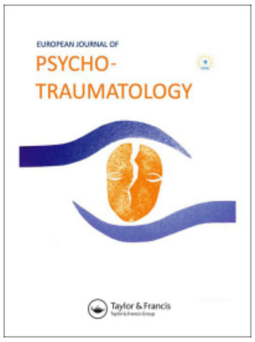

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BASIC RESEARCH ARTICLE

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Sensory modulation and trauma-related symptoms during rocket attacks

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ABSTRACT

Background: War is a highly traumatogenic experience that may result in trauma-related symptoms during exposure. Although most individuals exhibit recovery after the trauma ends, symptomatology during exposure may serve as an initial indicator underlying symptomatology at the posttraumatic phase, hence the imperative to identify risk factors for trauma-related symptoms during the peritraumatic phase. While research has uncovered several factors associated with peritraumatic distress, such as age, gender, history of mental disorder, perceived threat, and perceived social support, the role of sensory modulation has not been explored.
Method: To address this gap, 488 Israeli citizens were assessed using an online survey for sensory modulation and trauma-related symptoms during rocket attacks.
Results: Analyses revealed that while the association between high sensory responsiveness and elevated levels of specific trauma-related symptoms is somewhat weak ($0.19<r<.0.22$), it serves as a major risk factor for developing trauma-related symptoms during the peritraumatic phase in general. Specifically, the risk for elevated symptoms was doubled (OR = 2.11) for each increase in the high sensory-responsiveness score, after controlling for age, gender, history of mental disorder, perceived threat, and perceived social support.
Limitations: This study relied on convenience sampling and a cross-sectional design.
Conclusions: The present findings suggest that sensory modulation evaluation may serve as an important screening tool for identifying individuals who are vulnerable to trauma-related symptoms during the peritraumatic phase, and that implementing sensory modulation strategies as part of preventative interventions for PTSD might be effective.

Modulación sensorial y síntomas relacionados con el trauma durante los ataques con cohetes

Antecedentes: La guerra es una experiencia altamente traumatógena que puede provocar síntomas relacionados con el trauma durante la exposición. Aunque la mayoría de las personas muestran una recuperación después de que termina el trauma, la sintomatología durante la exposición puede servir como un indicador inicial de la sintomatología subyacente en la fase postraumática, por lo que es imperativo identificar los factores de riesgo para los síntomas relacionados con el trauma durante la fase peritraumática. Si bien la investigación ha descubierto varios factores asociados con la angustia peritraumática, tales como la edad, el sexo, los antecedentes de trastorno mental, la amenaza percibida y el apoyo social percibido, no se ha explorado el papel de la modulación sensorial.
Método: Para abordar esta brecha, se evaluaron a 488 ciudadanos israelíes mediante una encuesta en línea para la modulación sensorial y los síntomas relacionados con el trauma durante los ataques con cohetes.
Resultados: Los análisis revelaron que, si bien la asociación entre una alta capacidad de respuesta sensorial y niveles elevados de síntomas específicos relacionados con el trauma es algo débil ($0.19<r<.0.22$), sirve como un factor de riesgo importante para desarrollar síntomas relacionados con el trauma, en general, durante la fase peritraumática. Específicamente, el riesgo de síntomas elevados se duplicó (OR = 2,11) por cada aumento en la puntuación alta de respuesta sensorial, después de controlar por edad, sexo, antecedentes de trastorno mental, amenaza percibida y apoyo social percibido.
Limitaciones: Este estudio se basó en un muestreo por conveniencia y un diseño transversal.
Conclusiones: Los presentes hallazgos sugieren que la evaluación de la modulación sensorial puede servir como una importante herramienta de detección para identificar a las personas que son vulnerables a los síntomas relacionados con el trauma durante la fase peritraumática, y que la implementación de estrategias de modulación sensorial como parte de las intervenciones preventivas para el TEPT podría ser efectiva.

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KEYWORDS
Trauma-related symptoms; sensory modulation; perceived threat; perceived social support; war; trauma

PALABRAS CLAVE
Síntomas relacionados con el trauma; modulación sensorial; amenaza percibida; apoyo social percibido; guerra; trauma

关键词
创伤相关症状； 感觉调制； 感知到的威胁； 感知到的社会支持； 战争; 创伤

HIGHLIGHTS
- High sensory responsiveness was related to trauma-related symptoms.
- Low sensory responsiveness was unrelated to trauma-related symptoms.
- The risk for elevated trauma-related symptoms during exposure was doubled for each increase in high sensory-responsiveness score.

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火箭弹袭击期间的感觉调节和创伤相关症状

背景：战争是一种高度创伤性的经历，可能在暴露期间导致创伤相关症状。虽然大多数人在创伤结束后表现出恢复，但暴露期间的症状学可以作为创伤后阶段潜在症状学的初始指标，因此有必要识别围创伤期创伤相关症状的风险因素。虽然研究发现了围创伤期精神痛苦的一些相关因素，例如年龄、性别、精神障碍史、感知到的威胁和感知到的社会支持，尚未探究感觉调节的作用。
方法：为了弥补这一差距，使用在线调查评估了 488 名以色列公民在火箭弹袭击期间的感觉调节和创伤相关症状。
结果：分析表明，虽然高感觉反应与特定创伤相关症状水平升高之间的关联有些微弱 ($0.19<r<.0.22$)，但它总体上是围创伤期出现创伤相关症状的一个主要风险因素。具体来说，在控制了年龄、性别、精神障碍史、感知到的威胁和感知到的社会支持后，高感觉反应评分每增加一分，症状升高的风险就会增加一倍 (OR = 2.11)。
局限性：本研究依赖于便利抽样和横断面设计。
结论：本研究结果表明，感觉调节评估可以作为一种重要的筛查工具，用于识别在围创伤期创伤相关症状易感个体，且实施感觉调节策略作为 PTSD 预防性干预措施的一部分可能是有效的。

