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The Threshold Non-linear Model for the Effects of Cumulative Stressors and Traumas: A Chained Cusp Catastrophe Analysis

Ibrahim Kira[1,2*], Brian Barger[3], Hanaa Shuwiekh[4], Justyna Kucharska[5], Amthal Al-Huwailah[6]

[1]Center for Cumulative Trauma Studies, Stone Mountain, GA, USA
[2]Center for Stress, Trauma and Resiliency, Georgia State University, Atlanta, GA, USA
[3]Georgia State University, Atlanta, GA, USA
[4]Fayoum University, Fayoum, Egypt
[5]University of Westminster, London, UK
[6]College of Social Sciences, Kuwait University, Kuwait City, Kuwait
Email: *kiraaref@aol.com, bbarger1@gsu.edu, hanaashiwk2000@hotmail.com, j.kucharska@westminster.ac.uk, Alhuwailah.77@ku.edu.kw

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Abstract

Studying the macro-dynamics of traumatization should significantly advance psychological science. The current article tested the validity of the non-linear threshold model of the effects of cumulative stressors and traumas (CST). We used a combined data set of adults and adolescents from Egypt, Kuwait, and the UK (N = 968) that measured CST, internalizing, externalizing and thought disorders. We used the cusp catastrophe analysis that can identify the non-linear threshold dynamics. The non-linear cusp (threshold) model accounted for a much higher variance than the linear model, indicating the presence of threshold effects of CST on internalizing, externalizing and thought disorders. Interventions should target the multiply traumatized who are at risk for the cusp effects and not only those who are victims of the cusp. The study provided evidence for the utility of a paradigm shift to study the macro-dynamics of stressors and traumas, and not only their micro-dynamics.

Keywords

Cumulative Trauma, Stressors, Cusp Catastrophe Model, Non-Linear, Threshold Non-Linear CUSP Model

1. Clinical Vignette That Exemplify the Impact of Cumulative Stressors and Traumas

Mrs. XX was a 55*-year-old Iraqi refugee woman who has nine living children. In Iraq, she lost two brothers and two older sons who had been killed by Saddam's regime. She had to flee, walking in the desert for days with her family to Saudi Arabia. She spent* 4 *years in a refugee camp in the desert. When she arrived in the United States, she encountered discrimination and the bullying of her children in school. When she discovered her husband's infidelity, she divorced him. All of her family members described her as the heroine of the family, whose strength and resilience helped her and they survive. The clinician was treating one of her sons. Several years later, she was involved in a moderate car accident that resulted in some bruises. After this accident, she developed intense symptoms of fear, panic attacks, auditory and visual hallucinations* (*e.g., seeing blood everywhere in the house, some type of thought disorder*), *and nightmares related to the terror she had previously experienced. Further, she called her ex-husband to beg for forgiveness, for divorcing him, and for violating his rights as a man.* (Kira & Tummala-Narra, 2015).

Authors consider traumatic events as one type of stressors that are acute and are an intricate part of the general theory of stressors. Stressors, in this context, mean all kinds of acute (traumatic), chronic and non-chronic stressors. Studying the cumulative total impact and the macro-dynamics of the total impact of stressors will significantly advance clinical science. In this clinical vignette, the client survived a series of chained severe and chronic stressors over years that have a cumulative effect, and the last, which probably may have been one of the least severe, became the "the last straw that broke the camel's back.", with the sudden emergence of thought and internalizing disorders. While micro-dynamics of traumatization focus more on studying the impact of a single trauma or distinct trauma type which is the current dominant trend in stress and trauma research, traumatization macro-dynamics focus on the impact of total exposure and the interaction between different traumas and stressors and their total cumulative impact on the person's mental health. Cumulative stressors and traumas (CST) has consistently been a powerful linear predictor of the severity, complexity, and comorbidity of psychopathology (e.g., Cloitre et al., 2009; Kira et al., 2008; Kira et al., 2013c; Kira, Omidy, & Ashby, 2014; Martin, Cromer, DePrince, & Freyd, 2013). Macro-dynamics investigate also the impact of early traumas, e.g., of attachment and oppression on subsequent traumas or the mechanisms of trauma proliferation (Kira et. al., 2018a). Examples of the proliferated trauma dynamics are the proliferation of attachment and early childhood traumas to other subsequent traumas (Ferrajão, Badoud, & Oliveira, 2017; Kanninen, Punamäki, & Qouta, 2003; Mikulincer, Solomon, Shaver, & Ein-Dor, 2014; for meta-analysis see Madigan, Brumariu, Villani, Atkinson, & Lyons-Ruth, 2016; and Woodhouse, Ayers, & Field, 2015). This might include the proliferation of childhood poly-victimization (Collings, Penning, & Valjee, 2014; Ford, Elhai, Connor, & Frueh, 2010). It may also include the proliferation of early adolescence systemic

