Examination of post-traumatic growth, post-traumatic stress symptoms, and neurocognitive flexibility levels in individuals who have experienced a traffic accident

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SUMMARY

Objective: Pathological responses can occur in the aftermath of traumatic experiences, alongside positive changes in levels of functioning, such as Post-Traumatic Growth (PTG). Neurocognitive flexibility involves the adaptive restructuring of information in response to changing conditions. The aim of this study is to investigate the potential impact of neurocognitive flexibility on PTG. Post-Traumatic Stress Disorder (PTSD) and PTG are examined together.

Method: A total of 96 participants of had a traffic accident, consisting of 43 individuals with a diagnosis of PTSD and 53 without a diagnosis of PTSD, participated in the study. Structured Clinical Interview for DSM-5, Clinician-Administered PTSD Scale, Sociodemographic and Trauma-Related Characteristics Data Form, Life Events Checklist for DSM-5, PTSD Checklist for DSM-5, Depression Anxiety Stress Scale 42, Post-Traumatic Growth Inventory, Stroop Test, Trail Making Test, and Category Fluency Test were used as assessment tools.

Results: According to correlation analyses, weak significant relationships were found between the PTG inventory subdimension of changes in life philosophy and neurocognitive flexibility scores. Statistically significant relationships were found between PTSD and neurocognitive flexibility scores. However, no significant relationship was found between PTSD and PTG. Linear regression analyses revealed a trend between PTG inventory and Category Fluency scores.

Discussion: This study is the first in Turkey to examine the relationship between PTG and neurocognitive flexibility using neuropsychological tests. Including tests that measure neurocognitive flexibility in future studies with a larger sample size could yield more specific and robust findings. Investigating the impact of neurocognitive flexibility is theoretically important for understanding the cognitive variables that affect PTG and can help plan psychological interventions that encompass neurocognitive flexibility. This study was presented as a Poster Presentation at the 21st National Neuroscience Congress.

Key Words: Cognition, Post Traumatic Stress Disorder, Post Traumatic Growth, Psychological Trauma, Traffic Accident

INTRODUCTION

Trauma can be defined as a direct or witnessed exposure to an event that threatens an individual's psychological and physical well-being. It is expected that individuals who experience trauma will manifest emotional, behavioral, and cognitive responses. After trauma, individuals may either return to their previous level of functioning, respond with higher levels of functioning, or exhibit pathological responses resulting from maladaptive modulation of the stress response due to the trauma (1,2). Responses to trauma have been under scrutiny since the time of Herodotus. (3) It was not until after the Vietnam War that Post-Traumatic Stress Disorder (PTSD) was first formally defined in DSM-III, eventually reaching its current definitions in DSM-5 and ICD-11. (4, 5)Following a traumatic experience, disturbances in emotional state and cognitive functions, such as re-experiencing, avoidance of reminders, and physiological responses when confronted with reminders, as well as withdrawal from others, alienation, or other disintegrative reactions, including "depersonalization"