1. Introduction

War is a highly traumatogenic event that may psychologically damage civilians in various ways (Charlson et al., 2019; Palmieri et al., 2008). The adverse effects of war can be detected early, and may be manifested in peritraumatic reactions, namely in trauma-related perceptions, cognitions, and emotions during and immediately following the war (e.g. feelings of personal life threat, feelings of helplessness, dissociation). Furthermore, research has indicated that under conditions of ongoing exposure to series of potentially traumatic events, such as during war, symptoms which are often attributed to the posttraumatic phase, may also evolve. Symptoms such as re-experiencing of the trauma, avoiding stimuli associated with the trauma, holding pessimistic beliefs, as well as experiencing negative mood states and increased reactivity to stimuli, have been documented among civilians during exposure to war (Gelkopf et al., 2019; Lapid Pickman et al., 2017). The current research explored this type of initial trauma-related symptoms manifested in intrusion, avoidance, negative changes in mood and cognition, and arousal symptoms during the peritraumatic phase.

Yet, psychological distress during trauma may vary across individuals, with some people being more vulnerable to symptomatology than others (Bovin & Marx, 2011). Moreover, although most individuals are resilient and spontaneously recover after the trauma ends (Bonanno, 2004; Galea et al., 2003; Santiago et al., 2013), peritraumatic distress appears to be the most powerful predictor of subsequent post-traumatic stress disorder (PTSD; Ozer et al., 2003; Thomas et al., 2012; Vance et al., 2018), and trauma-related symptomatology during the peritraumatic phase is suggested to serve as an initial marker underlying the development of PTSD (Gelkopf et al., 2019; Lapid Pickman et al., 2017; Neria et al., 2010). Therefore, identifying populations that are particularly vulnerable to trauma-related symptomatology during trauma exposure and uncovering factors related to elevated symptoms may contribute to the development of preventative interventions for PTSD (Kearns et al., 2012).

Research has revealed distinct profiles of posttraumatic reactions and PTSD symptom clusters among survivors of varied traumatic events (Contractor et al., 2015; Hruska et al., 2014; Sripada et al., 2020). One might postulate that distinct profiles of trauma-related symptoms during the peritraumatic phase that encompass different combinations between the four clusters of symptoms might exist as well. To explore this prospect, it might not be sufficient to use a traditional one-variable-at-a-time statistical approach. Rather, a more nuanced exploration accounting for a wide range of combinations and patterns between clusters of symptoms is needed. Addressing this need, the present investigation aimed at detecting varied profiles of trauma-related symptoms among Israeli civilians during rocket attacks.

Thus far, research has uncovered several factors related to elevated levels of distress or symptomatology during the peritraumatic phase. These factors include age at time of trauma, gender, history of mental disorder, perceived threat, and perceived social support. Specifically, women (Brunet et al., 2001; Freedman et al., 2002; Irish et al., 2011; Neria et al., 2010), younger individuals (Hamam et al., 2021), and individuals with a history of psychiatric disorders (Gelkopf et al., 2017) have been found to have higher levels of distress or symptomatology during or immediately after exposure to trauma. In addition, previous studies suggest that elevated sense of threat (Lapid Pickman et al., 2017) and lower perceived social support (Brunet et al., 2001; Neria et al., 2010) also contribute to elevated peritraumatic reactions.

Nonetheless, the role of the sensory domain, specifically, individuals' ability to modulate sensory sensations, has received little attention in attempts to explain individuals' distress during the peritraumatic phase. This is quite surprising, given that traumatic events, such as war, by definition constitute highly aversive sensory stimuli, and that re-experiencing and avoiding such stimuli are intrinsic to trauma-related symptomatology (American Psychiatric Association, 2013). Therefore, this study aimed to explore, for the first time, the contribution of sensory modulation in explaining symptomatology during the peritraumatic phase.

Sensory modulation is the ability to regulate responses to sensory input in a graded and adaptive manner that enables efficient and adaptive functioning (Dunn, 2001; Koziol et al., 2011; Lane et al., 2010; Miller et al., 2007). Difficulties in sensory modulation affect single or multiple sensory systems, and impact daily functioning and quality of life (Bar-Shalita et al., 2015; Kinnealey et al., 2011; Miller et al., 2007). Two main patterns of sensory modulation difficulties have been documented (Miller et al., 2007). The first consists of high sensory responsiveness, which involves responding to daily non-painful sensory stimuli with greater intensity and for a longer time, as well as experiencing innocuous stimuli as unpleasant and even painful (Bar-Shalita et al., 2019; Weissman-Fogel et al., 2018). This pattern, linked to neuroticism (Bar-Shalita & Cermak, 2020), may not only negatively shape individuals' experiences, but may also result in maladaptive reactions, such as impulsivity, aggression, anxiety, avoidance of the stimulus, and difficulty relaxing (Bar-Shalita & Cermak, 2016; Engel-Yeger & Dunn, 2011). These maladaptive reactions were verified using electro-encephalogram, which demonstrated lower alpha power and faster pick alpha frequency in individuals identified with sensory over-responsivity, indicating pain hyper-sensitivity (Granovsky et al., 2019). Indeed, sensory over-responsivity has been related to alterations in vagal tone reactivity during experimental pain (Bar-Shalita et al., 2020). The second pattern of sensory modulation difficulty consists of low sensory responsiveness, which reflects hyposensitivity to stimuli, and leads the individual to miss or ignore sensory stimuli. Individuals with this pattern of response require stimulation to be more intense or to last for a longer period in order to detect and respond adequately, and may suffer from insufficient daily function in various life domains (Miller et al., 2007). These two phenotypical patterns are expressions of central nervous system modulatory alteration (Koziol et al., 2011) and thus are related as well as co-occur (Bar-Shalita et al., 2019; Weissman-Fogel et al., 2018). Importantly, while both patterns co-exist each pattern is usually presented in a different sensory system, eliciting an individual consistency within a sensory system. Thus the patterns of responding combination across the sensory systems, termed sensory modulation profile, is individually characterised (Miller et al., 2007).