trauma such as discrimination leading to subsequent traumas (Al-Ibraheem, Kira, Aljakoub, & Al-Ibraheem, 2017; Kira, Alawneh, Aboumediene, Lewandowski, & Laddis, 2014; Szymanski & Balsam, 2011). The inclusion of social identity systemic traumas (collective identity traumas) that are continuous and intersecting, such as different discrimination and oppression (e.g., refugees, minority groups experience, gender discrimination), have been identified as severe trauma types that proliferate to subsequent traumas (Holmes, Facemire, and DaFonseca, 2016; Reisner et al., 2016; Kira et al., 2018a).

However, these macro-dynamics are poorly understood. While most of the studies of micro-dynamics focus on the dose-response linear models, Macro-dynamics involve more the non-linear traumatization dynamics or the total impact of cumulative stressors and traumas (CST). Previous, concurrent and subsequent life events, impact the individual conjointly linearly and non-linearly. We emphasize that in evaluating the impact of life events, we cannot separate the impact of the exposure to chronic stressors, major life stressors and different trauma types in real life and real-time. Focusing solely on PTSD Criterion "A" trauma types, which was and still the dominant trend in trauma and PTSD research, can be misleading. A recent study found that adding the non-criterion "A" traumas of attachment and collective identity trauma types (a non-criterion "A" stressors and traumas) resulted in an increase in the incremental predictive validity of criterion "A" over six-fold (Kira et al., 2019b).

The total influence of cumulative and proliferated stressors, chronic and acute, on mental health outcomes, as we observed in the clinical vignette, is often complicated and nonlinear. Relatively small and inconsequential changes in predictive factors may lead to abrupt changes in behavior. Traditional statistical methods assume relationships linearity between variables and have provided a wealth of information about correlates of cumulative stressors and traumas (CST). However, complex behavior macro-dynamics may be poorly represented by linear models (e.g., Ehlers, 1995). Non-linear dynamic systems model provides a framework for exploring and evaluating complex systems and behaviors wherein the effects of independent variables such as CST might follow a threshold non-linear path.

Studies of cumulative risk found to follow a non-linear path in causing difficulties and distress (Oldfield, Humphrey, & Hebron, 2015). In this dynamic non-linear threshold model of causality (Kira & Wrobel, 2016), the accumulation of stressors' impact reaches a threshold where the last stressor becomes the "straw that breaks the camel's back" breaching the threshold of distress tolerance. This non-linear threshold model presumes that individuals have different breaking points. Even for people with higher distress tolerance, like the mother in the clinical vignette, the added stressor can cause the person to "break". These non-linear cusp shifts from one state to another can happen upon exposure to cumulative and proliferated external and internal pressures/stressors (Guastello, & Liebovitch, 2009; Kira & Wroble, 2016; Zeeman, 1976) and the most recent stres-

sor (or chain of stressors) can falsely appear as the direct cause of the disorder. Within this dynamic system model, including linear and non-linear causal chains and loops, the relatively recent single or chain traumas can be the stressor that finally triggers a pathological response, which is not the actual cause of the symptom presentation.

A complex dynamic systems perspective of macro dynamics may be more helpful than a traditional linear model in understanding the etiology of psychopathology. For example, the non-linear models of the relationship between trauma and PTSD explained over three times the variance explained by the linear model (Kira et al., 2019b). Armey and Crowther (2008), comparing a linear versus a non-linear model of aversive self-awareness, dissociation, and non-suicidal self-injury, found, as they predicted, that the non-linear model evidenced a better fit to the data, accounting for 6 times the variance (66%) than the linear model (9% - 10%). Similar results were observed in the effects of torture on mental health (Kira, 2017), and the role of identity salience in the mental health of Syrian refugees (Kira, Shuwiekh, Al Ibraheem, & Aljakoub, 2018b). Such a complex dynamic systems perspective of macro dynamics may be more helpful than a traditional linear model in understanding the etiology of different forms of psychopathology (i.e., internalizing, externalizing and thought disorders).