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and "derealization," can occur. These symptoms can disrupt a person's social, occupational, or other important areas of functioning (6). The examination of post-traumatic responses is crucial. It is known that PTSD increases the risk of suicide by 2.8% (7). Many studies have focused on the role of genetics in pathological responses to trauma, demonstrating genetic influences ranging from 30% to 72%, as well as exploring cortisol release, the Hypothalamus-Pituitary-Adrenal (HPA) axis, and the hypothalamus-pituitary-thyroid (HPT) axis (8) . Neurocognitive research has emphasized the modulation of the amygdala and hippocampus, as well as alterations in the ventromedial prefrontal cortex, dorsolateral prefrontal cortex, and anterior cingulate cortex in response to traumatic stress symptom severity. However, while approximately 41-86% of the population experiences at least one traumatic event in their lifetime, a significant portion of individuals can overcome these experiences without developing psychopathological disorders (9-11). To fully understand responses to trauma, it is essential to investigate why some individuals develop pathological responses while others do not, despite experiencing similar traumatic events. It is known that individuals attempt to make meaning of traumatic experiences and may exhibit positive responses such as Post-Traumatic Growth (PTG) during this process (12). PTG has been scientifically studied since the 1990s, primarily focusing on individuals with oncological diseases, war veterans, and survivors of traffic accidents. Studies on PTG have shown a U-shaped curve, indicating that the likelihood of PTG occurring increases within the first 24 months after a traumatic experience and then decreases after this period. PTG consists of five sub-dimensions: changes in self-perception, an increased sense of personal strength, improved interpersonal relationships, the identification of new opportunities, and changes in one's philosophy of life. These changes are believed to occur as individuals cope with the schema disruption caused by trauma (13). Similarly, according to the cognitive schema restructuring model, individuals construct new schemas as their previously held beliefs of a safe world and personal invulnerability are shattered (14). According to Schaefer and Moss' model, PTG develops as individuals actively cope with trauma. In the transformational coping model, individuals may experience both negative changes and the development of PTG (15). Examining the relationship between PTG and PTSD, it is possible for both to co-occur, and the development of PTG may be influenced by the severity of traumatic stress. Symptoms associated with PTSD, such as re-experiencing and rumination, can affect the development of PTG, while avoidance may have a negative impact on it. A meta-analysis of 42 studies showed that initially, PTSD symptom severity had a positive effect on PTG, but when it reached a critical level, the likelihood of PTG decreased (16).Nevertheless, it is essential to understand the relationship between PTG and PTSD completely. Thus, this study investigated whether there is a relationship between PTG levels and a diagnosis of PTSD among individuals who have experienced similar traumatic events. Numerous studies have examined responses to trauma from a neurocognitive perspective, with many of them focusing on neurocognitive flexibility, one of the subcategories of executive functions. Neurocognitive flexibility can be defined as the ability to restructure problem-solving strategies in response to the changing complexity of conditions, and it is evaluated across four main domains (17). Set-Shifting: The ability to redirect attention from one stimulus to another, when necessary, with a focus on dorsolateral prefrontal cortex and fronto-parietal regions. Cued Task Switching: The ability to adapt to changing rules depending on the task at hand, with an impact on the anterior cingulate cortex and putamen regions Cognitive Inhibition: The ability to suppress unwanted responses in line with the task's requirements, with evidence of reduced performance and slowing down indicating a weakness in this ability (18). Reversal Learning: The ability to adapt to the reversal of a previously learned pattern during a task, with a focus on the orbitofrontal cortex and prefrontal cortex (19). Neurocognitive flexibility has a positive relationship with psychological well-being and is negatively associated with various psychiatric disorders such as obsessive-compulsive disorder, anxiety disorders, depression, eating disorders, and schizophrenia (20-24). In trauma-focused studies, individuals with severe PTSD symptoms and low neurocognitive flexibility scores showed significant reductions in symptoms when undergoing neurocognitive therapy (25). However, despite the emphasis on cognitive restructuring in models explaining PTG, there is a

limited body of work that comprehensively examines PTG from a cognitive perspective. The hypothesis of this research is that neurocognitive flexibility may play a role in the formation of post-traumatic growth in trauma survivors and the probability of post-traumatic growth may increase as neurocognitive flexibility increases. Also, the side hypothesis of this research is that whether there is a statistically significant relationship between PTG and PTSD symptoms. Many studies have demonstrated the relationship between PTSD symptoms and neurocognitive flexibility, establishing the link between neurocognitive flexibility and PTG is crucial from a theoretical perspective to understand responses to trauma holistically and from a practical standpoint to design trauma interventions with a focus on enhancing neurocognitive flexibility.

METHOD

Between September 2019 and January 2020, a total of 96 individuals who had sought medical attention at Dokuz Eylül University Faculty of Medicine (DEUFM) Department of Forensic Medicine and DEUFM Psychiatry Outpatient Clinic due to a traffic accident were included in the study, while 9 individuals were excluded from the research. Inclusion criteria were as follows: having experienced a traffic accident, being 18 years of age or older, being literate, and providing informed consent through verbal and written informed consent forms. Exclusion criteria included diagnoses of Intellectual Disability or Autism Spectrum Disorder (ASD), cognitive impairment of a degree that would hinder continued participation in the study, visual or hearing impairment to a degree that would disrupt study participation, participation in any of the neuropsychological tests to be administered within the last 6 months, a major psychiatric diagnosis according to the DSM-5 (such as one of the diagnoses within the Schizophrenia Spectrum and Other Psychotic Disorders, Bipolar and Related Disorders), ongoing alcohol/substance use disorder or dependence as defined in the DSM-5.

