Trait vs. trajectory: Conceptualizations of resilience after mild traumatic brain injury

Stephanie Liu

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Public Health

University of Washington

2018

Committee:

Ali Rowhani-Rahbar

Jeanne Hoffman

Program Authorized to Offer Degree:

School of Public Health

University of Washington

Abstract

Trait vs. trajectory: Conceptualizations of resilience after mild traumatic brain injury

Stephanie Liu

Chair of the Supervisory Committee:

Ali Rowhani-Rahbar

Department of Epidemiology

Mild traumatic brain injuries (mTBIs) are associated with various physical, cognitive, and behavioral/emotional problems. Resilience has been conceptualized as both a personal "trait" and an outcome "trajectory". The objective of this study was to examine the association between 1) "trait" resilience and outcome trajectory of posttraumatic headache, and 2) to examine the relationship of both resilience constructs with various outcomes. Follow-up questionnaires at 12 months post mTBI included assessments of depression, posttraumatic stress, functional impairment, and quality of life. From this sample (N=212), positive (resilient) and negative headache trajectory categories were created, with 49 individuals (23%) in the positive group. Univariate analyses and logistic regression models were run to assess the relationship between "trait" resilience, headache trajectory, and outcomes of interest. For every one point increase in CD-RISC, the odds of having a positive trajectory increased by 6%, but results were not significant after adjustment for demographic variables. "Trait" resilience was significantly related to various adverse psychological and functional outcomes after mTBI. Individuals displaying a resilient trajectory were significantly less likely to meet DSM-IV clinical criteria for depression or PTSD and to have functional impairments.

Introduction:

Traumatic brain injury (TBI) is a significant public health concern with an estimated 2.8 million cases in the U.S. each year (Taylor 2017). About 75% of TBIs are mild (mTBIs), and are commonly called concussions (Ruff 2009). The most recent CDC estimate of rates of mTBI-related emergency department visits, hospitalizations and deaths in the U.S. is 823.7 per 100,000 per year, but the actual incidence is thought to be higher because many mTBI cases are not treated in hospitals. Economic costs of mTBI are estimated to amount to $16.5 billion per year (Thurman 2001), which doesn't capture the great toll mTBI takes on individuals and families.

mTBI is associated with a range of adverse outcomes. Concussion symptoms after mTBI include physical symptoms (headaches), cognitive deficits, and behavioral/emotional problems. The prevalence of self-reported concussion symptoms six months after mTBI is estimated to range from 11% to 39% (Voormolen 2018), depending on the classification method and rating score used. The most common concussion symptom after TBI is posttraumatic headache (PTH) regardless of severity (Minen 2016), with a cumulative incidence of 91% one year after mTBI (Lucas 2015). mTBI is associated with an increased risk for psychiatric illness, including PTSD, depression, anxiety, substance abuse, and various personality disorders (Holland 2015), although it is unclear if the risk for these disorders is higher after mTBI vs. traumatic non brain injury (Bryant 2010, Meares 2011). The psychiatric sequelae of mTBI are also associated with a considerable decrease in functional outcomes and health related quality of life (Haagsma 2015). Concussion symptoms are not unique to this type of injury; for example, patients with non-head injury-related chronic pain report frequent and severe post concussion symptoms (Iverson 1999). However, these symptoms are more common within the first month after mTBI than after other injuries or in the general population (Bazarian 1999, Paniak 2002, Paniak 1999). For the majority of cases, concussion symptoms (most commonly headache) are largely resolved within one to three months post mTBI (Caroll 2004); however, a subgroup of individuals are chronically impaired and have persistent symptoms from months to years post-injury. Examining the variable response after mTBI is of great interest to individuals, families, and health care providers in order to identify risk factors, inform care, and improve outcomes. In recent years, researchers (e.g. Iverson 2012, McCauley 2013) have identified resilience as a contributing factor to the variable response after mTBI, and its potential for modification may inform the management of mTBI.

Resilience has been defined variously as the process of, capacity for, or outcome of successful adaptation after trauma or severe stress (Butler 2007, Egeland 1993, Layne 2007, Masten 1990, Norris 2008, Werner 1982). Resilience has been conceptualized as both a dynamic personal "trait" and an outcome "trajectory" (Sullivan 2016). "Trait" resilience is generally defined as a personality characteristic and/or an adaptive process. "Trajectory" resilience can be defined as a temporal pattern of physical and psychological health that follows an adverse event; while there may be mild and transient distress reactions, resilience generally involves a stable trajectory of healthy functioning (Bonnano 2013). For example, in a study of psychological functioning after sustaining a spinal cord injury, the majority of participants displayed low initial depression and anxiety scores which remained stable over two years of follow up thus following a resilience trajectory (Bonanno 2012).

A limited number of studies have examined the relationship between mTBI and resilience. In the mTBI literature, researchers have almost exclusively taken the "trait" resilience approach. These studies rest on the assumption that "trait" resilience is a relatively stable phenomenon (McCauley 2013), and there is tentative evidence that sustaining a mTBI does not affect resilience (Hanks 2016). From studies of both veteran and civilian populations, lower “trait” resilience has generally been associated with greater post-concussion symptoms (Graham 2013, Merritt 2015, Sullivan 2015, Losoi 2015), post-traumatic stress symptoms and/or PTSD (Merritt 2015, Graham 2013, Elliot 2017, Losoi 2015), depression (Graham 2013, Elliot 2017, Losoi 2015), and perceived limitations (Graham 2013), and lower quality of life (Elliot 2017) and social support (Elliot 2017). In contrast, McCauley (2013) found that greater preinjury resilience (measured by a proxy taken after the injury) was associated with greater post-concussion symptoms, depression, anxiety and posttraumatic stress symptom severity. However, since these outcomes were assessed at one week and one month post-injury, one tentative explanation the authors offered was that there was insufficient time to “bounce back” or be resilient about the injury. In a prospective cohort study (Losoi 2015), those with moderate-high resilience reported significantly fewer post-concussion symptoms, traumatic stress, and depressive symptoms, and better quality of life at both one month and six month follow up, but by 12 months the moderate-high resilience individuals only reported less traumatic stress and better quality of life and no differences in post-concussion symptoms compared to the low resilience group. In summary, greater trait resilience has generally been found to be associated with more positive outcomes post mTBI, and for some outcomes, such as traumatic stress and quality of life, these benefits may persist up to one year.