Cumulative stressors and traumas (CST) has consistently been a powerful linear predictor of the severity and comorbidity of mental health disorders (e.g., Cloitre et al., 2009; Kira et al., 2008; Kira et al., 2013c; Kira, Omidy & Ashby, 2014; Martin, Cromer, DePrince, & Freyd, 2013). The impact of CST dynamics is related to various processes including distress tolerance (Leyro, Zvolensky, & Bernstein, 2010), stress sensitization, the kindling process (Post, Weiss, & Smith, 1995), and the diathesis-stress model (Stein, Jang, Taylor, Vernon, & Livesley, 2002). All assumed a stress tolerance and buffer that breaks upon reaching a threshold that may be different from person to person. There were previous attempts to address physical and mental health issues as cusp functions of age and stress in an occupational setting (Guastello, 1992, 1995).

The linear statistical approach would seriously limit knowing the effects of factors hypothesized to be relevant to the effects of different factors that influence behavior (i.e., cumulative stress, genetic, epigenetic and environmental factors). The nonparametric regressions do not have the mechanisms to identify and incorporate "cusp jumps", which are the fundamental advantages of the cusp catastrophe models. The statistical methods used to examine mental health variables in psychological research are typically based on a linear regression approach. While there are different non-linear statistical models (e.g., quadratic, cubic) that identify different non-linear trajectories, they do not identify if these non-linear trajectories inherent in the relationship between variables or follow a threshold breaking points. Catastrophe cusp theory (Chen & Chen, 2015; Thom, 1975) is one application of non-linear dynamics that can be used to verify the threshold model and to describe the factors contributing to the development of

psychopathology following the reach of a certain cumulative intensity value of CST. Catastrophe theory allows for the modeling of large, "catastrophic", non-linear changes in behavior that result from small changes in continuous predictor variables (as the observable sudden change in behavior in the clinical vignette). Nonparametric regressions do not have the mechanisms to identify and incorporate "cusp jumps", which are the fundamental advantages of the cusp catastrophe models. Theory and methodology from nonlinear dynamical systems (NDS) provided a considerable advantage to the study of psychopathology. Catastrophe cusp theory (Chen & Chen, 2015; Thom, 1975) is one application of non-linear dynamics that can be used to verify the threshold model and to describe the factors contributing to the development of psychopathology following the reach of a certain cumulative intensity value of CST. Catastrophe theory allows for the modeling of large, "catastrophic", non-linear changes in behavior that result from small changes in the continuous predictor. This type of catastrophe model is referred to as the "cusp catastrophe" model (Gilmore, 1993) since a sudden behavioral change is exhibited once a predictor variables cross the "cusp" threshold. These nonlinear cusp shifts from one state to another can happen upon exposure to cumulative and proliferated external and internal pressures/stressors (Guastello & Liebovitch, 2009; Kira & Wroble, 2016; Zeeman, 1976) and the most recent stressor (or chain of stressors) can falsely appear as the direct cause of psychopathological response. Within this dynamic system model, including linear and non-linear causal chains and loops, the relatively recent single or chain of stressors/traumas can be the event/s that finally triggers a psychopathological response and not the actual cause of the emerging symptom.

Catastrophe theory is a branch of bifurcation theory in the study of dynamical systems to study phenomena characterized by sudden shifts in behavior from small changes in circumstances. The most commonly used catastrophe model in health science investigations thus far has been the cusp, which has two control parameters: a) asymmetry, which has a smooth and linear relationship with the system output, and b) bifurcation, which induces a threshold effect on system output. The cusp catastrophe model is capable of handling complex linear and nonlinear relationships simultaneously using a high-order probability density function that has the advantage of being able to incorporate sudden behavioral jumps (Zeeman, 1976). Historically, the cusp catastrophe model has been applied to the prediction of health behaviors (Flay, 1978). For psychopathology, we propose two control factors to control the outcome response where personal characteristics as a function of his/her age maturity is the asymmetry control factor that controls the outcome changes asymmetrically from one mode to the another mode eventually as it increases, while the stressors and traumas accumulation is the bifurcation control factor that controls the outcome to split and bifurcate from smooth changes to sudden jumps as it increases.

To date, a dynamic systems approach has not yet been used to investigate the propositions of the non-linear cumulative stressors impact on psychopathology.

Most of the previous studies focused on personal characteristics, genetic, epigenetic and environmental factors that lead to psychopathology, however, the non-linear impact of cumulative stressors rarely been examined. A recent study tested the cusp model on suicidal phenomena and found that cumulative stressors and traumas are significant bifurcation factor and age as asymmetrical factor and the cusp non-linear model accounted for much higher variance than the linear model (Kira, Barger, Shuwiekh, Kucharska, & Al-Huwailah, 2019a). The primary aim of the present study was to examine the cumulative non-linear dynamics that lead to psychopathology and provide evidence that the non-linear model explains more variance than linear models of psychopathology.