For diagnosis, the Structured Clinical Interview for DSM-5 (SCID-5) was used. The "Socio-Demographic Information Form," prepared by the researchers to include variables that could be important for the study and containing comprehensive socio-economic and clinical questions about the research participants, was administered. The researchers completed the "Trauma-Related Characteristics" form to collect information on the details and severity of the traumatic event.

The Clinician-Administered PTSD Scale-5 (CAPS-5) was administered to confirm the diagnosis of PTSD. To gather detailed information about PTSD symptoms, severity, and variables that could affect the study, the DSM-5 PTSD Checklist, Depression Anxiety Stress Scale (DASS-42) were administered. To examine the relationship between Post-Traumatic Growth and Cognitive Flexibility, the Post-Traumatic Growth Inventory along with selected neuropsychological tests from the literature (Stroop Test, Trail Making Test Part A, Trail Making Test Part B, Category Fluency Test) were administered.

Socio-Demographic Information Form: This form, created by the authors based on the literature, aims to control for socio-demographic variables in the analyses. It includes information about the participant such as identification number, interview date, date of birth, gender, marital status, total years of education, per capita income in the household, employment status, and educational status.

Trauma-Related Characteristics Form: This form, created by the authors based on the literature, aims to control for variables related to the accident in the analyses. It includes variables related to the accident such as accident date, presence of loss in the accident, accident-related physical damage, type of vehicle involved in the accident, post-accident operation, post-accident intensive care unit treatment.

Clinical Interviews: Structured Clinical Interview for DSM-5 (SCID-5) Axis I Disorders Validation and reliability studies were conducted by Bayad et al (26) to ensure standardized application of diagnostic assessment.

Clinician-Administered PTSD Scale (CAPS-5) Validation and reliability studies, as well as adaptation to Turkish, were conducted by Boysan et al

(27). The English version was developed based on studies with Vietnam War veterans (28). It is a structured clinical interview form widely used to assess PTSD symptoms and their impact on the patient's social and occupational functionality.

DSM-5 PTSD Checklist (PCL-5): This is a self-report scale assessing PTSD symptoms, with each item scored on a scale from 0 to 4 (29). The validity and reliability study found composite reliability coefficients between 0.79-0.92 for re-experiencing symptoms, 0.73-0.91 for avoidance symptoms, 0.85-0.90 for negative alterations, and 0.81-0.88 for hyperarousal symptoms. The two-week test-retest intra-class correlation coefficients were determined as 0.70, 0.64, 0.78, and 0.76 respectively (29, 30).

Depression Anxiety Stress Scale-42 (DASS-42): DASS-42 is a self-report scale consisting of 42 questions with 4 multiple-choice options each, designed to measure depression, anxiety, and stress levels. Its Turkish validity and reliability were established in 2009, (31-33).

Post-Traumatic Growth Inventory (PTGI): PTGI is a psychological assessment tool that quantifies positive changes experienced by individuals following trauma or life challenges. Comprising 21 items, it evaluates posttraumatic growth across five domains: personal strength, new possibilities, relating to others, spiritual change, and appreciation of life. Participants rate items on a scale (often 0-5), with higher scores indicating greater growth. PTGI has applications in clinical therapy and research, shedding light on how individuals transform after adversity (34). Although the original test evaluates factors based on a 5-factor structure, for the Turkish validity and reliability study, a 3-factor structure was considered more appropriate (35).

Neuropsychological Assessment

Stroop Test: This test measures the ability to process attended and unattended stimuli in parallel, assessing processing speed, automatic process resistance, and the ability to resist the disruptive effects of automatic processes. The validity and reliability of the Turkish version of the Stroop Test have been established (36).

Trail Making Test Part A and B The standardized version of the Trail Making Test for Turkish was conducted by Cangöz et al(35).The test assesses different skills that require executive functions such as motor speed, visual-motor conceptual scanning, planning, numerical knowledge, abstract thinking, set shifting, resistance to response tendency generated by physical properties of the stimulus, concentration, and tolerance to inhibition (37).