While mTBI studies examining “trait” resilience have value, the wider literature supports the “trajectory” resilience approach, looking at the type of outcome trajectory following acute adverse events. Most of the variability in response to adverse or potentially traumatic events can be captured by four “prototypical” trajectories (Bonanno 2004). These trajectories, while they can assume different labels, are: (i) trajectory resilience/minimal-impact resilient response (continue functioning normally even soon after the event), (ii) recovery (struggle for months but gradually return to baseline levels of adjustment, (iii) delayed distress (moderate levels of symptoms and distress that gradually worsen), and (iv) chronic dysfunction (unable to function normally for years after the event).

This current study is a secondary analysis that will contribute to the nascent literature on mTBI and resilience. This study will examine a host of important functional and psychological outcomes at one year post injury. To my knowledge, this study will be the first to examine and compare both the "trait" and "trajectory" conceptualizations of resilience seen in the literature. Four types of headache trajectories across the first year post injury have been identified (Sawyer 2015), thus in the present study we will examine the association between 1) the constructs of "trait" resilience and type of PTH trajectory, and 2) we will examine outcomes for those with a resilient trajectory, defined in our sample as those with either improving (pain intensity lessens from moderate to no pain over 12 months) or resolved (pain resolves within three months) headaches. The first approach will be an exploratory analysis to see what overlap exists between "trait" and "trajectory" resilience – that if one has higher levels of "trait" resilience one might also experience a more resilient outcome post injury. It is thought that higher "trait" resilience will be associated with a more resilient outcome trajectory of PTH. This exploratory analysis will also examine the associations between "trait" resilience and various measures of psychopathology, concussion symptoms, and functional outcomes.

Methods:

Study Participants.—Data from the current study are a secondary analysis of 212 participants with mTBI who were enrolled within 1 week of injury at Harborview Medical Center, a Level 1 trauma center in Seattle, Washington. Prospective enrollment of subjects occurred from January 2010 to April 2011. Recruitment occurred while participants were hospitalized for observation or other system injuries. Participants were identified through electronic medical records, screening for mechanism of injury related to mTBI, or admission diagnosis codes related to concussion or head injury. Diagnosis of mTBI was confirmed by interviewing participants and reviewing their medical records using criteria described below. Initial data collection occurred within 1 week of the mTBI and follow-up data were collected by telephone 3, 6, and 12 months postinjury by trained research assistants. Of the 212 participants who completed the baseline assessment, 190 completed the follow-up assessment at 12 months, while 22 were lost to follow-up. The individuals lost to follow-up were significantly younger than those whose data were used in this analysis, but no other differences were found. Data checks were utilized to ensure accurate data entry and the database was kept on a secure server.

The inclusion criteria were (1) age >= 18 years; (2) an acute mTBI based on Center for Disease Control operational definition of mTBI (Glasgow Coma Scale [GCS] 13-15 on ED evaluation, any period of alteration of consciousness or posttraumatic amnesia that did not exceed 24 yours, or any period of loss of consciousness not exceeding 30 minutes); (3) the ability to provide consent; (4) the ability to speak English; and (5) access to a telephone for the follow-up assessment. Exclusion criteria for this study were (1) current or prior diagnosis of major psychiatric disorders (i.e., bipolar disorder, schizophrenia, or other psychoses) or other central nervous system disorders; (2) intoxication at the time of admission sufficient to obscure an mTBI diagnosis; (3) current alcohol dependence; and (4) current homelessness or incarceration. Most common reasons for exclusion were presence of another central nervous system disorder or age < 18 years. The University of Washington Institutional Review Board approved the original study protocol and informed consent, which was obtained prior to baseline assessment.

The initial results from the natural history study from these data (Lucas 2013) and an analysis of the trajectory of headache across the first year and how trajectories related to posttraumatic stress disorder (PTSD) have been previously published (Sawyer 2015).

Measures.—Demographic data were collected during the baseline assessment including age, education level, race and ethnicity, and sex. Additionally, participants answered standardized questions about their experience of preinjury headache. At 12 months postinjury participants were asked whether they were involved in any litigation related to their injury. History, prevalence, and characterization of headache were collected using a questionnaire developed by this research group. Results have been published previously on the current sample of individuals with mTBI (Lucas 2013, Lucas 2016, Sawyer 2015).

Connor-Davidson Resilience Scale 10.— The Connor–Davidson Resilience Scale 10 (CD-RISC) measures the degree of resilient coping in response to life challenges (Campbell-Sills 2007). The CD-RISC is a unidimensional self-reported scale consisting of 10-items measuring resilience. Respondents rate items on a 5-point Likert scale, ranging from 0 (not true at all) to 4 (true nearly all the time). Total scores for the CD-RISC range from a minimum of 0 to a maximum of 40. Total scores are calculated by summing all 10 items; a higher score indicates higher resilience. A previous study assessing resilience among spinal cord injury patients characterized a CD-RISC score of ⩾30 as "moderate to very high resilience" and a CD-RISC score < 20 as "less resilient". Therefore, a 10 point difference will be reported because it is more clinically meaningful than just a one point difference (Kilic 2013). Research has shown that the CD-RISC has an acceptable α coefficient of 0.85 (Campbell-Sills 2007).