Recent advanced analysis of the structure of psychopathology, using both the diagnostic and continuous models identified a single general factor with three basic components of psychopathology: internalizing, externalizing and thought disorder (psychoticism) (e.g. Caspi et al., 2014; Laceulle, Volleberge, & Ormel, 2015). It is important to verify the threshold model of the effects of CTS on Psychopathology in Western and non-Western cultures since most of the clinical studies have been conducted on samples from Western cultures.

The goal of the current study is to explore the validity of the cusp (threshold) model of the effects of cumulative stressors (chronic and traumatic) as bifurcation controlling factor (with age as asymmetrical controlling factor) on the emergence of the different types of psychopathology (i.e., internalizing, externalizing and thought disorder) in different age groups and Western and non-Western participants.

Hypotheses

Hypothesis 1: The non-linear models (quadratic and cubic) will explain more variance than the linear models in estimating the association between CST and internalizing, externalizing, and thought disorders.

Hypothesis 2: Cusp Model will explain a higher variance than the linear model in the association between CST as bifurcation control factor and age as asymmetry control factor and internalizing, externalizing, and thought disorders as outcome Cusp variables.

2. Method

2.1. Procedures and Participants

We combined three previously collected data sets (N = 968) from Western (the UK, N = 178) and non-Western countries (Egypt: N = 490, and Kuwait: N = 300) to check the research hypotheses. The combined dataset included 22% adolescents, 40.2% males. Age ranged from 14 - 75 (Mean = 26.12, SD = 9.40). For marital status 28% were married, 67.2% were single, 1.1% were widowers, 1.4% were divorced, and 2.2% had other marital statuses. For work, 58.7% were students, 24.8% were employees, 3.3% professionals and physicians, 2% retired, 1.9% workers, 1.3% merchants, and 8% other kinds of work. For the socioeco-

nomic (SES) level, 74.9% reported to be in the middle, while 19.3% reported high to very high SES, and 5.8% reported to be either poor or very poor. For religion, 56% were Muslims, 30% Christians, and 14% with no religious affiliation. The following describes in detail each of the three sub-samples.

2.2. Procedures for the First Sub-Sample: The Egypt Data (N = 490)

The questionnaire was administered to participants starting the first week of October through the first week of December of 2017. The participation was voluntary. Each participant was informed about the general goals of the study and signed informed consent to participate. The questionnaire took 45 - 60 minutes to complete. The study was approved by the IRB of the sponsoring University.

The study was conducted in three Egyptian cities that geographically and culturally represent the different mix in Egyptian society: Fayoum (Middle Egypt) Qena (Upper Egypt), and Giza/Cairo (which is mostly a melting pot of diversities) cities. Three research teams of clinical psychology graduate students collected the data under the direct supervision of their advisors in each cite.

To obtain a diverse sample of participants, a purposive snowball sampling strategy was used. Three research teams of graduate students in clinical psychology (a different team in each city) collected the data under the direct supervision of their advisors. Localities included Fayoum (Middle Egypt) (N = 184), Qena (Upper Egypt) (N = 210), and Giza/Cairo (N = 96) (which is mostly a melting pot of diversities) cities.

2.3. Procedures for the Second Sample: The Kuwait Data (N = 300)

The research team consisted of 4 doctoral students with a professor in Psychology as the project leader. The team members have been trained in conducting tools and interviewing. The sample designed was a purposeful quota sample to represent different age groups, students, and community (50% of students and 50% community). The questionnaire was administered to college students using group class format, while the community participants were interviewed personally.

2.4. Procedures for the Third Sample: The UK Data (N = 178)

Participants were recruited using two strategies. The first was by utilizing a crowdsourcing website "prolific.ac", where the participants received £2 for completing the survey. It was specified in the settings that they have to be students, survey. It was specified in the settings that they have to be students, age range 18 - 40, and nationality, country of birth and current country of residence: UK. Further, the link to the online survey was sent to a student's university organization in London. Table 1 details the demographics of each of three combined samples.