Category Fluency Test Participants are asked to name as many animal names as they can within one minute. It evaluates language skills, executive functions, and semantic memory. The Category Fluency Test is evaluated based on total count, clustering, and switching between clusters (38).

Statistical analyses were conducted using IBM SPSS Statistics v. 22.0 software. Variable distributions were tested, and non-normal distributions were transformed using natural logarithm (LN). For binary variables, chi-square independence tests were used, and for parametric measurements testing for significance between (continuous)variables in independent groups, t-tests were applied. Logistic regression analyses were used to analyze changes in significance levels when a variable affecting an independent variable was modeled with other added variables.

Ethics: The University Ethics Committee approved research as number 654 on 08/12/2022.

RESULTS

Out of the participants, 30 (31.3%) were female, 66 (68.8%) were male, 54 (56.3%) were married, and 42 (43.8%) were single. Among them, 49 (51%) were employed and 47 (49%) were unemployed. Among the unemployed participants, 6 (6.3%) described their work environment as comfortable, 18 (18.8%) as normal, and 20 (20.8%) as stressful.

When examining sociodemographic variables between groups, no statistical differences were found regarding age, income, body mass index, and years of education. Among the participants, 43

Table 1. Sociodemographic characteristics of the groups

	PTSD		Control		X^2/df	P
	Mean	SD.	Mean	SD.		
Age(year)	35,68	12,83	34,97	12,27	94	0,675
Income (TL) *	1349,76	1104,44	2010,71	3136,32	94	0,115
Education(year)	10,2	4,5	11,22	4,05	94	0,259

N: Number, %: Percentile, *: minimum wage of this years is: 2020,90 and 2324,71 (Republic of Turkey Official Gazette Number: 30991), TL: Turkish Lira

(45%) received a diagnosis of PTSD, while 53 (55%) did not. The mean age of the participants with PTSD was 35.68, while that of the control group was 34.97. The average monthly per capita income in the PTSD group was 1350 TL, and in the control group, it was 2011 TL. The minimum wage between the study dates was 2021-2325 TL. The mean years of education were 10.2 years in the PTSD group and 11.22 years in the control group. The sociodemographic characteristics of the groups are presented in Table 1.

Twenty-five individuals (26%) had a chronic illness, while 71 (74%) did not have any chronic illness requiring regular medication. 9.4% (n=9) of the participants had a psychiatric disorder diagnosis other than PTSD before the study (1 Major Depressive Disorder, 2 panic disorder, 3 General Anxiety Disorder,2 non-specified), and 90.06% (n=86) did not have any psychiatric disorder diagnosis before the study. 32.3% (n=31) of the participants received expert help (Medication or Psychotherapy for treatment and full recovery before the accident) after the accident, while 67.7% (n=65) did not receive expert help after the accident. None of the participants were diagnosed with ASD or adjustment disorder. 11 (11.5%) participants received a diagnosis of major depressive disorder (MDD). MDD is not included as an exclusion criterion because of its prevalence in trauma. 89.6% (n=86) of the participants experienced invehicle accidents, while 10.4% (n=10) experienced out-of-vehicle accidents. 7 (7.3%) participants experienced loss in the accident. 85 (88.5%) participants sustained physical damage in the accident, while 11 (11.5%) did not sustain any physical damage. 45 (47%) participants underwent surgery after the accident, and 51 (53%) participants did not require any surgery after the accident. 82 (85.4%) participants were admitted to the intensive care unit after the accident. The distribution of Clinical Characteristics and Traumatic Event-Related Characteristics of the Participants is given in Table 2.

Table 2. Distribution of participants' clinical characteristics and characteristics related to the traumatic event

Chronic Illness			Psychiatric Illness			Specialist Support			Major Depressive Disorder		
	N	%		N	%		N	%		N	%
Presence	25	26	Presence	9	9,4	Presence	31	32,3	Presence	85	88,5
Absence	71	74	Absence	87	90,6	Absence	65	67,7	Absence	11	11,5
Sum:	96	100		96	100		96	100		96	100

N: Number, %: Percentile

Post-traumatic growth was analyzed in terms of total scores and changes in self-perception, philosophy of life, and relationships using the PTGI scoring system. No significant differences were found between groups in terms of post-traumatic growth total and subcategory scores (Table 3).