Headache pain intensity: 0 to 10 numerical rating scale.— Participants were asked to rate the following question: On average, how painful are your current headaches? The question was rated on a 0 to 10 numerical rating scale, with 0 being no headache at all and 10 being worst pain imaginable. If participants reported no headaches, this was coded as 0 for the present study. Scores of 1 through 4 were considered to be indicative of mild pain, 5 and 6 were considered moderate pain, and 7 through 10 were considered severe pain intensity (Serlin

1995). Participants completed this numerical rating scale at baseline and at 3-, 6-, and 12-month follow-up assessments. Latent class growth analysis (Nagin 1993) was used to classify headache pain intensity (Numerical Rating Scale-11) into discrete longitudinal trajectory classes based on observed patterns in the data. Four discrete headache trajectories were identified (chronic, worsening, improving, resolved) and the results have been previously published (Sawyer 2015). The chronic category was characterized by a moderate to severe level of baseline headache pain intensity that remained stable during the year postinjury. The worsening group was characterized by low or absent headache pain intensity at baseline, followed by an increase to mild headache pain intensity during the course of the year postinjury. The resolved group had moderate headache pain intensity at baseline and the resolution of headaches within 3 months postinjury. The improving group had moderate headache pain intensity at baseline, improving to mild pain at 6 months postinjury and resolving by 1 year postinjury.

PTSD Checklist-Civilian Version.— Each item on the PTSD Checklist-Civilian Version (PCL-C) corresponds to one symptom of PTSD as defined by the Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV) (Blanchard 1996). Participants indicate to what extent they have been bothered by each symptom in the last month, from 1 (not at all) to 5 (extremely). Participants who select >= 3 for a particular item are considered to have endorsed that symptom of PTSD. The PCL-C was administered once, at 12 months postinjury. We used the PCL-C total score as a continuous measure of posttraumatic stress symptoms. We also used symptom scoring to identify participants who met DSM-IV criteria for PTSD (Blanchard 1996) at 12 months postinjury and created a dichotomous variable in which participants were classified as positive for PTSD if they met the DSM-IV criteria and negative for PTSD if they did not.

Patient Health Questionnaire (9-item screen for depression).—The PHQ-9 was developed to assess depression in medical patients and has been validated for use with TBI (Kroenke 2001, Fann 2005). The questionnaire lists each of the 9 symptoms of a major depressive episode, and participants indicate how frequently they have experienced that symptom in the last 2 weeks, from 0 (not at all) to 3 (nearly every day). We used the Patient Health Questionnaire (9-item screen for depression) (PHQ-9) total score as a continuous measure of depressive symptoms. The PHQ-9 was administered at 12 months postinjury.

The Rivermead Post-Concussion Symptoms Questionnaire— The Rivermead Post-Concussion Symptoms Questionnaire (RPCSQ) (Eyres, King, Potter) lists 16 concussion symptoms, and participants indicate the severity of that symptom they have experienced over the last 24 hours compared with before the accident, from 0 (not experienced at all) to 4 (a severe problem). We assessed the RPCSQ by continuous measurement using both the full scale and by dividing the symptoms into three clusters (somatic, cognitive, emotional) and then treating each as a continuous measure using counts in each symptom cluster. The RPCSQ was administered at 12 months postinjury.

Functional Impairments.—Subjects were asked whether their symptoms had interfered in the following 7 functional areas: self-care, walking, home management, leisure and recreation, social interactions, memory and concentration, and ability to manage feelings. This measure was used to assess impairment in Bell 2008.

Generic Health Status.—The SF-12 (Ware 1995) is a multipurpose short form (SF) measure of health status that yields summary physical (PCS-12) and mental (MCS-12) component summary scales. The SF-12 assesses the following eight health concepts: physical functioning, role limitations due to physical health problems, bodily pain, general health, vitality (energy/fatigue), social functioning, role limitations due to emotional problems, and mental health. The PCS-12 and MCS-12 are scored using norm based methods. The PCS-12 has a reliability of 0.89 and the MCS-12 has a reliability of 0.76 (Ware 1998). The SF-12 was administered at 12 months postinjury.

Perceived Quality of Life.— Quality of life was assessed using a slightly modified form of Patrick's Perceived Quality of Life Scale (PQOL) (Patrick 1988). Participants were asked to rate their satisfaction regarding various aspects of their lives using a scale from 0 to 100, with 0 indicating "not satisfied at all" and 100 indicating "extremely satisfied" with that aspect of their life. An average of the summated scores from each participant was calculated, and was used as a continuous measure of perceived quality of life. In this study, we omitted the "happiness" item and included an item on "sexual activity/romantic relationships". The PQOL was administered at 12 months postinjury.

Data Analysis:

Due to sample size concerns, the four headache trajectories were collapsed into a binary variable: a "negative" trajectory (chronic/worsening) and a "positive" trajectory (improving/resolved). 49 individuals (23%) were included in the positive pain trajectory category. Those in the positive pain trajectory were significantly more likely to be male and older than 40 years.

To assess the relationship between each covariate and positive/negative headache pain trajectory, univariate analyses were performed using Fisher exact tests for categorical variables and Kruskal-Wallis tests for continuous variables. To assess the relationship between each covariate and the CD-RISC, univariate analyses were performed using AnoVa tests for categorical variables and Pearson correlation tests for continuous variables. Significance level of $p<0.05$ was set as threshold for statistical significance.

To assess the relationship between CD-RISC and pain trajectory, we ran 4 logistic regression models: a crude model using CD-RISC to predict pain trajectory; a model including the demographic covariates (sex, age, race, education) and pain trajectory; a model including CD-RISC and pain trajectory adjusting for demographic covariates; and a model adjusting for demographics, depressive and posttraumatic stress symptomology, and concussion symptoms for the association between CD-RISC and pain trajectory.

To assess the relationship between CD-RISC and various measures of psychopathology, concussion symptoms, and functional impairment, individual logistic regression models were run. In each model we adjusted for the demographic covariates of sex, age, race, and education because each was significantly associated with either the exposure or the outcome.

A Pearson's correlation matrix was run between CD-RISC and various measures of psychopathology, concussion symptoms, the SF-12, and the PQoL to assess if the constructs underlying each of these measures were sufficiently distinct.