Evidence suggests that sensory modulation difficulties may predispose individuals to psychopathology (Bar-Shalita & Cermak, 2016; McMahon et al., 2019). Sensory modulation dysfunction relates to elevated psychological distress and anxiety (Bar-Shalita & Cermak, 2016; Kinnealey & Fuiek, 1999; Weissman-Fogel et al., 2018), obsessive compulsive symptoms (Ben-Sasson & Podoly, 2017), severe mental disorders (Serafini et al., 2016; Sutton & Nicholson, 2011), and substance use disorder (Assayag et al., 2020).

Sensory modulation difficulties may also be related to distress following trauma. According to Harricharan et al. (2021), high or low sensory responsiveness patterns may be implicated in hypervigilance and numbing reactions found in traumatised individuals. Although studies are scarce, evidence has supported this line of thought. Previous findings have indicated that children with a history of maltreatment suffer from a higher incidence of both patterns of sensory-modulation dysfunction compared to controls (Howard et al., 2020), and that childhood maltreatment is related to severity of sensory modulation dysfunction (Serafini et al., 2016). Furthermore, a study conducted on 30 individuals diagnosed with PTSD and 30 healthy controls, revealed an elevated frequency of both high and low sensory responsiveness among the PTSD group (Engel-Yeger et al., 2013). Similarly, a study conducted among children who had been exposed to continuous trauma indicated a link between sensory modulation dysfunction and PTSD (Yochman & Pat-Horenczyk, 2020).

Nevertheless, the aforementioned studies were conducted after the trauma ended (Engel-Yeger et al., 2013), or among survivors of continuous traumatic stress, who experienced an ongoing and protracted threat (Yochman & Pat-Horenczyk, 2020), and may subsequently have developed unique stress reactions (Lahav, 2020). As such, previous findings cannot illuminate the implications of sensory modulation on initial symptomatology in the face of trauma exposure, nor can they indicate whether sensory modulation difficulties might explain susceptibility to elevated trauma-related symptoms during the peritraumatic phase, above and beyond well-documented risk factors.

The implications of sensory modulation difficulties may not be limited to the post-traumatic phase; rather, they may very well affect an individual's adjustment during exposure to trauma. Specifically, the sensory patterns of high- and low-responsiveness may shape the way that individuals react to trauma, resulting in elevated symptomatology. Unlike individuals who are able to modulate sensory information adaptively and thus -habituate themselves to every day stimuli, individuals with sensory modulation difficulties often fail to adjust to ordinary, non-threatening stimuli, and this failure to adapt is heightened in the case of potent and aversive stimuli (Bar-Shalita et al., 2015, 2019; Miller et al., 2007), which are inherent in trauma exposure. Therefore, it might be that individuals with high sensory responsiveness experience adverse stimuli during trauma exposure in an amplified manner, and therefore respond to trauma with elevated symptomatology. At the same time, it might be that individuals with low sensory -responsiveness experience numbing and detachment during the trauma, and therefore fail to process the event and react in elevated symptomatology.

2. The current study

The present study explored these suppositions by assessing Israeli civilians' trauma-related symptoms in the face of rocket attacks during Operation Guardian of the Walls. The operation lasted 12 days (10 May 2021 through 21 May 2021), during which period almost 4400 rockets fired at Israel. These attacks exposed hundreds of thousands of Israeli civilians to the threat of rocket fire. The present study explored whether sensory modulation difficulties were related to trauma-related symptoms during the operation, and whether high and low sensory-responsiveness uniquely contribute to explaining differential profiles of symptoms, above and beyond other well-documented risk factors (i.e., age, gender, history of mental disorder, perceived threat, and perceived social support). Being the first, to our knowledge, to address this subject matter, the current study was exploratory in nature. Three main objectives were set:

(1) To explore the relationship between sensory modulation difficulties and trauma-related symptomatology during the peritraumatic phase.
(2) To identify profiles of trauma-related symptomatology during the peritraumatic phase, and their prevalence.
(3) To assess the contribution of sensory modulation difficulties in explaining trauma-related symptomatology profile type above and beyond age, gender, history of mental disorder, perceived threat, and perceived social support.

3. Methods

3.1. Participants and procedure

The research employed a convenience sample of Israeli adults using an online survey distributed on social media platforms from 14 May 2021 (the fifth day of the operation) to 21 May 2021 (several hours after the ceasefire). The survey was administered using Qualtrics software (QualtricsLabs Inc., Provo, UT, US), and the questionnaire completion time ranged between 15 and 30 min. The Tel Aviv University institutional review board (IRB) approved all procedures and instruments. Respondents were notified regarding the research goals, the nature of the questions, and its approval by the relevant IRB. Respondents signed a consent form stating that they understood the survey was anonymous, and that they could withdraw their participation at any point, without repercussions. A total of 794 responses were collected, of which 739 (93%) reported being exposed to rocket attacks.