A moderate negative relationship was found between years of education and TMT Part A duration, TMT Part B duration. A moderate negative relationship was found between years of education and Stroop Test (interference duration). A moderate positive relationship was found between age and TMT Part A duration, Stroop Test (interference duration). A weak positive relationship was found between age and Trail Making Test Part B. A weak negative relationship was found between

Table 3. Analysis of PTG in relation to PTSD t-test

PTG PTSD Relation	PTSD N=43	Control N=53	2 (*df*) / t (*df*)	P
Mean Sum of PTGI (SD)	36,65(18,88)	35,69 (25,13)	-0,212/94	0,123
Mean of Self Perception (SD)	19,37(11,64)	19,75(13,86)	0,144/94	0,191
Mean of Life Philosophy (SD)	10,3(5,8)	9,11(7,38)	-0,861/94	0,141
Mean of Relationships with others (SD)	6,97(4,95)	6,83(6,49)	-0,122/94	0,156

SD: Standard Derivative, N: Number, PTGI: Post Traumatic Growth Inventory, PTG: Post Traumatic Growth, PTSD: Post Traumatic Stress Disorder.

Table 4. Correlation analysis of all participants(n=96) demographic characteristics and cognitive flexibility

		P	R	N
Education (Year)	TMT A	0,000	-0,555	96
	TMT B	0,000	-0,492	96
	Stroop Test (Interference Time)	0,000	-0,396	96
Age (Year)	TMT A	0,000	0,527	96
	TMT B	0,003	0,298	96
	Stroop Test (Interference Time)	0,000	0,482	96
Income per Person (TL)	TMT A	0,041	-0,209	96
	TMT B	0,011	-0,260	96

*Pearson s R: Correlation coefficient, N: Number, TL: (Turkish Lira)

monthly per capita income and TMT Part A duration, TMT Part B duration (Table 4).

A weak negative relationship was found between (PTGI)sub-scores of changes in philosophy of life and TMT Part A duration (r=-0.263; p=-0.01). A weak negative relationship was found between (PTGI)sub-scores of changes in philosophy of life and Stroop Test (interference duration) (r=249; p=0.014). A weak positive relationship was found between (PTGI) sub-score of change in philosophy of life and Category Fluency Test total scores (r=0.299; p=0.003) (Table 5).

Table 5. Correlation analysis of PTG inventory scores and cognitive flexibility

		P	R	N
PTGI Life Philosophy	Sum of Categorical fluency Score (Animal Count)	0,003	0,299	96
	TMT A	0,01	-0,263	96
	Stroop Test (Interference Time)	0,014	-0,249	96

*Pearson s R: Correlation coefficient, N: Number

In the logistic regression analysis of (PTGI) total scores for PTSD group, no significant relationship was found. In the first model, only (PTGI)scores were included, in the second model, logistic regression analysis was conducted by modeling (PTGI)scores with age, gender, years of education, and income level. In the third model, logistic regression analysis was conducted by modeling (PTGI)scores with age, gender, years of education, income level, and DASS scores. However, no significant results were obtained in the Total (PTGI), PTSD Logistic Regression Analysis. The same modeling was used for Linear Regression Analyses. No statistically significant relationship was found between total (PTGI)scores and neurocognitive flexibility test scores in Linear Regression Analysis.

In the linear regression analysis of (PTGI)total scores and Category Fluency total scores, no significant relationship was found. However, a trend tendency was observed between (PTGI)and Category Fluency total scores (Table 6) (p= 0.068). Also, PTGI life Philosopy scores and Stroop Interference Scores shows significant relationship. (Table 7) (p=0,015).

DISCUSSION

It is imperative to acknowledge the inherent limitations within this study. Firstly, the cross-sectional nature of the study design precludes the establishment of causality. Longitudinal research is necessitated to explore the temporal relationships between neurocognitive flexibility, trauma, and Post-Traumatic Growth (PTG) over an extended

Table 6. Linear regression analysis of ptgi score and total category fluency test scores.