Data analyses were carried out in SAS version 9.3, SPSS version 19, and STATA version 14.2.

Missing Data:

No participants had missing data for variables collected in the baseline assessment. Seven had missing data for the 3-month assessment, 11 had missing data for the 6-month assessment, and 26 had missing data for the 12-month assessment. Some participants had missing data for multiple assessments; specifically, 16 were missing data for only 1 assessment, 5 had missing data for 2 of the assessments, and 5 had missing data for 3 of the assessment periods. In multilevel growth curve modeling, participants with missing data are included in the model and assigned to a trajectory class, provided they have data for at least 1 assessment period; therefore, there were no casewise exclusions for any of the analyses.

Additionally, 26 participants were missing data for the PCL-C. Those participants with missing data tended to be younger ($P<.05$) and were less likely to have completed high school ($P<.05$) than participants who did complete the PCL-C. There were no significant differences in sex, race, or preinjury headache between participants with and without missing PCL-C scores. 25 participants were missing data for the PHQ-9 and PQoL, 28 participants were missing data for both components of the SF12, and 24 participants did not report data for functional impairments.

Results:

Demographic Characteristics

Our sample was predominantly male (76%) and white (75%). Participants were on average 44 years old (range, 18 - 93), and 83% reported completing high school. Most were injured in vehicle related incidents. 18% of our sample reported suffering from headaches before sustaining a mTBI. The majority of participants (70%) reported no change in their primary activity pre and post injury; 13% reported what was considered to be a positive change in their primary activity while 17% reported a negative change. At 12 months post injury, 24% met DSM-IV criteria for depression, and 13% met criteria for PTSD. At 12 months postinjury, 9% endorsed experiencing at least one of the seven functional impairments. 19% (36/212) reported being involved with litigation within the 12 months postinjury.

Correlates of Trajectory Group Membership

We found significant associations of pain trajectory with sex, age, pre-injury headache, depression, PTSD diagnosis, anxiety, all concussion symptom clusters, functional impairment, and various measures of quality of life and well being. Interestingly, pain trajectory does not seem to be significantly associated with race, years of education, changes in work status, or litigation. No participants with PTSD were classified into the resolved/improving group, and no participants who experienced any functional impairments were classified into the resolved/improving group. Please refer to Table 1.

Correlates of Resilience

We found significant associations of CD-RISC with race, years of education, depression, PTSD diagnosis, anxiety, all concussion symptom clusters (somatic, cognitive, emotional), functional impairment, and various measures of quality of life and well being. The CD-RISC did not have a significant association with sex, age, changes in work status, or litigation. Please refer to Table 1.

Trait and Trajectory Constructs of Resilience

For a logistic model containing only CD-RISC for predicting headache trajectory, the OR for CD-RISC = 1.06, (95%CI: 1.00, 1.12). For every one point increase in CD-RISC, the odds of having an "improved/resolved" pain trajectory increases by 6%. For every ten point increase in CD-RISC, the odds of having a positive trajectory increase by about 70% (OR = 1.78, p=.048). Adjusting for sex, age, race (White/non-White), and education (high school and less/more than high school), the OR for CD-RISC is 1.05 (95%CI: 0.99, 1.11). After including the PHQ9, PCL-C, and RPCSQ into the model, the OR = 1.00 (95%CI: 0.93, 1.08). Please refer to Table 2.

Associations of Resilience and Psychopathology

The CD-RISC is significantly related to the PHQ-9 (OR=0.81, 95%CI: 0.72, 0.91), the RPCSQ cognitive (OR=0.92, 95%CI: 0.86, 0.98) and emotional (OR=0.93, 95%CI: 0.88, 0.99) symptom clusters, overall functional impairment (OR=0.92, 95%CI: 0.86, 0.98), and physical functional impairment (OR=0.92, 95%CI: 0.85, 0.98). Lower levels of CD-RISC were associated with higher levels of psychopathological and concussion symptoms, as well as greater functional impairment.

Discussion.—This study did not provide support for our hypothesis that higher levels of "trait" resilience would be associated with a more resilient outcome trajectory of PTH. The results are trending in the expected direction, but do not reach significance and may be attributable to chance. However, exploratory analyses yield several important findings for both the "trait" and "trajectory" constructs of resilience. "Trait" (CD-RISC) resilience is significantly related to various adverse psychological and perceived functional outcomes after mTBI, which is consistent with previous studies (Graham 2013, Merritt 2015, Sullivan 2015, Losoi 2015, Elliot 2017). Lower scores on the CD-RISC are associated with more depressive symptoms and higher overall functional impairment. Lower resilience scores are also associated with cognitive and emotional concussion symptoms, but not somatic symptoms. CD-RISC includes items that capture psychological functioning, such as the ability to cope with pressure and not being easily discouraged; therefore, it seems plausible that CD-RISC would be more correlated to the cognitive and emotional sequelae of a concussion. In the present study, individuals displaying a resilient trajectory (pain improved/resolved group) were significantly less likely to meet DSM clinical criteria for depression or PTSD and to have functional impairments. Notably, no participants with PTSD were classified into the headache resolved/improving group, and no participants who experienced any functional impairments were classified into the resolved/improving group. While the results for PTSD and headache trajectory have been published previously (Sawyer 2015), that chronic and worsening headache trajectories are associated with functional impairment is an important finding of this study that is consistent with prior literature; suffering from chronic headaches has been shown to significantly affect physical, social, and role functioning (Solomon 1993). There is evidence for a relationship between headache, PTSD, and functional impairment: in the same study by Solomon (1993), patients with chronic headaches also had significantly worse mental health compared to patients with chronic diseases.

