formisano, 2003). The third advantage of VAR is that the causality estimated from this model can be inferred from data, instead of a priori (Penny & Harrison, 2006). This approach in VAR is distinct from the approach in conventional SEM. In SEM, only prior defined associations are modeled and interpreted as embodying causal relations (Penny & Harrison, 2006). In VAR, all conceivable associations are estimated in the model and then different hypotheses are tested (Penny & Harrison, 2006). Thus, the causality in VAR can be inferred from data.

Despite its advantages, VAR models have been criticized. Similar to path analysis, the first critique of VAR is that it is based on inter-individual variation and often not estimates data from an intra-individual perspective. The second critique is that the model only captures linear relations among the variables (Penny & Harrison, 2006). Thus, the moderating impacts of one variable on the association between other variables may be ignored in the model. The third critique is that it only considers and involves lagged variables on the independent variable side of a regression equation (Gates et al., 2010; Kim et al., 2007). Therefore, the contemporaneous relationships among variables are ignored in this modeling (Gates et al., 2010; Kim et al., 2007).

Unified Structural Equation Modeling

To improve upon both path analysis and VAR models, Kim and colleagues (2007) developed an integrated method by combining these two approaches together, termed unified SEM (uSEM; Kim et al., 2007). uSEM estimates both contemporaneous and lagged relations *simultaneously* in a set of manifest variables (Beltz et al., 2013; Gates et al., 2011; Kim et al., 2007). This characteristic makes uSEM a dynamic approach when analyzing time series data

(Beltz et al., 2013; Beltz, Wright, Sprague, & Molenaar, 2016; Gates et al., 2011; Kim et al., 2007). The simultaneous estimation of contemporaneous and lagged relations is achieved by how variability in each variable is explained by the contemporaneous (at the same time) and lagged (a previous time point) variability in the other variables in the model (Wright et al., 2015). uSEM uses an automatic search procedure to estimate contemporaneous and lagged relations, which makes this analytic approach completely data-driven (de Marco et al., 2009; Kim et al., 2007).

uSEM has two advantages over path analysis and VAR modeling in analyzing time series data. First, uSEM has an ability to simultaneously model both contemporaneous and lagged relationships among different variables in time series data (Beltz et al., 2013; 2016; Kim et al., 2007). Although these relationships can be modeled separately, recent empirical evidence suggests that modeling contemporaneous and lagged relations in the same model yields more accurate estimations (Gates et al., 2010; Kim et al., 2007). Second, uSEM can be conducted at the individual level rather than group-level, with an emphasis on person-specific variation (Beltz et al., 2016), making this one of the prime candidates for idiographic analysis.

Idiographic Analysis

Idiographic analysis is a person-specific analytic approach that allows to model processes or associations and makes estimations or predictions that are specific to an individual (Beltz et al., 2016; Molenaar, 2004). The primary aim of idiographic analysis is to examine intra-individual variation, rather than inter-individual variation (Beltz et al., 2016; Molenaar, 2004). This analytic approach assumes heterogeneity across individuals and time (Beltz et al., 2016, which makes this approach particularly valuable when the goal is to obtain person-specific estimations in time series data (Beltz et al., 2016; Molenaar, 2004). In time series data, individual information is often collected repeatedly over a certain period of time. Thus, traditional group-level analytic approaches lose individual information when aggregating across the sample and time (Beltz et al., 2013; 2016). For example, aggregating PTSD symptoms across time will lose information on the variability of these symptoms. Consequently, it is impossible to identify potential patterns of change that emerge across time. Additionally, when aggregating across individuals and time, it is impossible to identify time-based patterns or relations among PTSD symptoms that may occur at an individual level. Such information can have high clinical value when an individual is in treatment.

Two analytic techniques have most often been used for idiographic analysis: P-technique (Jones & Nesselroade, 1990) and uSEM (Kim et al., 2007). Both are used with time series data, however, the circumstances where each should be applied are different. P-technique has been primarily used to examine the person-specific structure of a psychological construct (e.g., personality; Beltz et al., 2016). For example, in a study with the Big Five personality factors, conventional factor analysis (R-technique) yielded Big Five structure (Borkenau & Ostendorf, 1998). However, when P-technique was used, Molenaar and colleagues (2009) found different results. The five-factor structure of personality was not found in any participants in the study (Molenaar & Campbell, 2009). Results showed a two-factor structure of personality for eight participants, a three-factor structure for 13 participants, and a four-factor structure for one participants (Molenaar & Campbell, 2009). Overall, P-technique allows one to capture the heterogeneity in structures of a psychological construct across individuals in time series data (Beltz et al., 2016; Molenaar & Campbell, 2009).

uSEM has been primarily used to investigate person-specific dynamic processes in time series data. Unlike path analysis and VAR modeling, individual-level uSEM uses all the information collected over time within a single individual, then maps out covariations among variables of interest in a way that one variable may predict or be predicted by lagged or contemporaneous variation in other variables (Beltz et al., 2016). As a result, the estimation of relations among variables of interest is dynamic and person-specific (Beltz et al., 2016).

uSEM has been used across different disciplines when modeling dynamic processes or associations at the individual level in time series data. It was first proposed in analyzing functional neuroimaging data to understand the neural connectivity among different brain regions (Kim et al., 2007). However, it is not restricted to use with neuroimaging data. More recently, uSEM has also been applied in analyzing psychological and developmental processes individually (Beltz et al., 2013; Wright et al., 2015).

To understand the sex difference in the socio-temporal dynamics underpinning individual-level playing behaviors, Beltz and colleagues (2013) used individual-level uSEM to quantify relations between positive affect and vigor of activity within a single child in a sample of 65 children. The playing behaviors were recorded for 15 minutes in total and each behavior was coded in 10-second intervals (Beltz et al., 2013). The results revealed different patterns of relations between the two behaviors (positive affect and the vigor of activity) across children. For example, one boy's current positive affect was only influenced by his positive affect 10 seconds earlier (Figure 1C; Beltz et al., 2013). However, another girl did not have the same pattern. uSEM results for this girl showed that the variation of her current positive affect was explained by her positive affect 10 seconds prior, current vigor of activity, and vigor of activity 10 seconds earlier (Figure 1F; Beltz et al., 2013).

In addition to its applications in developmental science, Wright and colleagues (2015) used individual-level uSEM to investigate the person-specific interplay among four personality factors. The four factors (negative affect, detachment, disinhibition, and hostility) were assessed daily for approximately 100 days (Wright et al., 2015). Individual-level uSEM results revealed a unique pattern of the interplay among the four personality factors for each of the four participants. For example, in one participant, the variation of negative affect was explained by the negative affect on the previous day, the hostility on the same day, and the hostility on the previous day (Figure 4C; Wright et al., 2015). A different pattern of interplay was revealed in another participant. In this participant, the variation of negative affect was explained by the negative affect from the previous day as well as disinhibition and hostility on the same day (Figure 4B; Wright et al., 2015). Overall, the results map out how personality factors interplay with each other in each participant' daily life and provide significant implications on the tailored points of intervention for each individual.

Individual-level uSEM holds great potential to map out person-specific temporal dynamics (both contemporaneous and lagged relations) among PTSD symptom dimensions over time. uSEM allows to model temporal relations among PTSD symptom dimensions as dynamic processes. This analytic approach takes the fluctuations of symptom dimensions over time and the variations of symptom severity across individuals into account, which will help develop an integrative understanding in the psychopathology of PTSD. This approach can be conducted at the individual level and fits symptom temporal dynamics that only apply to one individual, but not the other. The person-specific parameters (e.g., beta weights) will be estimated. Similarly, the time-varying or person-specific covariates (e.g., stress) can be included and estimated in the model. The impacts of the covariates on temporal dynamics among the symptoms of a single individual will be estimated. In this way, factors that may contribute to temporal dynamics among PTSD symptom dimensions can be revealed. Specifically, factors that may influence certain relations among the symptom dimensions but not others can be further understood. In addition, the unique trigger(s) of each individual's symptoms can be quantified. Taken together, research in understanding temporal relations among PTSD symptoms has been limited with group aggregation analytic approaches. Individual-level uSEM has the potential to provide particular insights to map out temporal dynamics (both contemporaneous and lagged relations) among PTSD symptom dimensions at the individual level.