The present sample consisted of 488 participants who reported being exposed to rocket attacks and provided data regarding the study variables. While the survey was not limited to any sub-population or ethnic group, respondents were all Jewish, of which 360 (73.7%) stated being secular. In terms of income levels, 197 (40.3%) reported a below-average income, 119 (24.3%) reported an average income, and 172 (35.2%) an above-average level. 301 respondents (61.6%) were in a relationship. The mean years of education in the sample was 15.5 years (SD = 3.3), the equivalent of an undergraduate degree in Israel. All respondents reported being directly exposed to rocket attacks during the operation ($n = 488$, 100%). A fifth of the sample reported witnessing rocket landings in the vicinity of their home ($n = 96$, 19.7%), and a small minority reported suffering from damage to their homes or possessions ($n = 3$, 0.6%), or witnessing another person being physically or mentally injured by the attacks ($n = 35$, 7.2%).

3.2. Measures

3.2.1. Background variables

Participants completed a brief demographic questionnaire that assessed age, gender, education, relationship status, religiosity, and income. In addition, respondents were asked whether they had been diagnosed with a mental disorder in the past (i.e. prior to exposure to rocket attacks).

3.2.2. Trauma-related symptomatology during rocket attacks

Trauma-related symptoms in response to being exposed to rocket attacks were measured via a modified version of the PTSD Checklist (PCL-5) (Weathers et al., 2013). In this 20-item self-report measure, participants are asked to indicate the extent to which they experienced each PTSD symptom, on a 5-point Likert scale ranging from 0 (*not at all*) to 4 (*extremely*). Items corresponded to the newly approved PTSD symptom criteria in the Diagnostic and Statistical Manual of Mental Disorders (5th ed., DSM–5; American Psychiatric Association, 2013).

The original version was adapted so that the timeframe for experiencing each symptom was changed from ‘in the past month’ to ‘since being exposed to rocket attacks during Operation Guardian of the Walls,’ and the index event was being exposed to rocket attacks during Operation Guardian of the Walls. The PCL-5 demonstrates high internal consistency and test-retest reliability (Bovin et al., 2016). This study had good internal consistency reliabilities for intrusion, avoidance, negative alterations in mood and cognition, and hyperarousal clusters ($\alpha = 0.87$, 0.78, 0.84, 0.84, respectively).

3.2.3. Sensory responsiveness

High and low sensory responsiveness were measured via the Sensory Responsiveness Questionnaire-Intensity scale (Bar-Shalita et al., 2009). This scale consists of 58 scenarios typical in daily life, each of which is stated in a manner that attributes either a hedonic (e.g. ‘I enjoy being in a place that is brightly lit’; ‘I enjoy working and concentrating with background noises’) or an aversive valence (e.g. ‘Washing my face bothers me’; ‘Smelling perfume bothers me’) to it. Each item refers to one sensory stimulus in one of the following modalities: auditory; visual; gustatory; olfactory; vestibular; and somatosensory, excluding pain. Participants were asked to rate the intensity of their hedonic/aversive response to the scenario on a 5-point Likert scale ranging from 1 (not at all) to 5 (very much), yielding the SRQ-Aversive and SRQ-Hedonic scores indicating high and low sensory responsiveness, respectively. In detail in both scales, SRQ-Aversive and SRQ-Hedonic, higher scores indicate higher / lower responsiveness, respectively. The SRQ-IS demonstrates high internal consistency and test-retest reliability (Bar-Shalita et al., 2009). Internal consistency reliabilities in this study for SRQ-Aversive and SRQ-Hedonic scores were good ($\alpha = 0.77$, 0.73, respectively). Further, using electroencephalogram found lower alpha power and faster pick alpha frequency oscillations linked to higher scores in the SRQ-Aversive scale (Granovsky et al., 2019), where psychophysical testing demonstrated that pain hyper-sensitivity was also linked to higher scores in the SRQ-Aversive scale (e.g. Weissman-Fogel et al., 2018). Finally an exploratory study showed that during experimental pain higher scores in the SRQ-Aversive scale were related to vagal tone reactivity alterations (Bar-Shalita et al., 2020). Taken together the SRQ-Aversive scale scores may be indicative of a pro-nociceptive state (Bar-Shalita et al., 2019).

3.2.4. Covariates

Given that age, gender, history of mental disorder, perceived threat, and perceived social support have been associated with peritraumatic distress or symptomatology (Gelkopf et al., 2017; Hamam et al., 2021; Irish et al., 2011; Lapid Pickman et al., 2017; Neria et al., 2010), these factors were treated as covariates in this analysis. Perceived threat was measured by asking respondents to indicate their sense of threat from the rocket attacks during the operation on a scale of 0 (‘not at all’) to 100 (‘highly threatened’). Perceived social support was measured via the multidimensional scale of perceived social support (Zimet et al., 1988). This 12-item self-report measure asks participants to indicate the extent to which they experienced social support from family, friends, and partners in the past month, on a 7-point Likert scale ranging from 1 (very strongly disagree) to 7 (very strongly agree). The MSPSS demonstrates high reliability and validity (Bruwer et al., 2008; Zimet et al., 1990). Internal consistency reliability in this study was very good ($\alpha = 0.95$).

3.3. Analytic strategy

Pearson correlation tests (for continuous variables), independent samples *t*-tests and Chi square tests with Yate’s continuity correction (for dummy variables) were conducted to assess the associations between age, gender, history of mental disorder, perceived threat, perceived social support, sensory modulation difficulties, and trauma-related symptoms during the peritraumatic phase.

Using the four subscales of the PCL-5, respondents were classified into profiles of trauma-related symptoms using a Latent Profile Analysis analytic scheme. Respondents were aggregated into latent profiles using the tidyLPA package in R (Rosenberg et al., 2018). While the procedure allows testing for several variance-covariance structures, our sample size allowed testing for models with fixed variance between profiles only (i.e. class invariant parameterisation models). We decided on the number of latent profiles and the model appropriate for this work using the AIC, BIC, Entropy, and BLRT measures (Ferguson et al., 2020; Nylund et al., 2008), and the (Akogul & Erisoglu, 2017) integrated hierarchical procedure.