Several limitations need to be acknowledged. Our sample may not be fully representative of the larger population of those with MTBI because many persons with MTBI are evaluated in the emergency department and discharged or never come to a health care facility, which may limit generalizability. Additionally, depression and posttraumatic stress were assessed using self-reported measures (PHQ-9, PCL-C) instead of a structured diagnostic interview, which may lead to decreased validity. CD-RISC resilience was only measured at 12 months postinjury, but in this analysis was treated as the exposure based on an assumption that resilience is a personality trait that remains relatively stable (McCauley 2013, Hanks 2016). Since personality may be affected by situational and environmental influences (McCrea 2000), it is plausible that the experience of a traumatic event such as mTBI may influence the level of resilience, especially if it is measured many months after the traumatic event (Bonanno & Mancini 2008). Due to sample size concerns, we combined the "improved" and "resolved" trajectories from the Sawyer 2015 paper into a general "positive" outcome trajectory. However, multiple previous studies of resilience trajectories have identified four distinct trajectories: trajectory resilience/minimal-impact resilient response, recovery, delayed distress, and chronic dysfunction (Bonanno 2004, Bonanno 2013).The "resolved" category in the Sawyer 2015 paper corresponds most closely to the "minimal-impact resilient response" trajectory (Bonanno 2013) because the normal functioning resumed relatively quickly after the injury (the resolution of headaches occurred within the first three months postinjury). Therefore, in combining the "resolved" and "improved" categories and then comparing it to CD-RISC resilience, we lost some ability to detect the true association between "trait" and "trajectory" resilience, which perhaps explains the small effect size (OR = 1.06), which is further attenuated after adjustment for confounding.

In order to address these limitations and advance knowledge in the field of mTBI and resilience research, the following are suggestions for future studies. Ideally, future studies should assess resilience pre-injury to establish temporality, though this clearly is not feasible because estimates are unlikely to be found in medical records. An alternative approach taken by McCauley (2013) was the use of a preinjury proxy by assessing resilience within 24 hours of injury. While it is certainly plausible that resilience could be affected by the injury, baseline resilience did not significantly differ between subjects (mTBI) and controls (non-head orthopedic injuries) in this study. This suggests that sustaining an mTBI does not uniquely affect resilience level. After obtaining a preinjury resilience estimate and assessing for psychiatric distress and functional impairment at baseline, future studies should follow participants over time and take multiple measurements of all variables in order to identify and analyze trajectories. In order to build trajectories these measures should be administered at least three times (Norris 2009). Bonanno (2012) analyzed trajectories of depression and anxiety over two years (follow-ups at <6 weeks, 3 months, 1 year, 2 years) in a cohort of spinal cord injury patients, but to date these trajectories have not been examined in mTBI patients. It would be interesting to compare the CD-RISC resilience trajectory to headache trajectory and changes in depressive and posttraumatic stress symptomology, concussion symptoms, functional outcomes, etc. in mTBI patients over time; this will help in elucidating the etiology of disorders and inform health care and interventions. Another recommendation is that future studies should seek to analyze the association between CD-RISC "trait" resilience and exclusively the "minimal-impact resilient response" trajectory in order to more accurately assess the association between these two constructs of resilience.

Conclusion.—The current study was motivated by the results of a systematic review that examined two different approaches to conceptualizing resilience in mTBI research (Sullivan 2016). The authors pointed out that the few studies reviewed in this nascent field of inquiry only used a standardized scale of trait resilience to predict a pre-defined outcome instead of determining if there is a resilient trajectory response of stable, low, non-impactful symptoms, which is common practice for studying non-mTBI adverse events. This study sought to fill this gap in the literature by being the first to compare the "trait" and "trajectory" constructs of resilience using an assessment of posttraumatic headache over one year post-mTBI. Despite the lack of support for our hypothesis and various limitations, it is a first step towards gaining a more unified understanding of the concept of resilience that future studies can build upon. The results of future studies will have implications for clinical practice in addition to theory. If CD-RISC resilience and trajectory resilience are found to be highly related, perhaps the CD-RISC could be used to predict outcome trajectories soon after injury in order to identify high risk individuals for preventative interventions. Interventions to boost trait resilience may have important trajectory outcomes, such as serving as a buffer against pain and morbidity in the year post injury, which in turn may positively influence PTSD and functional outcomes. More research in this field is urgently needed to address this important public health problem.

Tables and Figures

Table 1—Exploratory Analyses

	Univariate	Bivariate with Pain Trajectory		Bivariate with CD-RISC	
	N (%)	Pain Improved/ Resolved N (%)	Sig. [1]	CD-RISC Mean (SD)	Sig. [2]
Subjects	**212**	**49 (23%)**		**212**	
				31.6 (6.8)	
Sex					
1 - Female	51 (24%)	6 (12%)	.035	30.3 (7.0)	.124
2 - Male	161 (76%)	43 (27%)		32.0 (6.7)	
Race					
1 - White	160 (75%)	41 (26%)	.519	32.3 (6.0)	.002
2 - Black	8 (4%)	1 (13%)		30.9 (7.8)	
3 - Asian	9 (4%)	2 (22%)		25.6 (11.7)	
4 - Hispanic	22 (10%)	3 (14%)		26.3 (5.8)	
5 - American Indian	7 (3%)	0 (0%)		33.5 (12.0)	
7 - Other	6 (3%)	2 (33%)		34.8 (3.5)	
Binary Race					
White	160 (75%)	41 (26%)	.184	32.3 (6.0)	.008
Non-White	52 (25%)	8 (15%)		29.2 (8.7)	
Age					
Mean (SD)	44 (19)		.005	-.00	.955
<40	98 (46%)	17 (17%)		31.7 (6.2)	
40+	114 (54%)	32 (28%)		31.5 (7.3)	
Education Years					
Mean (SD)	13 (3)		.279	.16	.033
High School or less	89 (42%)	21 (24%)		30.4 (7.4)	
Post High School	123 (58%)	28 (23%)		32.4 (6.3)	
Changes in Work Status					
Worse	32 (17%)	5 (16%)	.084	31.2 (5.6)	.206
Same	132 (70%)	31 (23%)		31.3 (7.2)	
Better	24 (13%)	10 (42%)		33.9 (5.9)	
Litigation					
No	152 (81%)	42 (28%)	.051	32.1 (6.7)	.055
Yes/maybe	36 (19%)	4 (1%)		29.6 (7.1)	