Summary and Conclusions

Accumulating evidence has suggested PTSD is not unitary, but consists of different symptom dimensions and these dimensions are temporally related. However, most research on temporal relations among PTSD dimensions has been done with group-level analytic approaches (i.e., path analysis). Such approaches cannot speak to person-specific variations in the nature of temporal relations among PTSD dimensions. Given that PTSD symptoms are heterogeneous and individuals' symptom experiences show substantial fluctuations over time, there is a need to examine and model temporal relations among PTSD dimensions as dynamic processes at the individual level.

The Present Study

To address the aforementioned gaps, the overarching goal of the present study was to model temporal relations among PTSD symptom dimensions as dynamic processes using uSEM at the individual level. Specifically, the study had two major aims.

The first aim of the proposed study was to examine the individual level heterogeneity in contemporaneous and longitudinal (i.e., lagged) relations among PTSD symptom dimensions.

Towards this aim, multivariate time series data collected on PTSD symptom dimensions was analyzed for each participant individually via a uSEM approach. The contemporaneous relations were defined as relationships among symptom dimensions measured at the same time point. The longitudinal relations were defined as relationships among symptom dimensions measured at multiple temporal time lags.

Hypothesis 1: PTSD symptom dimensions would show strong contemporaneous relations with each other. However, there would be individual differences in the size of the different relationships.

Hypothesis 2: Among the four symptom dimensions, hyperarousal would be the strongest predictor to the other three symptom dimensions in lagged relations. Again, there would be individual differences in the size of this relationship.

The second aim of the proposed study was to examine whether a potential covariate, daily stress, moderates specific temporal relations among PTSD symptom dimensions at the individual level. To address this aim, daily stress were then entered in the model for each participant individually.

Hypothesis 3: Daily stress would moderate temporal relations among PTSD symptom dimensions, with effects again varying by person.

CHAPTER 2

METHOD

Participants

A sample of 9/11 responders (N = 202; M_{age} = 54.28, SD = 9.69) were recruited from the Long Island site of the World Trade Center Health Program for an EMA study on PTSD and respiratory problems between October 2014 and February 2016. Participants worked or volunteered as a part of rescue, recovery, restoration, or cleanup of the WTC sites. The sample was primarily male (82.7%, n = 167), Caucasian (88.1%, n = 178), and non-Hispanic (80.7%, n = 163), with an average of 14.82 (SD = 2.26) years of education. The sample was oversampled for PTSD symptoms and 18.3% (n = 37) were diagnosed with current PTSD at the time of baseline assessment. All participants provided informed consent and the study was approved by the Stony Brook University Committees on Research Involving Human Subjects.

Measures

PTSD Diagnosis

The Structured Clinical Interview for *DSM-IV* (SCID; First, Spitzer, Gibbon, & Williams, 1997) was used for PTSD diagnosis at baseline. PTSD diagnosis was operationalized as meeting the *DSM-IV* diagnostic criteria. Participants were instructed to reference to the WTC disaster in the SCID interview. Previous assessments of reliability of the trained interviewers in this population demonstrated very good inter-rater agreement (κ = 0.82).

Momentary PTSD Symptoms

Momentary PTSD symptoms were assessed three times a day on seven consecutive days using eight items drawn from the PTSD Checklist for *DSM-5* (PCL-5; Weathers et al., 2013). Participants were instructed to “Tell us if you have had any of the following experience …” on a 5-point Likert scale ranged from 1 (*not at all*) to 5 (*extremely*). Items were selected based on the emotional numbing model, which posits that PTSD is composed of four factors: intrusion, avoidance, numbing, and hyperarousal (King et al., 1998). Two items were chosen for each PTSD symptom dimension and eight items in total were selected to assess momentary PTSD symptoms. The eight items included disturbing memories, thoughts or images; being upset by reminders; avoidance of thinking or talking about the experience; avoiding activities related to it; feeling distant; feeling emotionally numb; being “super alert;” and feeling jumpy or startled. Each of the momentary items was modified to begin with the stem “In the past 5 hours…” On average, the PCL-5 had excellent internal consistency for the momentary assessments ($\alpha = .91$).

Daily Stress

Daily stress was assessed via self-reported perceived stress. Participants completed one item asking how stressed they have felt (i.e., “How ‘stressed’ have you felt in general?”). Participants responded to the perceived stress item three times per day on a 5-point Likert scale from 1 (*no stress*) to 5 (*very severe*).

Procedure

At baseline, participants completed a battery of self-report questionnaires and the SCID interview. Following the baseline assessment, participants proceeded to the EMA component of the study. To capture a comprehensive picture of the changes of PTSD symptoms in daily life, the symptoms were assessed three times per day over a 7-day period. At each time point, participants were prompted to complete the momentary assessments. All participants in the present study were issued with an iPod and completed momentary assessment on the device. The average compliance rate for momentary assessments was 93.8% in the current sample.

Analytic Plan

Prior to testing hypotheses, data were inspected for any missingness and intra-individual variance. Because uSEM replies on intra-individual variation in the estimation, if a variable entered in the model has zero intra-individual variance, uSEM will not perform estimation. As such, the intra-individual variance for each variable and each corresponding lagged variable was estimated prior to entering the variables into the model. Of the 202 participants, 85 participants were deleted due to zero intra-individual variance in at least one of PTSD symptom variables, five participants were deleted due to zero intra-individual variance in one of the lagged PTSD symptom variables, and additional six participants were excluded from the final models because models failed to converge, leaving a sample of 106 participants in the final model.

Temporal relations among PTSD symptom dimensions were estimated with individual-level uSEM (Kim et al., 2007). The model is defined as the following equation:

$$\eta(t) = A\eta(t) + \Phi\eta(t-1) + \zeta(t)$$

where $\eta(t)$ is the p-variate time series of PTSD symptom dimension at time point t = 1, 2, 3…, T; with p is the number of PTSD symptom dimensions (i.e., four) and T is the number of momentary assessments (i.e., 20) in the present study. A is a p*p dimensional regression coefficients matrix of contemporaneous relations among PTSD symptom dimensions (i.e., how each dimension is influenced by other dimensions at the same time point). Φ is a p*p dimensional regression coefficients matrix of lagged one-time point relations among PTSD symptom dimensions (i.e., how each dimension is influenced by itself and other three symptom dimensions at the previous time point). ζ is the p-variate error process.

In the present study, individual-level uSEM was conducted in *R* using the package "*gimme*" (Lane, Gates, Molenaar, Hallquist, & Pike, 2016). The final model fit for each participant was evaluated using the following model fit indices (Brown, 2006), including confirmatory fit index (CFI) $\geq$ .95, Tucker-Lewis index (TLI) $\geq$ .95, non-normed fit index (NNFI) $\geq$ .95, standardized root mean square residual (SRMR) $\leq$ .08, and root mean square error of approximation (RMSEA) $\leq$ .05. Excellent model fitting was operationalized according to at least two above mentioned indices (Beltz et al., 2013).

CHAPTER 3

RESULTS

A summary of descriptive statistics of the EMA variables is presented in Table 1. Among the four PTSD symptom dimensions, the sample on average had the most severe symptoms in avoidance and hyperarousal, and avoidance fluctuated the most during the EMA period. On average, the final models fit data well according to three model fit indices (M_{RMSEA} = .05, M_{SRMR} = .11, M_{NNFI} = .99, and M_{CFI} = .97).

Exemplar Temporal Relations among PTSD Symptom Dimensions

In order to demonstrate the utility of individual-level uSEM as a person-specific analytic approach that allows one to capture intra-individual processes, data from four exemplar participants (A-D) were selected to describe and interpret in detail.

PTSD symptom patterns across all 20 assessment points for each exemplar participant are shown in Figure 1 and a visualization of the corresponding descriptive statistics for each participant is presented in Figure 2. An initial examination of the two figures indicated that all four exemplar participants showed great fluctuations in PTSD symptoms. However, individual differences were also observed in the fluctuation patterns across time. For example, exemplar participants A and B had similar means of hyperarousal ($M_{\text{hyperarousal}}$ = 3.75 and 3.55, respectively), but the symptom patterns were different between the two exemplar participants. The hyperarousal symptom of participant A showed only a few fluctuations across time and the peaks of hyperarousal occurred at the same time as the peaks in the other three symptom dimensions. In contrast, the hyperarousal symptom of exemplar participant B showed more frequent fluctuations over time. Exemplar participant C showed the most severe PTSD symptoms, especially avoidance symptoms. Importantly, as shown in Figure 1, the avoidance symptom persisted across the entire EMA period. This important information was not being captured by the conventional mean and standard deviation. The exemplar participant D showed a gradual decline in all four symptoms over time, although all symptoms fluctuated substantially. The symptom severity peaked during the first two days of the EMA period and then gradually decreased until the end of the assessment period.