Table 1. The detailed demographics of each of the three sub-samples.

variable	Egypt (N = 490)	Kuwait (N = 300)	UK (N = 178)
Age	Age ranged from 14 to75, Mean = 26.03, SD = 10.90, 20.4% adolescents	age ranged from 15 - 50 (M = 26.37, SD = 8.50), from which 18.7% were adolescents	Age ranged between 18 and 40, M = 25.89, and SD = 5.66
Gender	41.4 males	39% males	60.7% females
Religion	49.6% Muslims and 50.4%	99.7% Muslims, 0.3% Christians	24.2% Christians, 0.6% Jewish, 4.5% other religions, while 70.8% with no religious affiliation
Education	7.9% elementary level, 1.8% middle school level, 27.3% high school level, 51.8% college level, and 11% graduate studies level	4.7% elementary school, 20.6% high school, 72.7% college and 2% graduate students	21.3% had a high school, 57.3% had an undergraduate degree, and 21.3% had a postgraduate degree
Marital Status	28.6% married, 68.8% single, 1.6% widowed, .4% divorced, .06% other	35% married, 60.3% singles, 3% divorced, and 1.7% other	14.6% were married, 74.2% were single, 1.7% was divorced, and 9.6% had other marital statuses
Employment	64.5% Students, 12.9% Employees, 3.4% professionals, 3.1% workers, 2.4% merchants, 1.4% retired, and 12.2% others	55.3% students, 35.7% employees, 1.3% professionals, 4% retired, and 3.7% others	48.9% were college students, 39.3% were employees, 6.2% were professionals, and 5.6% were others.
Socio-Economic-Status	1% very low, 2% low, 75.1% in the middle, 18.2% high, 3.7% very high	0.0% very low, 0.7% low, 77% in the middle, 18.3% high, 4% very high	1.7% very low, 20.3% low, 70.6% in the middle, 7.3% high, 0.0% very high

3. Measures

The Cumulative Trauma Scale CTS-S (*short form*) is a measure that was constructed based on the development-based trauma framework (DBTF) (e.g., Kira, 2001; Kira, 2019; Kira et al., 2019b; Kira, et al., 2013a; Kira, Fawzi, & Fawzi, 2013c; Kira et al., 2008a; Kira et al., 2018b). DBTF identifies and measures different dimensions of individual development that may be affected by stressors and traumatic stressors (i.e., attachment, personal, collective and role identities, and interdependence, as well as serious non-acute and chronic stressors). It includes PTSD criterion "A" traumas and non-criterion "A" stressors and traumas. Initially, the CTS-S is a 32-item instrument that measures cumulative stressors and traumas in terms of occurrence, frequency, type, and negative and positive appraisals. Three optional items were added in further development that includes community violence, birthing trauma (complicated birth), and perpetration trauma. The scale is intended to be a comprehensive measure of cumulative stressors and traumas exposure. Cumulative non-traumatic stressors included the serious life changes associated with widowed/divorce and re-marrying, as well as the major life changes in forced relocations (e.g., uprootedness and immigration), and the experience of seemingly small but recurrent or unremitting hassles or chronic stressors. The scale includes, in addition to cumulative non-traumatic stressors (3 items), seven major trauma types (acute stressors): collective identity trauma (3 items), personal identity trauma (6 items), survival trauma (6 items), attachment trauma (2 items), secondary trauma (7 items), achievement traumas (2 items) and gender discrimination (2 items). Collective identity trauma includes trauma-related exposure to war and torture and discrimination based on race, eth-

nicity, or national origin. Personal identity trauma includes trauma related to sexual abuse, rape, incest, and being robbed. Attachment trauma includes abandonment by parents. Survival trauma includes car accidents, life-threatening illnesses, and natural disasters. The achievement or role identity trauma is intended to measure traumatic stressors related to the achievement of life goals like success in school or business. Secondary trauma includes trauma related to having witnessed a traumatic event occurring to another individual or group and affecting social interdependence. Gender discrimination includes gender discrimination by parents (family) and gender discrimination by society and institutions. Gender discrimination items are worded to apply to both genders. In response to each item on the measure, participants are instructed to indicate their experience with a traumatic event on a 5-point Likert-type scale (0 = never; 4 = many times). If a participant denotes that she/he has experienced the traumatic event, then he/she is asked to describe her/his appraisal of its effect on a 7-point Likert-type scale (1 = extremely positive; 7 = extremely negative). CTS-S includes two general subscales for cumulative trauma dose: occurrence and frequency of experience, and two appraisal subscales: negative and positive appraisal of events. These four sub-scales may be also generated for each of the trauma types.