Pre Injury Headache					
No	174 (82%)	46 (26%)	.018	31.9 (6.8)	0.14
Yes	38 (18%)	3 (12%)		30.1 (6.9)	
PHQ-9					
Mean (SD)	6.6 (6.1)	14.9	.000	-.50	.000
>=11	45 (24%)	4 (9%)		27.0 (6.8)	
<11	142 (76%)	41 (29%)		33.1 (6.2)	
PCL-C					
Mean (SD)	20.2 (17.6)	38.3	.000	-.40	.000
PTSD diagnosis					
No	161 (87%)	45 (28%)	.001	32.6 (6.2)	.000
Yes	25 (13%)	0 (0%)		25.1 (7.3)	
RPCSQ					
RPCSQ Mean (SD)	17.0 (15.2)	29.8	.000	-.37	.000
Somatic					
Mean (SD)	7.1 (8.1)	19.3	.000	-.30	.000
Cognitive					
Mean (SD)	3.7 (3.8)	9.4	.002	-.37	.000
Emotional					
Mean (SD)	4.3 (4.6)	15.0	.000	-.38	.000
Any Functional Impairment (7 items)					
No	171 (91%)	46 (27%)	.014	32.1 (6.5)	.002
Yes	17 (9%)	0 (0%)		26.8 (7.8)	
SF-12					
Physical	40.6 (11.9)	7.5	.006	.25	.001
Mental	49.3 (12.4)	5.3	.021	.49	.000
PQoL					
Mean (SD)	72.6 (18.0)	15.0	.000	.44	.000

1. Statistical significance by Chi-square (Fisher's exact) or Kruskal-Wallis tests as appropriate
2. Statistical significance by AnoVa or Pearson correlation tests as appropriate

CD-RISC, Connor-Davidson Resilience Scale 10; PHQ-9, Patient Health Questionnaire; PCL-C, PTSD Checklist-Civilian Version; RPCSQ, Rivermead Post-Concussion Symptoms Questionnaire; SF-12, Short Form Health Survey; PQoL, Perceived Quality of Life

Table 2 – Predicting Headache Trajectory from CD-RISC Resilience

	Model 1	Model 2	Model 3	Model 4
CD-RISC	1.06 (1.00, 1.12)		1.05 (0.99, 1.11)	1.00 (0.93, 1.08)
Sex		3.75 (1.41, 9.98)	3.30 (1.22, 8.94)	1.55 (0.51, 4.75)
Age		1.03 (1.01, 1.05)	1.03 (1.01, 1.05)	1.01 (0.99, 1.04)
Race		1.41 (0.59, 3.39)	1.25 (0.48, 3.22)	1.65 (0.49, 5.56)
Education		0.85 (0.43, 1.70)	0.85 (0.41, 1.78)	0.88 (0.38, 2.02)
PHQ-9				1.17 (1.00, 1.37)
PCL-C				0.89 (0.83, 0.95)
RPCSQ				0.90 (0.84, 0.97)

CD-RISC, Connor-Davidson Resilience Scale 10; PHQ-9, Patient Health Questionnaire; PCL-C, PTSD Checklist-Civilian Version; RPCSQ, Rivermead Post-Concussion Symptoms Questionnaire

Table 3—Predicting Other Measures of Psychopathology and Functional Impairment from CD-RISC Resilience*

Outcome	Predictor: Resilience
PHQ-9	0.81 (0.72, 0.91)
PCL-C	1.04 (0.96, 1.12)
RPCSQ	0.97 (0.89, 1.05)
Somatic	1.00 (0.94, 1.06)
Cognitive	0.92 (0.86, 0.98)
Emotional	0.93 (0.88, 0.99)
Overall Functional Impairment	0.92 (0.86, 0.98)
Physical	0.92 (0.85, 0.98)
Emotional	0.95 (0.84, 1.07)
Social	0.95 (0.86, 1.04)

*Controlling for sex, age, race and education.
CD-RISC, Connor-Davidson Resilience Scale 10; PHQ-9, Patient Health Questionnaire; PCL-C, PTSD Checklist-Civilian Version; RPCSQ, Rivermead Post-Concussion Symptoms Questionnaire

Correlation Matrix

	CD-RISC	PHQ-9	PCL-C	RPCSQ	SF-12P	SF-12M	PQoL
CD-RISC	1						
PHQ-9	-.50*	1					
PCL-C	-.40*	.74*	1				
RPCSQ	-.37*	.71*	.70*	1			
SF-12P	.25*	-.42*	-.36*	-.43*	1		
SF-12M	.49*	-.70*	-.57*	-.53*	.02	1	
PQoL	.44*	-.70*	-.57*	-.56*	.37*	.65*	1

*Significant at the p=.05 level.
CD-RISC, Connor-Davidson Resilience Scale 10; PHQ-9, Patient Health Questionnaire; PCL-C, PTSD Checklist-Civilian Version; RPCSQ, Rivermead Post-Concussion Symptoms Questionnaire; SF-12P, Short Form Health Survey Physical Summary Scale; SF-12M, Short Form Health Survey Mental Summary Scale; PQoL, Perceived Quality of Life

Acknowledgements:

I would like to thank Dr. Ali Rowhani-Rabar and Dr. Jeanne Hoffman for their valuable mentorship and feedback throughout this process, and Dr. Jeanne Hoffman for providing the dataset. I would like to thank Jason Barber for his assistance with the data management and analysis. I have no conflicts of interest to declare.

References:

Bazarian JJ, Wong T, Harris M, Leahey N, Mookerjee S, Dombovy M. Epidemiology and predictors of post-concussive syndrome after minor head injury in an emergency population. Brain Inj 1999; 13: 173–189.