The final model fit the data well for each exemplar participant. Specifically, exemplar participant C had excellent fitting model according to all four model fit indices specified earlier ($\chi^2 = 14.77$, $df = 14$, $p = .394$, NNFI = .99, CFI = .98, RMSEA = .05, SRMR = .08). The rest three exemplar participants had very good fitting model according to three model fit indices (Exemplar participant A: $\chi^2 = 10.20$, $df = 9$, $p = .335$, NNFI = .99, CFI = .97, RMSEA = .08, SRMR = .07; Exemplar participant B: $\chi^2 = 14.26$, $df = 14$, $p = .430$, NNFI = .99, CFI = .99, RMSEA = .03, SRMR = .09; Exemplar participant D: $\chi^2 = 15.56$, $df = 14$, $p = .341$, NNFI = .98, CFI = .95, RMSEA = .08, SRMR = .07).

However, results showed different number of relations among PTSD symptoms across the four exemplar participants. By counting the number of relations (both contemporaneous and lagged), exemplar participant A had the largest number of relations (i.e., 13 relations in total), which resulted in the densest temporal relations among four example participants. The temporal relations for the rest three were relatively sparse with each exemplar participants having equally eight relations. This observation is particularly interesting, given that exemplar participant A did not endorse the most severe symptomatology over time but had the most dynamic relations among the symptom dimensions.

In addition, the final models revealed different patterns of temporal relations among PTSD symptoms among four exemplar participants. For example, for exemplar participant C, avoidance was the least influential symptom. Intrusion was the most susceptible symptom. At a given time point, symptom severity of intrusion was positively influenced by severity of numbing and negatively influenced by severity of hyperarousal from the previous time point. Symptom severity of hyperarousal was explained by severity of intrusion at the same time point, but it also predicted severity of numbing at the same time point.

More complicated temporal relations were found in exemplar participant A. With respect to lagged relations, at a given time point, symptom severity of intrusion and hyperarousal were both explained by severity of avoidance and numbing from the previous time point. Avoidance and numbing also showed a temporal relation with each other, with severity of avoidance was explained by severity of numbing from the previous time point. With respect to contemporaneous relations, intrusion was the most influential symptom dimension for this exemplar participant. Specifically, at a given time point, symptom severity of intrusion predicted severity of avoidance and hyperarousal at the same time point, but it was also predicted by severity of numbing at the same time point. Exemplar participant A's symptom severity of avoidance was also explained by severity of hyperarousal at the same time point.

Temporal relations revealed in exemplar participants B and D shared certain similarities, although distinct relations were also observed. Exemplar participants B and D both showed only one lagged association among PTSD symptom dimensions. Specifically, for exemplar participant B, at a given time point, symptom severity of avoidance predicted severity of numbing at the next time point. However, for exemplar participant D, at a given time point, symptom severity of avoidance was explained by severity of intrusion from the previous time point. In both exemplar participants, at a given time point, severity of numbing was predicted by severity of intrusion at the same time point. Symptom severity of avoidance, numbing, and hyperarousal showed associations with each other in both exemplar participants, but these associations were in opposite directions between the two exemplar participants. At a given time point, severity of avoidance was predicted by severity of hyperarousal at the same time point in exemplar participant B, but the reverse direction was observed in exemplar participant D. Similarly, at a given time point, severity of numbing predicted severity of hyperarousal at the same time point in exemplar participant B, but exemplar participant D showed the reversed effect between these two symptom dimensions. Furthermore, exemplar participants A, B, and D all showed a contemporaneous association between avoidance and hyperarousal. This relation may speak to an observation that patterns of fluctuations were very similar between avoidance and hyperarousal in these three exemplar participants (see Figure 1).

Group Temporal Relations among PTSD Symptom Dimensions

Table 2 presents the mean values of the estimated path coefficients in the final sample. Across all participants, each symptom dimension at a given time point was associated with itself at the next time point ($M_{\beta s}$ = .02 to .16). Consisted with the first hypothesis, hyperarousal, on average, showed strong effects in predicting subsequent intrusion, avoidance, and numbing symptom dimensions ($M_{\beta s}$ = -.57, .23, and .29, respectively), with the strongest effect in predicting subsequent intrusive symptoms.

By counting the number of participants endorsed in each path, results showed that the most common contemporaneous path in the sample was the relation between intrusion and avoidance. That is, symptom severity of avoidance was explained by severity of intrusion at the same time (M_{β} = .62), with 25 participants (23.58%) showing this relation. The most common lagged path was also between intrusion and avoidance, which had a bidirectional relation. That is, at a given time point, symptom severity of avoidance predicted severity of intrusion at the next time point (M_{β} = .07), with 17 participants (16.04%) showing this relation. The same number of participants showed the reversed effect, with severity of intrusion predicting avoidance symptoms at the next time point (M_{β} = .10). However, the magnitudes of this bidirectional relation were relatively small. Interestingly, although hyperarousal showed strong predictive effects to subsequent symptom dimensions, in total, no more than half of the sample (n = 36, 33.96%) endorsed such effects.

Temporal Relations between Daily Stress and PTSD Symptom Dimensions

In addition to temporal relations of PTSD symptoms, the impacts of daily stress were also examined for each participant. On average, the final models fit data well according to three model fit indices (M_{RMSEA} = .04, M_{SRMR} = .12, M_{NNFI} = .99, and M_{CFI} = .98).

The final model of temporal relations between PTSD symptoms and daily stress fit data well for each exemplar participant. According to three model fit indices, all four exemplar participants had very good fitting model (Exemplar participant A: χ^2 = 20.57, df = 19, p = .361, NNFI = .99, CFI = .98, RMSEA = .07, SRMR = .10; Exemplar participant B: χ^2 = 25.00, df = 25, p = .462, NNFI = 1.00, CFI = 1.00, RMSEA = .00, SRMR = .09; Exemplar participant C: χ^2 = 24.27, df = 23, p = .389, NNFI = .99, CFI = .97, RMSEA = .05, SRMR = .09; Exemplar participant D: χ^2 = 22.24, df = 21, p = .386, NNFI = .98, CFI = .97, RMSEA = .06, SRMR = .07).

The number of relations revealed in the final model were also counted for each exemplar participant. Exemplar participant A had the largest number of relations (i.e., 16 relations), which included both contemporaneous and lagged relations, followed by exemplar participant D (i.e., 14 relations). It is not surprising that exemplar participant A had the densest temporal relations when entering daily stress in the model, given the dynamic relations revealed in the model with just PTSD symptoms.

The final models of temporal relations between PTSD symptoms and daily stress showed different dynamic processes for each exemplar participant. For example, daily stress of exemplar participant B showed no association with PTSD symptom dimensions. However, more complex stories were found in the other three exemplar participants. For daily stress in exemplar participant A: At a given time point, daily stress was explained by levels of daily stress (i.e., itself) from the previous time point but it also negatively predicted severity of hyperarousal on the next time point. Daily stress of exemplar participant A was also explained by severity of intrusion on the same time point. Unlike the processes revealed in exemplar participant A, at a given time point, daily stress of exemplar participant B was explained by severity of hyperarousal at the same time point but it positively predicted severity of avoidance on the next time point. Daily stress of exemplar participant D showed complex associations with symptom severity of numbing. Specifically, at a given time point, daily stress negatively predicted severity of numbing but it was positively explained by symptom severity of numbing on the same time point. Daily stress of this exemplar participant was also explained by symptom severity of numbing from the previous time point.

Table 3 presents the mean values of the estimated path coefficients for daily stress and PTSD symptom dimensions in the final sample. Across all participants, daily stress at a given time point was associated with itself at the next time point (M_{β} = .22). Consisted with the second hypothesis, for the sample as a whole, daily stress predicted subsequent PTSD symptom dimensions ($M_{\beta s}$ = .10 to .26), with the strongest effect in predicting hyperarousal symptoms ($M_{\beta s}$ = .26).