Linear Regression Analysis	B	P	%95 CI
Model 1	0,758	0,068	-0,057/1,572
Model 2	0,835	0,080	-0,102/1,773
Model 3	0,829	0,085	-0,116/1,774

CI: Confidence Interval
Model 1: Sum of PTGI + Sum of Animal Naming Count
Model 2: Sum of PTGI + Sum of Animal Naming Count + Age + Sex + Education + Income
Model 3: Sum of PTGI + Sum of Animal Naming Count + Age + Sex + Education + Income + Sum of DASS-42 scores

Table 7. Linear regression analysis of PTGI score and stroop interference scores

Linear Regression Analysis	B	P	%95 CI
Model 1	-0,76	0,015	-0,137/-0,015

Dependent Variable: Sum of PTGI Life Philosopy Score
Model 1: Stroop Interference Score

period. Secondly, the study centered around a specific traumatic event (traffic accidents), potentially constraining the generalizability of findings to other traumatic contexts, and the study's small sample size limits the robustness of results. Further research encompassing diverse traumatic experiences is imperative to substantiate the association between neurocognitive flexibility and PTG across varied populations. Thirdly, the reliance on self-report measures may introduce response bias, potentially impacting data accuracy. In summary, this study aspires to contribute theoretically to the understanding of neurocognitive flexibility's role in comprehending post-traumatic growth and practically to clinical interventions by incorporating neurocognitive flexibility into trauma-focused treatments. The core hypothesis posited that individuals with higher levels of neurocognitive flexibility would exhibit higher levels of PTG. Additionally, all traumas experienced by participants prior to their enrollment were recorded, and potential relationships between trauma and neurocognitive flexibility were included in the analyses. Weak, statistically significant positive correlations were identified between neurocognitive flexibility levels and the change in the philosophy of life sub-dimension of PTG. Regression analyses further supported our hypothesis. Although this research is distinctive in its examination of neurocognitive flexibility and PTG in Turkey, the findings alone are not sufficient to establish that neurocognitive flexibility enhances PTG. The research outcomes suggest that increasing the sample size and revisiting the topic with different trauma types may demonstrate the impact of neurocognitive flexibility on PTG more clearly. A meta-analysis conducted in 2019 compared PTG across different trauma types and found that PTG was lowest in the group of individuals who had experienced traffic accidents. Given that all participants in this study had experienced traffic accidents, it is possible that this particular trauma type influenced PTG levels (39). Therefore, future studies could focus on a different type of trauma to address this issue. Another limitation is that neurocognitive flexibility was measured solely through tests like the Trail Making Test, categorical fluency, and Stroop tests. The inclusion of other neurocognitive flexibility measurement tools such as the Tower of London or the Wisconsin Card Sorting Test might yield more specific results. In this study, the relationship between PTSD symptoms and PTG levels was also investigated; however, no statistically significant relationship was found. One of the limitations here is that this research was cross-sectional. Future research with a longitudinal design, considering specific symptoms like avoidance and re-experiencing in separate analyses, may provide more precise insights into the relationship between PTSD and PTG and demonstrate a temporal relationship. Examining the clinical characteristics of the participants, it is worth noting that 11% of them received a diagnosis of Major Depressive Disorder (MDD) according to DSM-5 criteria. In the literature, the comorbidity rate of PTSD and MDD is approximately 25%, making it challenging to exclude individuals with MDD from trauma studies (40). The presence of MDD in 11% of the participants might have negatively affected their cognitive flexibility test performance due to symptoms such as psychomotor retardation and decreased motivation. However, including DASS-42 scores as a control variable in statistical modeling aimed to mitigate these limitations. The finding that neurocognitive flexibility levels positively correlate with changes in the philosophy of life sub-dimension of PTG is believed to be attributed to the fact that increased levels of neurocognitive flexibility lead to changes in one's philosophy of life, consistent with the literature (41). It is believed that similar associations may exist with other sub-dimensions in different types of traumas. Additionally, future research can explore the personalization of treatment and the incorporation of neurocognitive interventions in clinical settings, focusing on the impact of cognitive flexibility on traumatic stress symptoms and levels of PTG.

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