Bell, K. R., Hoffman, J. M., Temkin, N. R., Powell, J. M., Fraser, R. T., Esselman, P. C., …Dikmen, S. (2008). The effect of telephone counselling on reducing post-traumatic symptoms after mild traumatic brain injury: A randomised trial. *Journal of Neurology, Neurosurgery & Psychiatry*, *79*(11), 1275–1281. https://doi.org/10.1136/jnnp.2007.141762

Blanchard EB, Jones-Alexander J, Buckley TC, Forneris CA. Psychometric properties of the PTSD checklist (PCL). Behav Res Ther. 1996;34:669-73.

Bonanno, G. A., & Diminich, E. D. (2013). Annual Research Review: Positive adjustment to adversity - trajectories of minimal-impact resilience and emergent resilience. Journal of Child Psychology and Psychiatry, 54(4), 378–401. https://doi.org/10.1111/jcpp.12021

Bonanno, G. A., Kennedy, P., Galatzer-Levy, I. R., Lude, P., & Elfström, M. L. (2012). Trajectories of resilience, depression, and anxiety following spinal cord injury. Rehabilitation Psychology, 57(3), 236–247. https://doi.org/10.1037/a0029256

Bonanno, G. A., & Mancini, A. D. (2008). The human capacity to thrive in the face of potential trauma. Pediatrics, 121(2), 369e375.

Bryant, R. A., O'Donnell, M. L., Creamer, M., McFarlane, A. C., Clark, C. R., and Silove, D. (2010). The psychiatric sequelae of traumatic injury. Am J Psychiatry 167, 312-320.

Burch, R. C., Loder, S., Loder, E., & Smitherman, T. A. (2015). The Prevalence and Burden of Migraine and Severe Headache in the United States: Updated Statistics From Government Health Surveillance Studies. *Headache: The Journal of Head and Face Pain*, *55*(1), 21–34. https://doi.org/10.1111/head.12482

Butler, L., Morland, L., & Leskin, G. (2007). Psychological resilience in the face of terrorism. In B. Bongar, L. Brown, L. Beutler, J. Breckenridge, & P. Zimbardo (Eds.), Psychology of terrorism (pp. 400–417). NY: Oxford University Press Egeland, B., Carlson, E., & Sroufe, L. (1993). Resilience as process. Development & Psychopathology, 5, 517–528.

Campbell-Sills L, Stein MB. Psychometric analysis and refinement of the Connor Davidson Resilience Scale (CD-RISC): validation of a 10-Item measure of resilience. *J Trauma Stress* 2007; 20: 1019–1028.

Carroll, L. J., Cassidy, J. D., Peloso, P. M., Borg, J., von Holst, H., Holm, L., … WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. (2004). Prognosis for mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. Journal of Rehabilitation Medicine, (43 Suppl), 84–105. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15083873

Elliott, T. R., Hsiao, Y.-Y., Kimbrel, N. A., Meyer, E., DeBeer, B. B., Gulliver, S. B., … Morissette, S. B. (2017). Resilience and Traumatic Brain Injury Among Iraq/Afghanistan War Veterans: Differential Patterns of Adjustment and Quality of Life. Journal of Clinical Psychology, 73(9), 1160–1178. https://doi.org/10.1002/jclp.22414

Eyres S, Carey A, Gilworth G, Neumann V, and Tennant A. (2005).Construct validity and reliability of the Rivermead Postconcussion Symptoms Questionnaire. Clin Rehabil 19: 878–887.

Fann JR, Bombardier CH, Dikmen S, et al. Validity of the Patient Health Questionnaire-9 in assessing depression following traumatic brain injury. J Head Trauma Rehabil. 2005;20:501-511.

Graham, D. P., Helmer, D. A., Harding,M. J., Kosten, T. R., Petersen, N. J.,&Nielsen, D. A. (2013). Serotonin transporter genotype and mild traumatic brain injury independently influence resilience andperception of limitations in veterans. Journal of Psychiatric Research, 47(6), 835–842.

Haagsma, J. A., Scholten, A. C., Andriessen, T. M. J. C., Vos, P. E., Van Beeck, E. F., & Polinder, S. (2015). Impact of depression and post-traumatic stress disorder on functional outcome and health-related quality of life of patients with mild traumatic brain injury. Journal of Neurotrauma, 32(11), 853–62. https://doi.org/10.1089/neu.2013.3283

Iverson GL, McCracken LM. "Postconcussive" symptoms in persons with chronic pain. Brain Inj 1997; 11: 783–790.

Kilic, S. A., Dorstyn, D. S., & Guiver, N. G. (2013). Examining factors that contribute to the process of resilience following spinal cord injury. *Spinal Cord*, *51*, 553. Retrieved from http://dx.doi.org/10.1038/sc.2013.25

King NS, Crawford S, Wenden FJ, Moss NE, and Wade DT. (1995). The Rivermead Post Concussion Symptoms Questionnaire: A measure of symptoms commonly experienced after head injury and its reliability. J Neurol 242: 587–592.

Kroenke K, Spitzer R, Williams J. The PHQ-9: Validity of a brief depression symptom severity measure. J Gen Intern Med. 2001;16:606-613.

Holland, J. N., & Schmidt, A. T. (2015). Static and Dynamic Factors Promoting Resilience following Traumatic Brain Injury: A Brief Review. Neural Plasticity, 2015, 1–8. https://doi.org/10.1155/2015/902802

Layne, C. M., Warren, J. S., Watson, P. J., & Shalev, A. Y. (2007). Risk, vulnerability, resistance, and resilience: toward an integrative conceptualization of posttraumatic adaptation. In M. Friedman, T. Keane, & P. Resick (Eds.), Handbook of PTSD: Science and practice (pp. 497–520). New York: Guilford Press.