CHAPTER 4

DISCUSSION

The overarching goal of the present study was to use a person-specific analytic approach, uSEM, to capture the heterogeneity in temporal relations among PTSD symptom dimensions in daily life. Application of uSEM at the individual level provided unique insight into the dynamic processes underlying PTSD symptoms. The present study revealed three important findings. First, each individual tracked different symptom severity and fluctuations of PTSD symptoms. Importantly, regardless of their current PTSD diagnosis, symptom fluctuations were independent of severity of the symptoms. Second, the temporal relations revealed by mapping the contemporaneous and lagged relations among symptom dimensions suggested highly specific temporal relations for each individual. Specifically, the heterogeneity in PTSD symptomatology among the four exemplar participants, or essentially within the entire sample, was evident in the results revealed in this study. Third, the heterogeneity in the impacts of daily stress on PTSD symptoms was also evident in the results from uSEM. Specifically, the longitudinal effects of daily stress varied substantially among PTSD symptom dimensions and individuals. This finding may challenge current understanding that stress plays a critical role in the maintenance of PTSD symptoms (e.g., Zvolensky et al., 2015).

Present findings supported the hypothesis that hyperarousal plays an important role in driving other symptom dimensions. For the sample as a whole, hyperarousal emerged as a strong predictor of subsequent symptom severity, with the strongest effect in predicting symptom severity of intrusion. The results are consistent with previous work using group-level analytic approaches (Doron-LaMarca et al., 2015; Marshall, Schell, Glynn, & Shetty, 2006; Pietrzak et al., 2013; Schell et al., 2004; Solomon, Horesh, & Ein-Dor, 2009). This finding may have important implications in understanding the progresses of PTSD symptoms. Existing literature has emphasized on PTSD, a psychiatric syndrome as a whole, rather than its multidimensionality nature. Yet, the present study, along with other previous studies, has suggested that hyperarousal may play a distinctively role in the temporal course of other PTSD symptoms. As such, the conventional approach of aggregating to create a single score of PTSD could fail to differentiate the unique role of hyperarousal in the progresses of PTSD symptoms.

Importantly, findings further confirmed the hypothesis that each individual has highly specified dynamic temporal relations of PTSD symptoms in daily life. For the sample as a whole, hyperarousal is the key symptom dimension that subsequently drives the other three symptom dimensions. However, this is not the case for everyone. For example, among the four exemplar participants, none of them showed the effects of hyperarousal at a given time point on the other three symptom dimensions at the next time point. On the contrary, hyperarousal seems to be the most susceptible symptom in exemplar participant A, with its being predicted by avoidance and numbing at the previous time point. Individual-level uSEM further revealed a highly distinct pattern of temporal relations among the PTSD symptom dimensions for each individual. For example, the associations between avoidance and hyperarousal differed among all four exemplar participants, with hyperarousal positively predicting avoidance at the same time point and avoidance positively predicting hyperarousal at the next time point for exemplar participant A, avoidance positively predicting hyperarousal at the same time point for exemplar participant D but an opposite effect for exemplar participant B, and no association between the two symptom dimensions for exemplar participant C.

Additionally, the present results showed that daily stress was a strong predictor to subsequent PTSD symptoms, especially to hyperarousal symptoms. However, findings further confirmed that the impacts of daily stress on PTSD symptoms are heterogeneous. Importantly, the impacts vary among PTSD symptom dimensions and individuals. Stress, including environmental, psychological, and physiological stress, has been evidenced to have a strong association with the PTSD symptoms in various populations (Esch, Stefano, Fricchione, & Benson, 2002; Zoladz & Diamond, 2015; Zvolensky et al., 2015). In a study conducted with a sample from the same population (i.e., WTC responders), Zvolensky and colleagues (2015) found that life stress was strongly related to later PTSD symptoms. Consistent with this finding, the present study revealed that daily stress at a given time point did influence PTSD symptoms at the next time point. However, the present findings further suggest that daily stress does not influence all four PTSD symptom dimensions in the same way and the impacts of daily stress also vary greatly from one individual to another. For example, the temporal relations between daily stress and PTSD symptoms were distinct for each exemplar participant, with daily stress showing both contemporaneous and lagged relations with only numbing symptoms for exemplar participant D, but these relations with hyperarousal and intrusion symptoms for exemplar participant A, similar relations with hyperarousal and avoidance symptoms for exemplar participant C, and no relation with PTSD symptoms for exemplar participant B.

Findings have two important clinical implications. First, understanding how temporal relations play out in daily life may help develop targeted points of intervention. With the advancement of technology, there is a great potential and possibility that clinicians or health care providers can integrate mobile devices into traditional clinic setting, capturing psychiatric symptoms and collecting similar data outside clinic in individuals' naturalistic environment. This information can then be used to develop models to describe how individuals' psychiatric symptoms change, fluctuate, and influence each other on a daily basis in a person-specific way.

Armed with an individual's daily pattern of psychiatric symptoms, a targeted point of intervention may be developed to address a specific symptom. Second, person-specific temporal relations create possibilities and potential for personalized health care. It would be helpful to create a path diagram for each exemplar participant in the present study to help understand dynamic processes and where would be a good point of disruption. However, such visualization has not yet been used in clinic settings. With the development of computational methods, visual diagrams could be generated in a short period of time and might be used as a communication tool between patients and clinicians in the near future. Essentially, clinicians may use a diagram to involve individuals into their own treatments, collaborate with patients on their treatment progress, and tailor the treatment to each individual.

Findings should be interpreted within the context of several limitations. First, PTSD symptoms were assessed three times a day over seven consecutive days, so a total of 20 time points were used in the analysis. This length of time was relatively shorter than the time frame used in other studies using the same analytic approach (e.g., 100 days; Wright et al., 2015). However, given the lack of EMA research in the field of PTSD, the present study serves as a great starting point to understand the person-specific PTSD symptomatology on a daily basis. Future research in PTSD is needed to collect data on PTSD symptoms in daily life in a longer time period in various samples. Second, individual-level uSEM is a data-driven and person-specific analytic approach, as such, results from the present study may not generalize to other clinical samples, including other samples drawn from the WTC responder cohort. Given generalizability has been a key weakness of individual-level uSEM, recent efforts have been made to overcome this weakness by using both group-level and individual-level information in the statistical modeling (Gates & Molenaar, 2012). Future work is needed to examine temporal relations among PTSD symptoms using aggregated information from the full sample and person-specific information from each individual.

In conclusion, individual-level uSEM, a person-specific analytic approach, can be applied to characterize temporal relations among PTSD symptom dimensions for each individual on a daily basis. Such information is important to advance our current understanding of heterogeneity in PTSD symptomatology over time. Beyond PTSD symptoms, this analytic approach holds a great potential to model dynamic processes in psychopathology, which has been increasingly recognized as dynamic and changeable in nature (Nelson, McGorry, Wichers, Wigman, & Hartmann, 2017).

Table 1

Descriptive Statistics of the EMA Variables in the Final Sample

	Intra-individual Mean				Intra-individual Variation			
	M	*SD*	Min	Max	*M*	*SD*	Min	Max
PTSD dimensions								
Intrusion	3.60	1.24	2.05	7.00	1.18	.52	.23	2.42
Avoidance	4.34	1.75	2.05	9.95	1.27	.54	.22	3.05
Numbing	3.67	1.47	2.05	8.95	.97	.49	.23	2.69
Hyperarousal	4.39	1.84	2.05	9.60	.96	.44	.22	2.42
Daily stress	2.40	.76	1.05	4.42	.61	.24	.22	1.34

Note. *N* = 106.

Table 2

Mean Values of the Estimated Contemporaneous and Lagged Path Parameters of Temporal Relations among PTSD Symptoms

	Lagged path parameters				Contemporaneous path parameters			
Outcomes	Intrusion lagged	Avoidance lagged	Numbing lagged	Hyperarousal lagged	Intrusion	Avoidance	Numbing	Hyperarousal
Intrusion	.16	.07	.27	-.57	1	.34	-.01	.39
Avoidance	.10	.02	-.01	.23	.62	1	.52	.41
Numbing	.09	.04	.11	.29	.65	-.16	1	.70
Hyperarousal	-.34	.25	.15	.12	.49	-.02	.50	1

Note. Beta-weights are reported in the table to show the magnitude of the relations, on average.

Table 3

Mean Values of the Estimated Contemporaneous and Lagged Path Parameters of Temporal Relations between Daily Stress and PTSD Symptoms

	Lagged path parameters					Contemporaneous path parameters				
Outcomes	Intrusion lagged	Avoidance lagged	Numbing lagged	Hyperarousal lagged	Daily stress lagged	Intrusion	Avoidance	Numbing	Hyperarousal	Daily stress
Intrusion	.02	.14	.29	-.03	.22	1	.66	.44	.39	.26
Avoidance	.14	.04	-.11	.24	.10	.61	1	.62	.43	-.14
Numbing	.23	.16	.05	.24	.11	.52	-.12	1	.66	.50
Hyperarousal	-.18	.16	.15	.10	.26	.58	.16	.46	1	.24
Daily stress	.27	-.07	.10	.08	.22	.81	-.31	-1.13	.84	1

Note. Beta-weights are reported in the table to show the magnitude of the relations, on average.