Finally, in order to estimate the propensity of each respondent to belong to a certain profile, according to our study variables–, we employed a Generalized Linear Model (GLM) strategy. Since the dependent variable is categorical in nature, the error distribution called for the use of the binomial family, with a logit link function. All of the analysis in this work was performed using R.

4. Results

4.1. Trauma-related symptoms during rocket attacks

Of the total sample, 43.3% ($n = 208$) reported at least one intrusion symptom, 27.3% ($n = 131$) reported at least one avoidance symptom, 58.2% ($n = 279$) reported at least one symptom reflecting negative alterations in mood and cognition, and 83.1% ($n = 399$) reported at least one hyperarousal symptom.

4.2. Associations between the study's variables and trauma-related symptoms during rocket attacks

As can be seen in Table 1, age, gender, history of mental disorder, participants' perceived threat, and their perceived social support were related to trauma-related symptoms during rocket attacks. Being female, having a history of mental disorder prior to the operation, and experiencing an elevated sense of threat were associated with higher levels of symptoms. Being younger was associated with higher levels of trauma-related symptoms, except for avoidance symptoms; having low levels of perceived social support was associated with higher levels of trauma-related symptoms, excepting intrusion symptoms. Lastly, high sensory responsiveness was associated with higher levels of trauma-related symptoms: the greater the levels of high sensory responsiveness, the higher the levels of intrusion, avoidance, hyperarousal, and symptoms of negative alterations in mood and cognition. Low sensory responsiveness was not associated with trauma-related symptoms.

4.3. Profiles of trauma-related symptoms during rocket attacks

We performed an LPA procedure for all PCL-5 questionnaire items as a preliminary stage in our analysis, in order to validate that items cluster together by their intensity. Results of the LPA procedure yielded a 4 profile structure, using the invariant unrestricted parameterisation model (results are suppressed from this manuscript). Profile centroids were linearly aligned, and formed an ordered structure of *high, moderate-high, moderate-low,* and *low* symptomology levels. We therefore were able assume a positive linear dependence between item scores, and analyse the questionnaire using the DSM-5 (APA, 2013) suggested four cluster structure of Intrusion, Avoidance, Negative alterations in mood and cognition, and Hyperarousal.

Results for the finite mixture models produced by the LPA procedure are shown in Table 2. As suggested by comparing the AIC and BIC values, the best fitting model is the class invariant unrestricted parameterisation model (model 3) with 2 profiles. While less parsimonious in comparison to the restricted model (model 1), it allows for non-zero values of both the variances and the covariances of each profile, but restricts a fixed value for each profile (i.e. $COV_{ij}^{p} = const,\ \sigma_{ij}^{p} = const,\ \forall p,$ where p is the number of latent profiles). The choice of the discussed model is also supported by the BLRT ratio test, and by the (Akogul & Erisoglu, 2017) procedure. We also note that the entropy value for the chosen model is highly satisfactory (0.92) by all common standards used in Social and Behavioral Sciences (Clark & Muthén, 2009; Nylund et al., 2008). The use of a dichotomised profile structure is also supported by a planned-contrasts test on the PCL-5 questionnaire items, which yielded significant differences for a high vs. low symptomology contrast for all 20 items (i.e. $-0.5\mu_1 + 0.5\mu_2 - 0.5\mu_3 - 0.5\mu_4 \neq 0$).

The model of choice generates two distinct profiles, representing *high* versus *low* levels of trauma-related symptoms. Profile 1 includes a total of 109 respondents (22.3%), characterised by high levels of the four dimensions of the PCL-5. Profile 2 includes the remaining 379 respondents (77.7%), characterised by low levels of the four sub-scales. Centroid values of each component of the profiles do not overlap, and are not within the 90% confidence interval for the true mean of their counterparts. These results are also supported by a series of *t*-tests performed for the difference in mean between profiles for their respective centroid values (Arousal scale: $t_{124} = -5.51,\ p < .001$; Avoidance scale: $t_{134} = -5.5, p < .001$; Intrusion scale: $t_{126} = -5.19,\ p < .001$; Negative alterations scale: $t_{127} = -5.77,\ p < .001$). Hence, we conclude that the procedure generated two statistically significant and unique profiles. Centroid values for all four dimensions of the PCL-5, for both profiles, are as shown in Figure 1.

4.4. Trauma-related symptoms profiles and sensory responsiveness

We used a GLM regression model to estimate the contribution of our explanatory variables to the probability of belonging to each profile. Since our mixture model produced two distinct profiles, we estimated the model using a quasi-logistic estimation model, where the dependent variable is denoted as: 0 = belonging to profile 2 (i.e. the profile less prone to trauma-related symptoms), and 1 = belonging to profile 1. Results for the regression model are shown in Table 3.

Model fit indices indicated satisfactory explanatory power for the model ($\chi^2_8 = 69.7,\ p < 0.001$). Since we employ a GLM modelling scheme, our pseudo-R^2 value for the model does not measure the explained variability, but instead the improvement from the null model to the fitted one. Since we are dealing with categorical data, common practice suggests using adjusted measures of the Cox & Snell pseudo-R^2 value (Bo et al., 2006; Veall & Zimmermann, 1996). We use the Cragg–Uhler value, which scales the transformation of the $-2\ln\left(\frac{\mathcal{L}(M_{intercept})}{\mathcal{L}(M_{full})}\right)^{N/2}$ statistic used

Table 1. Inter-correlations between trauma-related symptoms during the peritraumatic phase and the study variables ($n = 488$).