The CTS-S has shown adequate internal consistency (α = 0.85; Kira et al., 2008, Kira, et al., 2013c). Evidence of the instrument's predictive validity includes cumulative trauma significantly predicting post-traumatic stress disorder (r = 0.54, $p < 0.001$), cumulative trauma-related disorders (r = 0.24, $p < 0.001$), and poor health (r = 0.37, $p < 0.001$; Kira et al., 2008). CTS-S has also shown divergent validity: It was significantly negatively correlated with sociocultural adjustment (r = −0.25, $p < 0.001$) and futuristic orientation (r = −0.37, $p < 0.001$). CTS-S has been used with a variety of clinical and community samples of adults and adolescents from numerous sociocultural groups and has been shown to possess adequate reliability (with an alpha ranging between 0.80 and 0.92), good construct validity (e.g., Kira et al., 2008, Kira, Lewandowski, Somers, Yoon, & Chiodo, 2012; Kira, Smith, Lewandowski, & Templin, 2010), and validity across different cultural and clinical groups, including American Indians, Mayans, Palestinians, Egyptians, refugees, and torture survivors from 32 countries (e.g., Kira, Ashby, Odenat, & Lewandowski, 2013b; Kira, et al., 2013c; Kira, Omidy, & Ashby, 2014; Kira, 2010; Eltan, 2019). The measure has been translated into different languages including Arabic, Spanish, Polish, Korean, Turkish, and Nigerian and proved to have good psychometric properties in these languages. Test-retest using an independent sample of 35 males with four weeks interval yielded excellent stability coefficients (0.995 for cumulative trauma frequency, and 0.997 for cumulative trauma appraisal). The alpha for the main scale of occurrence was 0.89 in current data.

Psychopathology Screening Measure (Kira, Shuwiekh, & Kucharska, 2017) Adapted GAIN Short Screener (GAIN-SS) (Dennis, Chan, & Funk, 2006) is a screener, that quickly identifies clients (adults and adolescents) who are likely to

have mental health disorders, issues with crime/violence, and issues with substance use. The participant is asked to indicate if the behavior (or feeling) happened in the past month (scored 4), or happened in the last 2 - 3 months (scored 3), or in the last 3 - 12 months (scored 2), or the last year or more (scored 1), or never happened (scored 0). The original measure includes three parts: Internalizing, Externalizing, and substance abuse sections. High scores indicate potentially higher symptoms in these areas. The measure was adapted to include a section for psychoticism and dissociation, adding items from psychoticism/dissociation subscale of cumulative trauma disorder scale (Kira et al., 2012). Further, items were added to internalizing that are related to PTSD symptoms. The original version did not include different PTSD symptoms. The goal of its adaptation was to include the three basic components of psychopathology: Internalizing, Externalizing and thought disorder (psychoticism) (e.g. Caspi et al., 2014; Laceulle, Volleberge, & Ormel, 2015). The current adapted measure includes 20 items. Exploratory and Confirmatory Factor Analysis of the adapted measure in different data in Egypt and Poland yielded three factors: Internalizing, Externalizing and psychoticism. Test-retest using an independent sample of 35 males with four weeks interval yielded excellent stability coefficients (0.970 for internalizing, 0.908 for externalizing, 915 for the combined externalizing and addiction subscale. In the current study, alpha reliability for internalizing was 0.84, 0.88 for externalizing and addiction, and 0.93 for psychoticism. The psychopathology scale has an alpha of 0.89 in current data.

4. Data Analysis

Descriptive statistics (frequency, rate, mean and standard deviation) were used to describe the sample characteristics. The linear and non-linear (quadratic and cubic) relationships among the predictor variable: cumulative Stressors and Traumas (CST) and the outcome variables: internalizing, externalizing and thought disorder, were examined first using the conventional curve-estimation regression. We used SPSS-IBM 22 in data analysis, at this stage. The chained cusp quantum models were tested employing a cusp catastrophe modeling method to test three models. Cusp catastrophe models involve asymmetry controlling factors (e.g., age) and bifurcation factors (e.g., CST) that contribute to the cusp, or critical shift in behavior, or a dependent variable (e.g., internalizing, externalizing, and thought disorders). We used age as an asymmetry variable and CST as the bifurcation variable to explore the potential Cusp change in the effects of CST on internalizing, externalizing and thought disorders. The three cusp models were used to assess the fit of each of the three cusp models of CST cusp impact across age (asymmetry) and the bifurcating impact of CST on internalizing, externalizing, and thought disorders. The appropriateness of a cusp catastrophe model is evaluated based on the comparison with both linear and cusp models by using an R^2 value, the Akaike information criterion (AIC), and the Bayesian information criterion (BIC) statistics (Browne, 2000; Zucchini, 2000). The model with the highest

R^2 and the lowest AIC and BIC values provided the best fit to the data. Cusp catastrophe analyses were completed using the open-source software R version 3.2.4 (Team R, 2013).