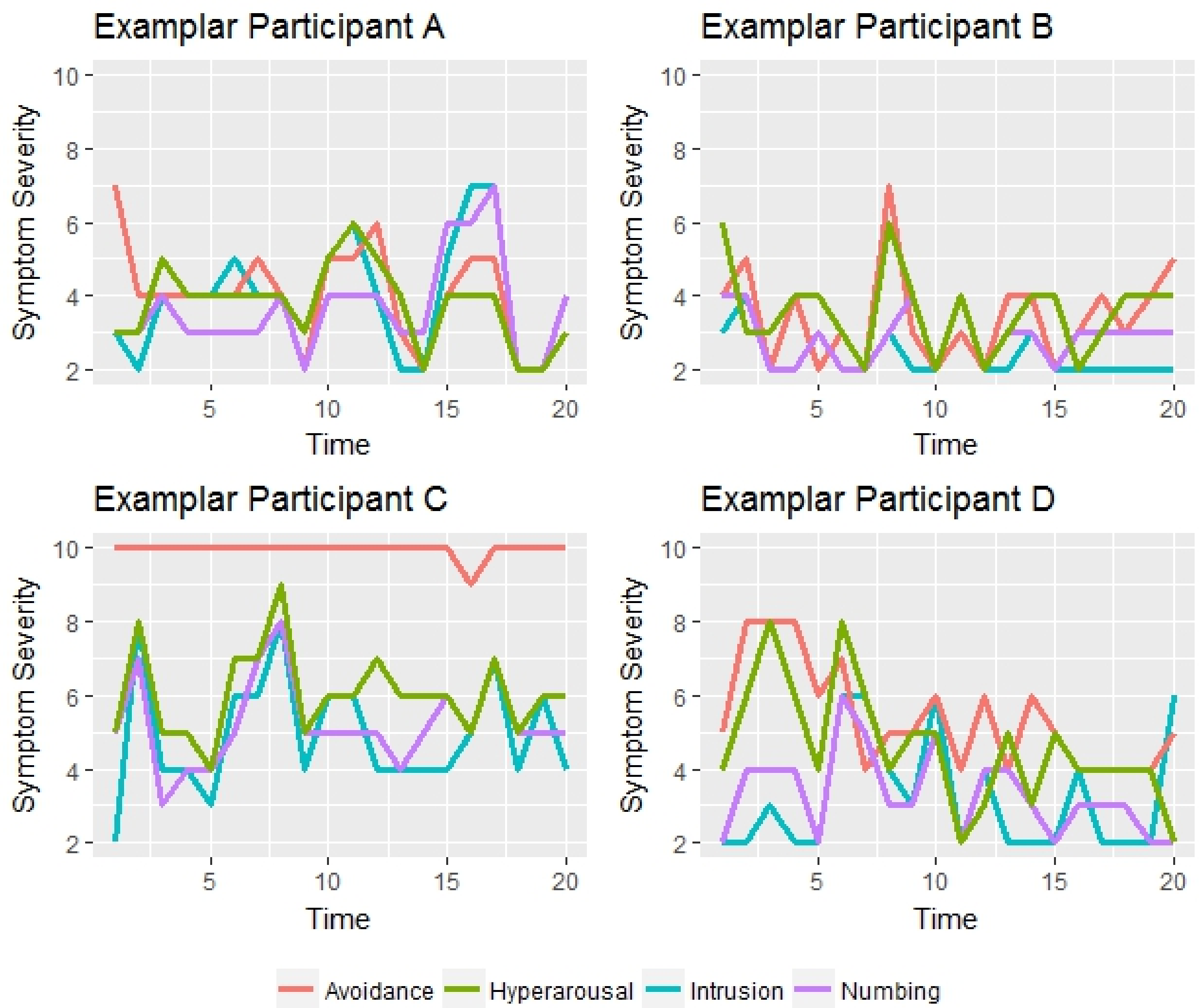

Figure 1. Time series plots for the raw scores of four PTSD symptom dimensions for each exemplar participant (A-D).

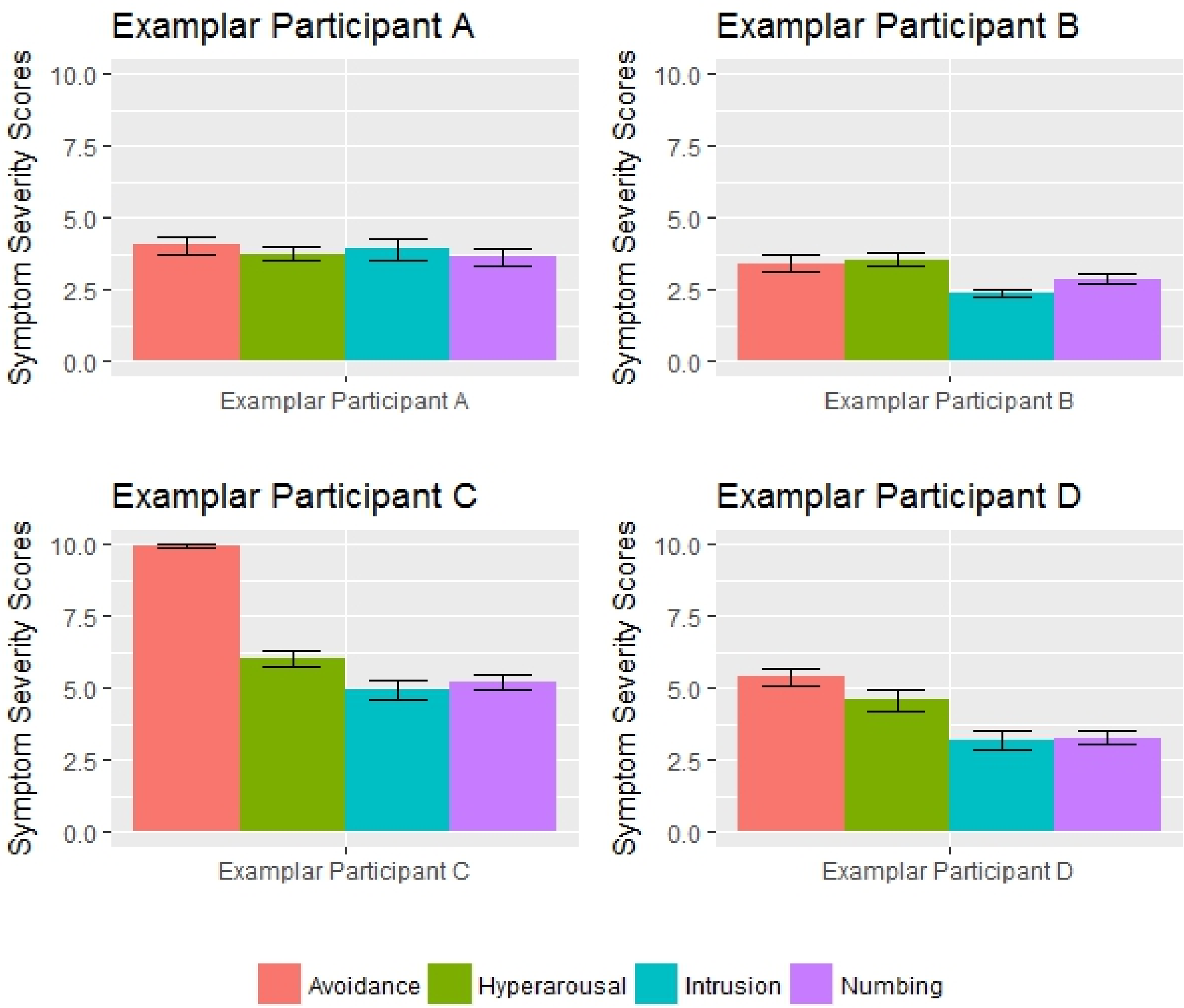

Figure 2. Descriptive statistics of the scores of four PTSD symptom dimensions across the EMA period. The bar graphs show the means and standard errors of the mean values for each exemplar participant (A-D).