Losoi, H., Silverberg, N. D., Wäljas, M., Turunen, S., Rosti-Otajärvi, E., Helminen, M., … Iverson, G. L. (2015). Resilience Is Associated with Outcome from Mild Traumatic Brain Injury. Journal of Neurotrauma, 32(13), 942–949. https://doi.org/10.1089/neu.2014.3799

Masten, A., Best, K., & Garmezy, N. (1990). Resilience and development: contributions from the study of children who overcome adversity. Development & Psychopathology, 2, 425–444.

McCauley, S. R., Wilde, E. A., Miller, E. R., Frisby, M. L., Garza, H. M., Varghese, R., … McCarthy, J. J. (2013). Preinjury Resilience and Mood as Predictors of Early Outcome following Mild Traumatic Brain Injury. Journal of Neurotrauma, 30(8), 642–652. https://doi.org/10.1089/neu.2012.2393

McCrae, R. R., Costa, P. T., Ostendorf, F., Angleitner, A., Hrebickova, M., Avia, M. D.,et al. (2000). Nature over nurture: temperament, personality, and life span development. Journal of Personality and Social Psychology, 78(1), 173e186.

Meares, S., Shores, E. A., Taylor, A. J., Batchelor, J., Bryant, R. A., Baguley, I. J., Chapman, J., Gurka, J., and Marosszeky, J. E. (2011). The prospective course of postconcussion syndrome: the role of mild traumatic brain injury. Neuropsychology 25, 454- 465.

Merritt, V. C., Lange, R. T., & French, L. M. (2015). Resilience and symptom reporting following mild traumatic brain injury in military service members. Brain Injury, 29(11), 1325–1336. https://doi.org/10.3109/02699052.2015.1043948

Minen, M. T., Boubour, A., Walia, H., & Barr, W. (2016). Post-Concussive Syndrome: a Focus on Post-Traumatic Headache and Related Cognitive, Psychiatric, and Sleep Issues. Current Neurology and Neuroscience Reports, 16(11), 100. https://doi.org/10.1007/s11910-016-0697-7

Nagin DS, Land KC. Age, criminal careers, and population heterogeneitydspecification and estimation of a nonparametric, mixed Poisson model. Criminology 1993;31:327-62.

Norris, F.,&Stevens, S. (2008). Community resilience and the principles ofmass trauma intervention. Psychiatry: Interpersonal and Biological Processes, 70, 320–328. Werner, E. E., & Smith, R. S. (1982). Vulnerable but invincible: A longitudinal study of resilient children and youth. New York: McGraw-Hill.

Paniak C, Phillips K, Toller-Lobe G, Durand A, Nagy J. Sensitivity of three recent questionnaires to mild traumatic brain injury-related effects. J Head Trauma Rehabil 1999; 14: 211–219.

Paniak C, Reynolds S, Phillips K, Toller-Lobe G, Melnyk A, Nagy J. Patient complaints within 1 month of mild traumatic brain injury: a controlled study. Arch Clin Neuropsychol 2002; 17: 319–334.

Patrick, D. L., Danis, M., Southerland, L. I., & Hong, G. (1988). Quality of life following intensive care. *Journal of General Internal Medicine*, *3*(3), 218–223. https://doi.org/10.1007/BF02596335

Potter S, Leigh E, Wade D, and Fleminger S. (2006). The Rivermead Post Concussion Symptoms Questionnaire: A confirmatory factor analysis. J Neurol 253: 1603–1614.

Ruff, R. M., Iverson, G. L., Barth, J. T., Bush, S. S., & Broshek, D. K. (2009). Recommendations for diagnosing a mild traumatic brain injury: A National Academy of Neuropsychology education paper. Archives of Clinical Neuropsychology, 24(1), 3–10.

Sawyer, K., Bell, K. R., Ehde, D. M., Temkin, N., Dikmen, S., Williams, R. M., … Hoffman, J. M. (2015). Longitudinal Study of Headache Trajectories in the Year After Mild Traumatic Brain Injury: Relation to Posttraumatic Stress Disorder Symptoms. Archives of Physical Medicine and Rehabilitation, 96(11), 2000–6. https://doi.org/10.1016/j.apmr.2015.07.006

Serlin RC, Mendoza TR, Nakamura Y, Edwards KR, Cleeland CS. When is cancer pain mild, moderate or severe? Grading pain severity by its interference with function. Pain 1995;61:277-84.

Solomon, G. D., Skobieranda, F. G., & Gragg, L. A. (1993). Quality of Life and Well-Being of Headache Patients: Measurement by the Medical Outcomes Study Instrument. *Headache: The Journal of Head and Face Pain*, *33*(7), 351–358. https://doi.org/10.1111/j.1526-4610.1993.hed3307351.x

Sullivan, K. A., Edmed, S. L., Allan, A. C., Smith, S. S., & Karlsson, L. J. E. (2015). The role of psychological resilience and mTBI as predictors of postconcussional syndrome symptomatology. Rehabilitation Psychology, 60(2), 147–154. https://doi.org/10.1037/rep0000037

Taylor, C. A., Bell, J. M., Breiding, M. J., & Xu, L. (2017). Traumatic Brain Injury–Related Emergency Department Visits, Hospitalizations, and Deaths — United States, 2007 and 2013. MMWR. Surveillance Summaries, 66(9), 1–16. https://doi.org/10.15585/mmwr.ss6609a1

Thurman DJ. (2001). The epidemiology and economics of head trauma In: Head Trauma: Basic, Preclinical, and Clinical Directions. Miller L, Hayes RL (eds). John Wiley and Sons: New York.

Voormolen, D. C., Cnossen, M. C., Polinder, S., von Steinbuechel, N., Vos, P. E., & Haagsma, J. A. (2018). Divergent Classification Methods of Post-Concussion Syndrome after Mild Traumatic Brain Injury: Prevalence Rates, Risk Factors and Functional Outcome. Journal of Neurotrauma, neu.2017.5257. https://doi.org/10.1089/neu.2017.5257

Ware, John & A. Kosinski, M & D. Keller, S. (1998). SF-12: How to Score the SF-12 Physical and Mental Health Summary Scales.