	1	2	3	4	5	6	7	8	9	10	11
1. Intrusion symptoms	–										
2. Avoidance symptoms	0.61***	–									
3. Negative alterations in mood and cognition	0.6***	0.53***	–								
4. Hyperarousal symptoms	0.59***	0.45***	0.65***	–							
5. Gender†	5.33***	3.82***	3.18***	7.16***	–						
6. Age	−0.17***	−0.1	−0.15***	−0.2***	−2.37**	-					
7. Mental disorder†	3.07***	2.32**	4.84***	2.06**	1.34	−3.3***	-				
8. Sense of threat	0.42***	0.32***	0.27***	0.42***	5.55***	0	−0.72	-			
9. Perceived social support	−0.07	−0.11**	−0.22***	−0.08*	2.03**	−0.02	−3.85***	0.02	-		
10. High sensory responsiveness	0.19***	0.2***	0.21***	0.22***	2.09**	−0.07	4.23***	0.07	−0.24***	-	
11. Low sensory responsiveness	0.02	−0.04	−0.01	0	1.38	−0.03	−1.51	0	0.02	0.19***	-
M/%	1.08	0.40	1.77	2.78	82.6%	36.66	20.5%	54.39	64.37	1.85	1.73
(SD)/category	(1.55)	(0.71)	(2.01)	(1.88)	(Female)	(10.36)	(Yes)	(27.92)	(17.08)	(0.42)	(0.4)

Note: * $p < .05$; ** $p < .01$; *** $p < .001$; † Intercorrelations between dummy variables was calculated using either an independent samples *t*-test, or the Chi square test for independence with Yate's continuity correction.

Table 2. Latent profile analysis fit indices ($n = 488$).

Model	Class	AIC	BIC	Entropy	PV of BLRT
1	1	4912.25	4945.77	1	
1	2	4038.6	4093.08	0.91	0.01
1	3	3813.69	3889.11	0.85	0.01
1	4	3730.81	3827.18	0.84	0.01
3	1	3874.66	3933.33	1	
3	2[a]	3661.66	3741.27	0.92	0.01
3	3	3655.24	3755.8	0.71	0.02
3	4	3674.14	3795.66	0.56	1

Note: [a] The best fitting model. AIC = Akaike information criterion, BIC = Bayesian information criterion, BLRT = Bootstrap likelihood ratio test. Lower AIC, BIC values indicate a better fitting model. Higher entropy values indicate higher probabilities of each subject being assigned to a single profile. PV of the BLRT measures the statistical significance of the increase in model fit between the k−1 and k profile models.

Table 3. Estimates of the contribution of study variables to the probability to belong to profile 1 (high trauma-related symptoms during the peritraumatic phase) ($n = 488$).

	β	OR_{adj}
Intercept	−2.49**	
Gender (Male)	−0.6	0.55
Age	−0.01	0.99
Mental disorder (No)	−0.69**	0.50
Perceived social support	−0.01*	0.99
Sense of threat	0.03***	1.03
High sensory responsiveness	0.75***	2.11
Low sensory responsiveness	−0.19	0.83
χ^2	69.7***	
Cragg-Uhler pseudo-R^2	0.20	

Note: *p<.05; ** p < .01; *** p < .001.

to determine the convergence of the regression model. The pseudo-R^2 value for our model is 0.2, and is considered acceptable for a model capturing a single phenomenon within a wide range of psychological factors that may affect the propensity to develop trauma-related symptoms.

The results, however, highlight the significant effect of the variables of interest in this study. As expected, both history of mental disorder and having low perceived social support increased the propensity to experience trauma-related symptoms during rocket attacks; while the effect of perceived threat was statistically significant, but miniscule in its effect. More importantly, high sensory responsiveness increased the propensity to experience such symptoms. The estimation equation yields a relationship where, *ceteris paribus*, the risk for extensive trauma-related symptoms is doubled (OR = 2.11) for each marginal increase in the SRQ-Aversive score. Since the estimation equation employs a single-step GLM technique, it does not capture the individual effect of the sensory responsiveness. In order to estimate its unique effect, above and beyond that of all other variables, we employed a two-step hierarchical process, where we first excluded the high sensory responsiveness variable from our analysis, and then tested its effect on the residual values of the estimation process using a Gaussian GLM model. The analysis yields a significant effect for the variable, as well as a significant contribution to the model fit ($t = -4.31$, $\chi^2 = 6.47$f, PV<0.01).

5. Discussion

Exposure to war can cause intensified distress, manifested in trauma-related symptoms among civilians. The current study, which was conducted during Operation Guardian of the Walls, revealed a high prevalence of symptomatology. Frequencies of experiencing one symptom or more ranged from 27% to 83% for the four clusters of symptoms.

Exploring the clusters of symptoms revealed two profiles. The first was characterised by low levels in all 4 clusters of symptoms, while the second was characterised by high levels in all 4 clusters of symptoms. These findings, which are consistent with earlier studies that have revealed distinct profiles of post-traumatic reactions among survivors of varied traumatic events (Contractor et al., 2015; Hruska et al.,