5. Results

Curve Estimation results: CST was associated with internalizing disorders only non-linearly (F = 11.17, $p < 0.000$, $R^2 = 0.114$ (the quadratic model)). CST was associated with externalizing disorders both linearly (F = 5.34, $p < 0.022$, $R^2 = 0.03$), and non-linearly (the cubic model) (F = 4.19, $p < 0.008$, $R^2 = 0.067$), with the non-linear model accounting for over twice the percentage of variance in the linear model. CST was associated with thought disorders both linearly (F = 8.90, $p < 0.003$, $R^2 = 0.048$), and non-linearly (the cubic model) (F = 8.26, $p < 0.000$, $R^2 = 0.125$), with the non-linear model accounting for over twice the percentage of variance in the linear model.

Cusp results: The results of polynomial regression cusp catastrophe models showed that CST was a significant bifurcation factor for internalizing, externalizing and thought disorder emergence. Age was a significant asymmetry controlling factor as well. Polynomial factors (i.e., Z values) were significant, indicating that the change in internalizing, externalizing, and thought disorder can be explained by the cusp model with the combination of the significant bifurcation and asymmetry controlling factors. The R^2 in the cusp models, $R^2 = 0.43$ for internalizing disorders, $R^2 = 0.77$ for externalizing disorders, and $R^2 = 0.30$ for thought disorders, accounting for much higher variance than the linear models. Results indicated, for example, that the cusp model for externalizing ($R^2 = 0.77$; AIC =1255.13; BIC = 1283.16) provided a superior fit to the data than could the linear model ($R^2 = 0.028$; AIC = 4817.55; BIC = 4836.24). These results suggest that the linear model greatly underestimates the fit of the data to the model, accounting for much less than of the variance explained by the Cusp catastrophe model. Specifically, the Cusp catastrophe model is much more accurate ($R^2 = 0.77$) bettering the corresponding linear model ($R^2 = 0.028$). The BIC and AIC values greatly lower in the cusp model than the linear model. Similar results were found for the internalizing and thought disorder. Table 2 detailed these findings.

Figures 1-3 illustrate three dimensions Cusp models for externalizing, internalizing and thought disorders. Analyses of the adults' and adolescents' sub-samples showed similar results.

6. Conclusion

Current findings propose a paradigm shift in clinical research to investigate the trauma macro-dynamics such as cumulative and proliferation impact of stressors (chronic and traumatic), instead, or in addition to the microdynamics of studying single trauma which is the current focus of most clinical science research.

Table 2. Cusp catastrophe modeling of the impact of cumulative stressors and traumas on externalizing, internalizing and thought disorders.

Change Variable		Z Value	
Outcome: Externalizing Disorders			
Asymmetry			
	Intercept	−18.98***	
	Age	−101.54***	
Bifurcation			
	Intercept	1065.36***	
	CST	−76.11***	
Modelfit	R^2	AIC	BIC
Cusp	0.773	1255.125	1283.157
Linear	0.028	4817.553	4836.241
Outcome: Internalizing Disorders		Z Value	
Asymmetry			
	Intercept	4.726***	
	Age	−5.439***	
Bifurcation			
	Intercept	4.544***	
	CST	−0.788	
Modelfit	R^2	AIC	BIC
Cusp	0.431	2120.710	2148.742
Linear	0.068	5150.627	5169.315
Outcome: Thought Disorders		Z Value	
Asymmetry			
	Intercept	3.523***	
	Age	−7.329***	
Bifurcation			
	Intercept	9.756***	
	CST	−4.559***	
Modelfit	R^2	*AIC*	*BIC*
Cusp	0.299	1948.010	1985.387
Linear	0.132	5158.513	5186.545

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

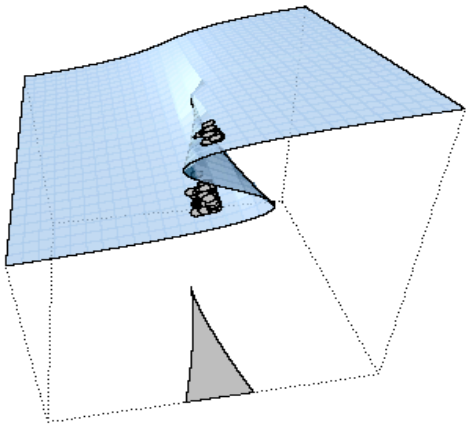

Figure 1. Three dimensional for Cusp catastrophe analyses for the CST as bifurcation factor (vertical axis) and age as asymmetrical factor (horizontal axis) to externalizing as cusp outcome.