REFERENCES

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4^{th} ed.). Washington, DC: Author.

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5^{th} ed.). Arlington, VA: Author.

Armour, C., Contractor, A. A., Palmieri, P. A., & Elhai, J. D. (2014). Assessing latent level associations between PTSD and dissociative factors: is depersonalization and derealization related to PTSD factors more so than alternative dissociative factors?. *Psychological Injury and Law*, *7*(2), 131-142.

Armour, C., Contractor, A., Shea, T., Elhai, J. D., & Pietrzak, R. H. (2016). Factor Structure of the PTSD Checklist for DSM-5: Relationships Among Symptom Clusters, Anger, and Impulsivity. *The Journal of Nervous and Mental Disease*, *204*(2), 108-115.

Armour, C., & Shevlin, M. (2010). Testing the dimensionality of PTSD and the specificity of the dysphoria factor. *Journal of Loss and Trauma*, *15*(1), 11-27.

Armour, C., Tsai, J., Durham, T. A., Charak, R., Biehn, T. L., Elhai, J. D., & Pietrzak, R. H. (2015). Dimensional structure of DSM-5 posttraumatic stress symptoms: Support for a hybrid anhedonia and externalizing behaviors model. *Journal of Psychiatric Research*, *61*, 106-113.

Asmundson, G. J., Frombach, I., McQuaid, J., Pedrelli, P., Lenox, R., & Stein, M. B. (2000). Dimensionality of posttraumatic stress symptoms: A confirmatory factor analysis of DSM-IV symptom clusters and other symptom models. *Behaviour Research and Therapy*, *38*(2), 203-214.

Asmundson, G. J., Stapleton, J. A., & Taylor, S. (2004). Are avoidance and numbing distinct PTSD symptom clusters?. *Journal of Traumatic Stress*, *17*(6), 467-475.

Asmundson, G. J., Wright, K. D., McCreary, D. R., & Pedlar, D. (2003). Post-traumatic stress disorder symptoms in United Nations peacekeepers: An examination of factor structure in peacekeepers with and without chronic pain. *Cognitive Behaviour Therapy*, *32*(1), 26-37.

Baschnagel, J. S., O'Connor, R. M., Colder, C. R., & Hawk, L. W. (2005). Factor structure of posttraumatic stress among Western New York undergraduates following the September 11th terrorist attack on the World Trade Center. *Journal of Traumatic Stress*, *18*(6), 677-684.

Beltz, A. M., Beekman, C., Molenaar, P. C., & Buss, K. A. (2013). Mapping temporal dynamics in social interactions with unified structural equation modeling: A description and demonstration revealing time-dependent sex differences in play behavior. *Applied Developmental Science*, *17*(3), 152-168.

Beltz, A. M., & Molenaar, P. C. (2016). Dealing with multiple solutions in structural vector autoregressive models. *Multivariate Behavioral Research*, *51*, 357-373.

Beltz, A. M., Wright, A. G., Sprague, B. N., & Molenaar, P. C. (2016). Bridging the Nomothetic and Idiographic Approaches to the Analysis of Clinical Data. *Assessment*, *23*(4), 447-458

Biehn, T. L., Elhai, J. D., Seligman, L. D., Tamburrino, M., Armour, C., & Forbes, D. (2013). Underlying dimensions of DSM-5 posttraumatic stress disorder and major depressive disorder symptoms. *Psychological Injury and Law*, *6*(4), 290-298.

Black, A. C., Cooney, N. L., Justice, A. C., Fiellin, L. E., Pietrzak, R. H., Lazar, C. M., & Rosen, M. I. (2016). Momentary assessment of PTSD symptoms and sexual risk behavior in male OEF/OIF/OND Veterans. *Journal of Affective Disorders*, *190*, 424-428.

Blake, D., Weathers, F., Nagy, L., Kaloupek, D., Klauminzer, G., Charney, D., & Keane, T. (1990). *Clinician-administered PTSD scale (CAPS)*. National Center for Post-Traumatic Stress Disorder, Behavioral Science Division Boston-VA, Boston, MA.

Boelen, P. A., van den Hout, M. A., & van den Bout, J. (2008). The factor structure of posttraumatic stress disorder symptoms among bereaved individuals: A confirmatory factor analysis study. *Journal of Anxiety Disorders*, *22*(8), 1377-1383.

Borkenau, P., & Ostendorf, F. (1998). The Big Five as states: How useful is the five-factor model to describe intraindividual variations over time?. *Journal of Research in Personality*, *32*(2), 202-221.

Brown, T. A. (2006). *Confirmatory factor analysis for applied research*. New York: Guilford Press.

Carragher, N., Mills, K., Slade, T., Teesson, M., & Silove, D. (2010). Factor structure of posttraumatic stress disorder symptoms in the Australian general population. *Journal of Anxiety Disorders*, *24*(5), 520-527.

Cordova, M. J., Studts, J. L., Hann, D. M., Jacobsen, P. B., & Andrykowski, M. A. (2000). Symptom structure of PTSD following breast cancer. *Journal of Traumatic Stress*, *13*(2), 301-319.

Cox, B. J., Mota, N., Clara, I., & Asmundson, G. J. (2008). The symptom structure of posttraumatic stress disorder in the National Comorbidity Replication Survey. *Journal of Anxiety Disorders*, *22*(8), 1523-1528.

Creamer, M., Burgess, P., & Pattison, P. (1992). Reaction to trauma: a cognitive processing model. *Journal of Abnormal Psychology*, *101*(3), 452-459.

de Marco, G., Vrignaud, P., Destrieux, C., de Marco, D., Testelin, S., Devauchelle, B., & Berquin, P. (2009). Principle of structural equation modeling for exploring functional interactivity within a putative network of interconnected brain areas. *Magnetic Resonance Imaging*, *27*(1), 1-12.

Doron-LaMarca, S., Niles, B. L., King, D. W., King, L. A., Pless Kaiser, A., & Lyons, M. J. (2015). Temporal Associations Among Chronic PTSD Symptoms in US Combat Veterans. *Journal of Traumatic Stress*, *28*(5), 410-417.

DuHamel, K. N., Ostrof, J., Ashman, T., Winkel, G., Mundy, E. A., Keane, T. M., ... & Chhabra, R. (2004). Construct validity of the posttraumatic stress disorder checklist in cancer survivors: analyses based on two samples. *Psychological Assessment*, *16*(3), 255-266.

Elhai, J. D., Biehn, T. L., Armour, C., Klopper, J. J., Frueh, B. C., & Palmieri, P. A. (2011b). Evidence for a unique PTSD construct represented by PTSD's D1–D3 symptoms. *Journal of Anxiety Disorders*, *25*(3), 340-345.

Elhai, J. D., Biehn, T. L., Naifeh, J. A., & Frueh, B. C. (2011a). Posttraumatic stress disorder instrument wording content is associated with differences in factor structure. *Journal of Traumatic Stress*, *24*(2), 208-212.

Elhai, J. D., Engdahl, R. M., Palmieri, P. A., Naifeh, J. A., Schweinle, A., & Jacobs, G. A. (2009a). Assessing posttraumatic stress disorder with or without reference to a single, worst traumatic event: Examining differences in factor structure. *Psychological Assessment*, *21*(4), 629-634.

Elhai, J. D., Ford, J. D., Ruggiero, K. J., & Frueh, B. C. (2009b). Diagnostic alterations for post-traumatic stress disorder: examining data from the National Comorbidity Survey Replication and National Survey of Adolescents. *Psychological Medicine*, *39*(12), 1957-1966.

Elhai, J. D., Gray, M. J., Docherty, A. R., Kashdan, T. B., & Kose, S. (2007). Structural validity of the Posttraumatic Stress Disorder Checklist among college students with a trauma history. *Journal of Interpersonal Violence*, *22*(11), 1471-1478.

Elhai, J. D., Grubaugh, A. L., Kashdan, T. B., & Frueh, B. C. (2008). Empirical examination of a proposed refinement to DSM-IV posttraumatic stress disorder symptom criteria using the National Comorbidity Survey Replication data. *Journal of Clinical Psychiatry*, *69*(4), 597-602.

Elhai, J. D., Miller, M. E., Ford, J. D., Biehn, T. L., Palmieri, P. A., & Frueh, B. C. (2012). Posttraumatic stress disorder in DSM-5: Estimates of prevalence and symptom structure in a nonclinical sample of college students. *Journal of Anxiety Disorders*, *26*(1), 58-64.