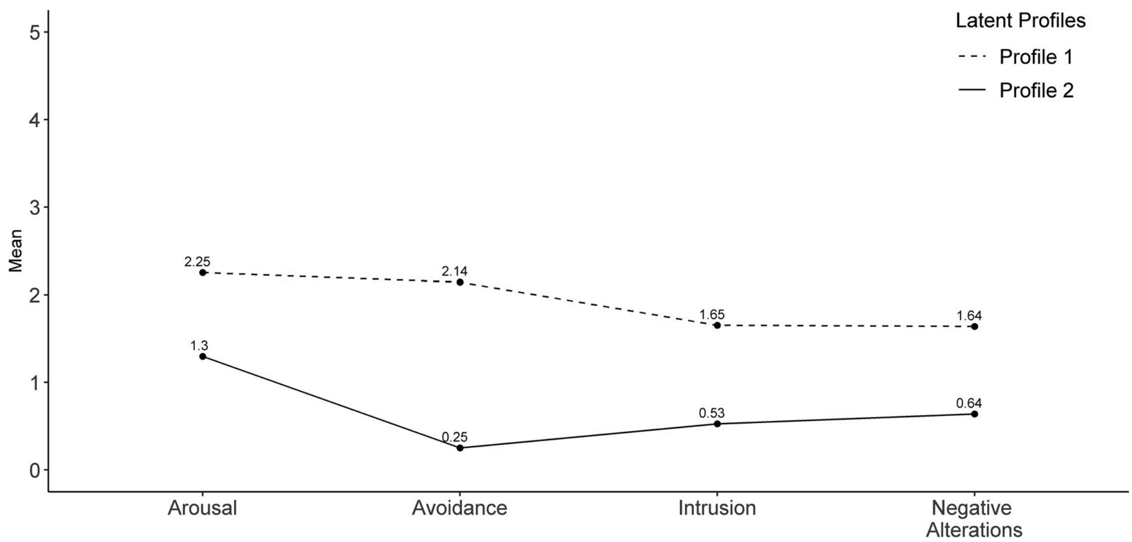

Figure 1. Centroid values for hyperarousal, avoidance, intrusion and negative alterations in mood and cognition according to profile.

2014; Sripada et al., 2020), suggest that there might be different profiles of trauma-related symptomatology during the peritraumatic phase as well. In addition, our findings, which indicated that most of our sample belonged to the low-level profile (78.7%), imply that, while most civilians might be resilient in the face of war trauma, a substantial number may suffer from intensified symptomatology. Given that peritraumatic reactions serve as a potent predictor for future PTSD (Ozer et al., 2003; Thomas et al., 2012; Vance et al., 2018) and given that trauma-related symptoms during the peritraumatic phase may be an initial marker at the basis of the development of PTSD (Gelkopf et al., 2019; Lapid Pickman et al., 2017; Neria et al., 2010), it might be that the high-level profile group identified in this study not only endured elevated symptomatology during the war, but were are also susceptible to PTSD. Therefore, identifying factors that explain elevated symptoms during the peritraumatic phase, which was the aim of this study, is imperative.

The innovation of this study, however, is its exploration of the relationship between sensory modulation and trauma-related symptoms during the peritraumatic phase. Thus far, the few studies that have explored the link between sensory modulation and psychological distress have been conducted after the trauma ended, or long after it had begun (Engel-Yeger et al., 2013; Yochman & Pat-Horenczyk, 2020). Hence, the current investigation, which assessed the contribution of sensory modulation in explaining initial responses to trauma, illuminates the role of the sensory domain in shaping distress in the peritraumatic phase, a subject that has heretofore been neglected.

The present findings revealed significant associations between high sensory responsiveness and all four clusters of trauma-related symptoms during the peritraumatic phase: higher levels of sensory responsiveness were related to elevated intrusion, avoidance, negative alterations in mood and cognition, and hyperarousal during the war. Moreover, our final model indicated that, ceteris paribus, the risk for the high symptoms profile was doubled (OR = 2.11) for each marginal increase in the SRQ-Aversive score. Notably, this relationship holds despite the somewhat weak initial correlation between high sensory responsiveness and the four symptoms clusters ($0.19 < r_p < .22$). Our results suggest that while high sensory responsiveness may be weakly linked with trauma-related symptoms during the peritraumatic phase, it considerably explains the general risk of suffering from elevated symptomatology. Given that various factors may be implicated in the link between sensory modulation and distress during trauma exposure, several processes may underlie the current findings.

The present findings imply that dysfunctional patterns of sensory modulation, manifested in high sensory responsiveness, could shape individuals' reactions to trauma at the time of exposure. Trauma, by definition, exposes individuals to adverse stimuli. In the context of rocket attacks, these adverse stimuli included the sounds of rocket being launched and exploded, the smell of fire, sights of destruction, and witnessing injuries. Individuals with high sensory responsiveness may experience these stimuli in an amplified matter (Miller et al., 2007), and therefore react with intensified distress.

Alternatively, other problems associated with high sensory responsiveness may contribute to their elevated symptomatology. Specifically, elevated distress and anxiety, poorer executive functions (Engel-Yeger & Rosenblum, 2021), and impeded functioning (Dunn et al., 2016; Engel-Yeger & Rosenblum, 2021), all of which were found to be related to high sensory responsiveness, could hamper individuals' ability to effectively cope with stressors, the more so with highly aversive and traumatic ones, such as war. Lastly, the present findings may also reflect the implications of distress during trauma exposure for sensory modulation. According to this explanation, individuals who suffered from elevated symptomatology experienced excessive stimulation of the central nervous system, which in turn eventuated in neural changes that hamper habituation to sensory stimuli, as reflected in high sensory responsiveness (Warner et al., 2013).

At the same time, however, we did not find evidence for adverse implications of low sensory responsiveness in the context of trauma-related distress. Low sensory responsiveness was unrelated to any of the clusters of symptoms and had a non-significant effect in explaining the risk for the high symptoms profile. These findings are surprising, given that previous studies indicated associations between low sensory responsiveness and trauma history (Howard et al., 2020) as well as PTSD (Engel-Yeger et al., 2013). We offer two main explanations for these results.