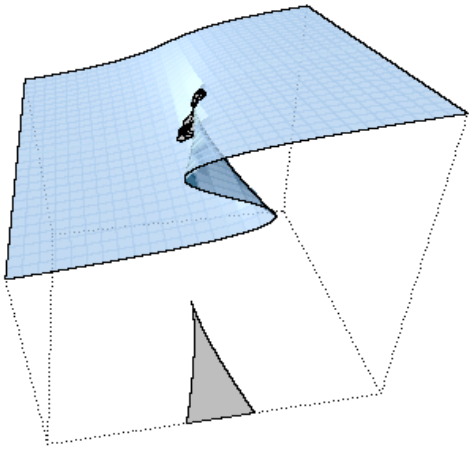

Figure 2. Three dimensional for Cusp catastrophe for the CST as bifurcation factor (vertical axis) and age as asymmetrical factor (horizontal axis) to internalizing as cusp outcome.

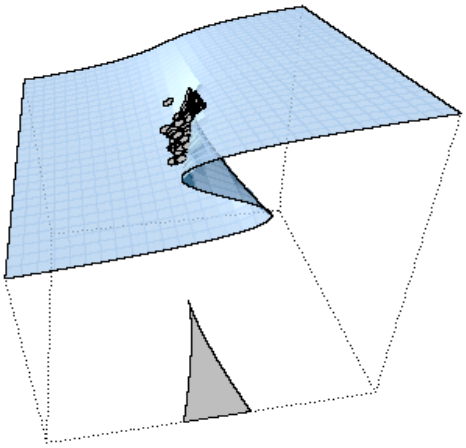

Figure 3. Three dimensional for Cusp catastrophe analyses for the CST as bifurcation factor (vertical axis) and age as asymmetrical factor (horizontal axis) to thought disorder as cusp outcome.

These results provided evidence of the superiority of a Cusp catastrophe model over a regression linear model when investigating CST as a bifurcation control factor as a nonlinear predictor of internalizing, externalizing, and thought disorders in both adults and adolescents. Cumulative impact and stress macro-dynamics, in general, are better investigated using non-linear and cusp statistical methods, contrasted with the linear models employed in micro-dynamics (studying the impact of a single trauma or distinct trauma type). This is, to our knowledge, the first study to employ non-linear modeling techniques to the prediction of CST impact on internalizing, externalizing and thought disorders. Given that a cusp catastrophe model explains a greater proportion of the variance in CST than does the linear model, non-linear modeling techniques may represent a more appropriate match statistical analysis to the characteristics of the data in question. The results indicate that radical behavior changes happen under cumulative stressors pressure in sudden cusps when the resilience buffer breaks. Future research should consider the use of nonlinear modeling to understand the development and occurrence of other low base rate behaviors, such as suicide, or of diagnoses, such as PTSD factors, to ultimately identify individuals who may be at risk for the effects of such threshold jumps in such forms of psychopathology. Also identifying and investigating other variables that their relationships potentially may be more linear or non-linear (e.g., religion, spirituality, will-to-exist-live and survive, post-traumatic growth), but do not follow a cusp catastrophe model, may be important for resiliency research. The results have important implications for clinical prevention and intervention. Interventions should target those who are multiply traumatized, regardless if they are resilient or already impacted by mental health disorders. The accumulation impact, when reached a threshold, even for resilient individuals, will have a cusp sudden impact, as happened to the mother in the case vignette.

The current study, while provides significant potential contributions to understanding the dynamics leading to internalizing, externalizing and thought disorders, has several limitations. One of the limitations was using age as a function of the person's characteristics at a certain point of time as the asymmetrical factor in the Cusp dynamics. Age can provide a limited representation of a person's characteristics. A variety of alternative asymmetrical factors may be possible. Another limitation is that the study used mostly convenient samples that may have limited and biased representation. We recommend more studies that use more representative samples. Another limitation is that the measures we used are based on participants' self-reports, which could be subject to under- or over-reporting of events due to current symptoms, embarrassment, shame, or social desirability. Another limitation is that we utilized a cross-sectional design in testing our model; cross-sectional data can produce biased estimates (Maxwell & Cole, 2007). Cross-sectional design does not provide deterministic hard science models, only probabilistic relationships. Deterministic causal relationships can be obtained using experimental designs if feasible.

Compliance with Ethical Standards and Ethical Approval Note by Authors

No funding was provided to any of the authors to support this work. The authors declare no conflict of interest. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. The study was approved by the academic institution IRBs.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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