Elhai, J. D., & Palmieri, P. A. (2011). The factor structure of posttraumatic stress disorder: A literature update, critique of methodology, and agenda for future research. *Journal of Anxiety Disorders*, *25*(6), 849-854.

Elklit, A., Armour, C., & Shevlin, M. (2010). Testing alternative factor models of PTSD and the robustness of the dysphoria factor. *Journal of Anxiety Disorders*, *24*(1), 147-154.

Elklit, A., & Shevlin, M. (2007). The structure of PTSD symptoms: A test of alternative models using confirmatory factor analysis. *British Journal of Clinical Psychology*, *46*(3), 299-313.

Esch, T., Stefano, G. B., Fricchione, G. L., & Benson, H. (2002). The role of stress in neurodegenerative diseases and mental disorders. *Neuroendocrinology Letters*, *23*(3), 199-208.

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. (1997). *Structured clinical interview for DSM-IV clinical version*. New York: Biometrics Research Department, New York State Psychiatric Institute.

Foa, E. B., Riggs, D. S., Dancu, C. V., & Rothbaum, B. O. (1993). Reliability and validity of a brief instrument for assessing post-traumatic stress disorder. *Journal of Traumatic Stress*, *6*(4), 459-473.

Forbes, D., Lockwood, E., Elhai, J. D., Creamer, M., Bryant, R., McFarlane, A., ... & O'Donnell, M. (2015). An evaluation of the DSM-5 factor structure for posttraumatic stress disorder in survivors of traumatic injury. *Journal of Anxiety Disorders*, *29*, 43-51.

Ford, J. D., Elhai, J. D., Ruggiero, L. J., & Frueh, B. C. (2009). Refining posttraumatic stress disorder diagnosis: evaluation of symptom criteria with the National Survey of Adolescents. *The Journal of Clinical Psychiatry*, *70*(5), 748-755.

Foy, D. W., Wood, J. L., King, D. W., King, L. A., & Resnick, H. S. (1997). Los Angeles Symptom Checklist: Psychometric evidence with an adolescent sample. *Assessment*, *4*(4), 377-384.

Gates, K. M., & Molenaar, P. C. (2012). Group search algorithm recovers effective connectivity maps for individuals in homogeneous and heterogeneous samples. *Neuroimage*, *63*(1), 310-319.

Gates, K. M., Molenaar, P. C., Hillary, F. G., Ram, N., & Rovine, M. J. (2010). Automatic search for fMRI connectivity mapping: an alternative to Granger causality testing using formal equivalences among SEM path modeling, VAR, and unified SEM. *Neuroimage*, *50*(3), 1118-1125.

Gates, K. M., Molenaar, P. C., Hillary, F. G., & Slobounov, S. (2011). Extended unified SEM approach for modeling event-related fMRI data. *NeuroImage*, *54*(2), 1151-1158.

Goebel, R., Roebroeck, A., Kim, D. S., & Formisano, E. (2003). Investigating directed cortical interactions in time-resolved fMRI data using vector autoregressive modeling and Granger causality mapping. *Magnetic Resonance Imaging*, *21*(10), 1251-1261.

Grubaugh, A. L., Long, M. E., Elhai, J. D., Frueh, B. C., & Magruder, K. M. (2010). An examination of the construct validity of posttraumatic stress disorder with veterans using a revised criterion set. *Behaviour Research and Therapy*, *48*(9), 909-914.

Horowitz, M. J. (2001). *Stress response syndromes*. Jason Aronson Incorporated.

Hoyt, T., & Yeater, E. A. (2010). Comparison of posttraumatic stress disorder symptom structure models in Hispanic and White college students. *Psychological Trauma: Theory, Research, Practice, and Policy*, *2*(1), 19-30.

Kassam-Adams, N., Marsac, M. L., & Cirilli, C. (2010). Posttraumatic stress disorder symptom structure in injured children: Functional impairment and depression symptoms in a confirmatory factor analysis. *Journal of the American Academy of Child & Adolescent Psychiatry*, *49*(6), 616-625.

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Archives of General Psychiatry*, *62*(6), 593-602.

Kim, J., Zhu, W., Chang, L., Bentler, P. M., & Ernst, T. (2007). Unified structural equation modeling approach for the analysis of multisubject, multivariate functional MRI data. *Human Brain Mapping*, *28*(2), 85-93.

King, D. W., Leskin, G. A., King, L. A., & Weathers, F. W. (1998). Confirmatory factor analysis of the clinician-administered PTSD Scale: Evidence for the dimensionality of posttraumatic stress disorder. *Psychological Assessment*, *10*(2), 90-96.

Kline, R. B. (2010). *Principles and practice of structural equation modeling*. Guilford publications.

Krause, E. D., Kaltman, S., Goodman, L. A., & Dutton, M. A. (2007). Longitudinal factor structure of posttraumatic stress symptoms related to intimate partner violence. *Psychological Assessment*, *19*(2), 165-175.

Lane, S. T., Gates, K. M., Molenaar, P. C. M., Hallquist, M., & Pike, H. (2016). gimme: Group Iterative Multiple Model Estimation. *Computer Software. Retrieved from https://CRAN. R-project. org/package= gimme*.

Lawrence, J. W., Fauerbach, J., & Munster, A. (1996). Early avoidance of traumatic stimuli predicts chronicity of intrusive thoughts following burn injury. *Behaviour Research and Therapy*, *34*(8), 643-646.

Liu, P., Wang, L., Cao, C., Wang, R., Zhang, J., Zhang, B., ... & Elhai, J. D. (2014). The underlying dimensions of DSM-5 posttraumatic stress disorder symptoms in an epidemiological sample of Chinese earthquake survivors. *Journal of Anxiety Disorders*, *28*(4), 345-351.

Mansfield, A. J., Williams, J., Hourani, L. L., & Babeu, L. A. (2010). Measurement invariance of posttraumatic stress disorder symptoms among US military personnel. *Journal of Traumatic Stress*, *23*(1), 91-99.

Marshall, G. N., Schell, T. L., Glynn, S. M., & Shetty, V. (2006). The role of hyperarousal in the manifestation of posttraumatic psychological distress following injury. *Journal of Abnormal Psychology*, *115*(3), 624-628.

McDonald, S. D., Beckham, J. C., Morey, R., Marx, C., Tupler, L. A., & Calhoun, P. S. (2008). Factorial invariance of posttraumatic stress disorder symptoms across three veteran samples. *Journal of Traumatic Stress*, *21*(3), 309-317.

McFarlane, A. C. (1992). Avoidance and intrusion in posttraumatic stress disorder. *The Journal of Nervous and Mental Disease*, *180*(7), 439-445.

McFarlane, A. C. (2000). Posttraumatic stress disorder: a model of the longitudinal course and the role of risk factors. *Journal of Clinical Psychiatry*, *61*, 15-23.

McWilliams, L. A., Cox, B. J., & Asmundson, G. J. (2005). Symptom structure of posttraumatic stress disorder in a nationally representative sample. *Journal of Anxiety Disorders*, *19*(6), 626-641.

Milanak, M. E., & Berenbaum, H. (2009). The relationship between PTSD symptom factors and emotion. *Journal of Traumatic Stress*, *22*(2), 139-145.

Miller, M. W., Wolf, E. J., Kilpatrick, D., Resnick, H., Marx, B. P., Holowka, D. W., ... & Friedman, M. J. (2013). The prevalence and latent structure of proposed DSM-5 posttraumatic stress disorder symptoms in US national and veteran samples. *Psychological Trauma: Theory, Research, Practice, and Policy*, *5*(6), 501-512.

Molenaar, P. C. (1985). A dynamic factor model for the analysis of multivariate time series. *Psychometrika, 50*, 181–202.

Molenaar, P. C. (2004). A manifesto on psychology as idiographic science: Bringing the person back into scientific psychology, this time forever. *Measurement*, *2*(4), 201-218.

Molenaar, P. C. (2013). On the necessity to use person-specific data analysis approaches in psychology. *European Journal of Developmental Psychology*, *10*(1), 29-39.

Molenaar, P. C., & Campbell, C. G. (2009). The new person-specific paradigm in psychology. *Current Directions in Psychological Science*, *18*(2), 112-117.

Molenaar, P., Sinclair, K. O., Rovine, M. J., Ram, N., & Corneal, S. E. (2009). Analyzing developmental processes on an individual level using nonstationary time series modeling. *Developmental Psychology*, *45*(1), 260-271.