As noted above, contrary to earlier studies that assessed sensory modulation during the post-traumatic phase (Engel-Yeger et al., 2013), or a long time after the exposure to trauma had begun (Yochman & Pat-Horenczyk, 2020), the present investigation was conducted over a course of only seven days, when the present sample was exposed to rocket attacks. It might be that individuals with low sensory responsiveness and who have difficulties in detecting and reacting to stimuli in real time (Miller et al., 2007) also tend to overlook signs of distress during such a short period, particularly if they are subtle, and therefore under-reported their symptomatology, thereby preventing detection of a link between low sensory responsiveness and trauma-related symptoms during the peritraumatic phase.

Alternatively, it might be that low sensory responsiveness does have adverse effects in the context of trauma exposure, but that these implications are more pronounced in the long, rather the short, run. According to this explanation, individuals with low sensory responsiveness may not identify the threatening situation in which they find themselves in real time, but may instead react with a delayed or decreased response, as well as with reduced arousal and numbness (Miller et al., 2007). Although these reactions may not produce immediate distress, they may impede the individual's ability to reprocess the event and thus resolve the trauma experience, and this lack of resolution may lead to long-term consequences. Therefore, whereas low sensory responsiveness may be unrelated to symptomatology in the peritraumatic phase, as our findings suggest, it may nonetheless serve as a risk factor for PTSD, as former studied have implied (Engel-Yeger et al., 2013; Yochman & Pat-Horenczyk, 2020). Longitudinal studies assessing the implications of low sensory responsiveness over time, from the peritraumatic phase to the post-traumatic phase, and incorporating clinical interviews alongside self-reported measures are needed to explore these suppositions.

In line with former studies (Gelkopf et al., 2017; Hamam et al., 2021; Hammen et al., 2000; Irish et al., 2011; Lapid Pickman et al., 2017; Neria et al., 2010), we found that age, gender, history of mental disorder, elevated levels of perceived threat, and low perceived social support were all related to elevated trauma-related symptoms during the peritraumatic phase. Yet, in our final model, which explored the contribution of all of the study's variables in explaining the probability of belonging to the high symptoms profile, the only factors that were significant (in addition to high sensory responsiveness) were a history of mental disorder, perceived threat, and perceived social support.

Earlier studies have indicated that a pre-existing mental disorder may be a risk factor for peritraumatic symptomatology, as well as for PTSD (DiGangi et al., 2013; Gelkopf et al., 2017; Ozer et al., 2003). Individuals with pre-existing mental disorders may suffer from functioning difficulties as well as from emotion dysregulation (American Psychiatric Association, 2013), both of which could impede their ability to adaptively cope with trauma (Koenen, 2006; Siegel et al., 2021).

Our findings, which indicated that perceived threat explained the probability of belonging to the high symptoms profile, align with cognitive theories that underscore the importance of individuals' appraisals of the traumatic event in shaping their trauma-related symptomatology (Foa et al., 2006). The sense of threat experienced during traumatic events has been viewed as a risk factor for PTSD (Ozer et al., 2003), and has been found to mediate the relationships between trauma exposure and PTSD (Iversen et al., 2008; King et al., 1995; Renshaw, 2011). The current results, alongside earlier findings that explored reactions during trauma exposure (Lapid Pickman et al., 2017), add to the existing body of knowledge by revealing the role of perceived threat in explaining heterogenicity in trauma-related symptoms during trauma exposure.

Abundant research has indicated that poorer perceived social support increases the risk of future PTSD (Brewin et al., 2000; Guay et al., 2006; Ozer et al., 2003). Although more scarce, studies that explore peritraumatic reactions (Brunet et al., 2001; Neria et al., 2010) have revealed a similar pattern; that is, lower levels of perceived social support have been associated with elevated distress. Our findings provide further support for this association, indicating that lower perceived social support explained the probability of belonging to the high symptoms profile during rocket attacks. These findings may be explained by Cohen and Wills' (1985) stress-buffering model, which views social support as a powerful buffer against potential negative health effects subsequent to trauma exposure, and may reflect the effect of individuals' perceived social support in shaping their appraisals and responses during trauma exposure (Wills & Cleary, 1996).

The current study suffered from several limitations. First, the cross-sectional design precludes any conclusions regarding causal relations regarding the direction of the associations found between the study variables. Second, our sample was gathered online, potentially leading to a self-selection bias. Furthermore, this study was conducted among Israeli participants, relied on convenience sampling, and only included participants who provided data regarding the study variables. These limitations should be acknowledged prior to generalising from the results to other populations. Third, this study was based on self-reported data, which may be subject to response biases. Fourth, this study focused on trauma-related symptoms that occurred during exposure to ongoing rocket attacks, and did not explore other reactions which are known as peritraumatic responses, such as dissociation. Future prospective studies should explore the relation between sensory modulation difficulties and trauma-related responses and symptoms over time and among a variety of populations with diverse cultural backgrounds, while incorporating data from clinical interviews.

Despite these limitations, the current study enriches our understanding of the relations between sensory modulation difficulties and trauma-related symptoms during the peritraumatic phase. The present findings suggest that sensory modulation plays a role in shaping trauma-related symptomatology, and that individuals who suffer from high sensory responsiveness may be particularly susceptible to distress during exposure to trauma. Translating these results to the clinical realm suggests that sensory modulation evaluation may serve as an important screening tool for detecting vulnerable populations who have previously fallen under the radar. Furthermore, our findings suggest future directions for the development of secondary preventative interventions for PTSD. To date, several intervention programmes, such as Sensorimotor psychotherapy (Ogden et al., 2006) and Sensory Motor Arousal Regulation Treatment (Warner et al., 2013), aim to improve sensory modulation among trauma survivors. Implementing the sensory modulation strategies used in these interventions, such as Sensory Diet or Comfort Zone, as part of preventative interventions provided in the peritraumatic phase might be effective in alleviating distress among individuals with sensory modulation difficulties.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

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