Naifeh, J. A., Elhai, J. D., Kashdan, T. B., & Grubaugh, A. L. (2008). The PTSD Symptom Scale's latent structure: An examination of trauma-exposed medical patients. *Journal of Anxiety Disorders*, *22*(8), 1355-1368.

Naifeh, J. A., Richardson, J. D., Del Ben, K. S., & Elhai, J. D. (2010). Heterogeneity in the latent structure of PTSD symptoms among Canadian veterans. *Psychological Assessment*, *22*(3), 666-674.

Naragon-Gainey, K., Simpson, T. L., Moore, S. A., Varra, A. A., & Kaysen, D. L. (2012). The correspondence of daily and retrospective PTSD reports among female victims of sexual assault. *Psychological Assessment*, *24*(4), 1041-1047.

Nelson, B., McGorry, P. D., Wichers, M., Wigman, J. T., & Hartmann, J. A. (2017). Moving From Static to Dynamic Models of the Onset of Mental Disorder: A Review. *JAMA Psychiatry*, *74*(5), 528-534.

Nesselroade, J. R., & Molenaar, P. C. M. (1999). Pooling lagged covariance structures based on short, multivariate time series for dynamic factor analysis. In R. H. Hoyle (Ed.), *Statistical Strategies for Small Sample Research* (pp. 223-251). London: Sage.

Olff, M., Sijbrandij, M., Opmeer, B. C., Carlier, I. V., & Gersons, B. P. (2009). The structure of acute posttraumatic stress symptoms: 'Reexperiencing', 'active avoidance', 'dysphoria', and 'hyperarousal'. *Journal of Anxiety Disorders*, *23*(5), 656-659.

Palmieri, P. A., & Fitzgerald, L. F. (2005). Confirmatory factor analysis of posttraumatic stress symptoms in sexually harassed women. *Journal of Traumatic Stress*, *18*(6), 657-666.

Palmieri, P. A., Marshall, G. N., & Schell, T. L. (2007). Confirmatory factor analysis of posttraumatic stress symptoms in Cambodian refugees. *Journal of Traumatic Stress*, *20*(2), 207-216.

Palmieri, P. A., Weathers, F. W., Difede, J., & King, D. W. (2007). Confirmatory factor analysis of the PTSD Checklist and the Clinician-Administered PTSD Scale in disaster workers exposed to the World Trade Center Ground Zero. *Journal of Abnormal Psychology*, *116*(2), 329-341.

Penny, W., & Harrison, L. (2007). Multivariate autoregressive models. *Statistical Parametric Mapping: The Analysis of Functional Brain Images. Academic Press, Amsterdam,* 534-540.

Pietrzak, R. H., Feder, A., Schechter, C. B., Singh, R., Cancelmo, L., Bromet, E. J., ... & Crane, M. (2014). Dimensional structure and course of post-traumatic stress symptomatology in World Trade Center responders. *Psychological Medicine*, *44*(10), 2085-2098.

Pietrzak, R. H., Tsai, J., Armour, C., Mota, N., Harpaz-Rotem, I., & Southwick, S. M. (2015). Functional significance of a novel 7-factor model of DSM-5 PTSD symptoms: Results from the National Health and Resilience in Veterans Study. *Journal of Affective Disorders*, *174*, 522-526.

Rasmussen, A., Smith, H., & Keller, A. S. (2007). Factor structure of PTSD symptoms among west and central African refugees. *Journal of Traumatic Stress*, *20*(3), 271-280.

Saul, A. L., Grant, K. E., & Carter, J. S. (2008). Post-traumatic reactions in adolescents: how well do the DSM-IV PTSD criteria fit the real life experience of trauma exposed youth?. *Journal of Abnormal Child Psychology*, *36*(6), 915-925.

Schell, T. L., Marshall, G. N., & Jaycox, L. H. (2004). All symptoms are not created equal: the prominent role of hyperarousal in the natural course of posttraumatic psychological distress. *Journal of Abnormal Psychology*, *113*(2), 189-197.

Scher, C. D., McCreary, D. R., Asmundson, G. J., & Resick, P. A. (2008). The structure of post-traumatic stress disorder symptoms in three female trauma samples: A comparison of interview and self-report measures. *Journal of Anxiety Disorders*, *22*(7), 1137-1145.

Schinka, J. A., Brown, L. M., Borenstein, A. R., & Mortimer, J. A. (2007). Confirmatory factor analysis of the PTSD checklist in the elderly. *Journal of Traumatic Stress*, *20*(3), 281-289.

Shelby, R. A., Golden-Kreutz, D. M., & Andersen, B. L. (2005). Mismatch of posttraumatic stress disorder (PTSD) symptoms and DSM-IV symptom clusters in a cancer sample: Exploratory factor analysis of the PTSD Checklist-Civilian Version. *Journal of Traumatic Stress*, *18*(4), 347-357.

Shevlin, M., McBride, O., Armour, C., & Adamson, G. (2009). Reconciling the differences between the King et al.(1998) and Simms et al.(2002) factor models of PTSD. *Journal of Anxiety Disorders*, *23*(7), 995-1001.

Simms, L. J., Watson, D., & Doebbelling, B. N. (2002). Confirmatory factor analyses of posttraumatic stress symptoms in deployed and nondeployed veterans of the Gulf War. *Journal of Abnormal Psychology*, *111*(4), 637-647.

Sims, C. A. (1980). Macroeconomics and reality. *Econometrica: Journal of the Econometric Society*, 1-48.

Solomon, Z., Horesh, D., & Ein-Dor, T. (2009). The Longitudinal Course of Posttraumatic Stress Disorder Symptom Clusters Among War Veterans [CME]. *The Journal of Clinical Psychiatry*, *70*(6), 837-843.

Sörbom, D. (1989). Model modification. *Psychometrika*, *54*(3), 371-384.

Stone, A. A., & Shiffman, S. (1994). Ecological momentary assessment (EMA) in behavorial medicine. *Annals of Behavioral Medicine, 16*, 199-202.

Tsai, J., Harpaz-Rotem, I., Armour, C., Southwick, S. M., Krystal, J. H., & Pietrzak, R. H. (2014). Dimensional structure of DSM-5 posttraumatic stress disorder symptoms: Results from the National Health and Resilience in Veterans Study. *The Journal of Clinical Psychiatry*, *76*(5), 546-553.

Watson, D. (2005). Rethinking the mood and anxiety disorders: a quantitative hierarchical model for DSM-V. *Journal of Abnormal Psychology*, *114*(4), 522-536.

Watson, D. (2009). Differentiating the mood and anxiety disorders: A quadripartite model. *Annual Review of Clinical Psychology*, *5*, 221-247.

Weathers, F., Huska, J., & Keane, T. (1991). *The PTSD checklist military version (PCL-M)*. Boston, MA: National Center for PTSD.

Weathers, F. W., Litz, B. T., Keane, T. M., Palmieri, P. A., Marx, B. P., & Schnurr, P. P. (2013). *The PTSD checklist for DSM-5 (PCL-5)*. Scale available from the National Center for PTSD at www. ptsd. va. gov.

Wright, A. G., Beltz, A. M., Gates, K. M., Molenaar, P. C., & Simms, L. J. (2015). Examining the dynamic structure of daily internalizing and externalizing behavior at multiple levels of analysis. *Frontiers in Psychology*, *6*, 1914.

Yufik, T., & Simms, L. J. (2010). A meta-analytic investigation of the structure of posttraumatic stress disorder symptoms. *Journal of Abnormal Psychology*, *119*(4), 764-776.

Zoellner, L. A., Pruitt, L. D., Farach, F. J., & Jun, J. J. (2014). Understanding heterogeneity in PTSD: fear, dysphoria, and distress. *Depression and Anxiety*, *31*(2), 97-106.

Zoladz, P. R., & Diamond, D. (2016). Psychosocial predator stress model of PTSD based on clinically relevant risk factors for trauma-induced psychopathology. In J. D. Bremner (Ed.), *Posttraumatic Stress Disorder: From Neurobiology to Treatment*, (pp. 125-143). Hoboken, New Jersey: John Wiley & Sons, Inc.

Zvolensky, M. J., Farris, S. G., Kotov, R., Schechter, C. B., Bromet, E., Gonzalez, A., ... & Moline, J. (2015). World Trade Center disaster and sensitization to subsequent life stress: a longitudinal study of disaster responders. *Preventive Medicine*, *75*, 70-74.