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Context as a barrier: Impaired contextual processing increases the tendency to develop PTSD symptoms across repeated exposure to trauma

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A R T I C L E I N F O

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A B S T R A C T

Growing evidence links repeated traumatic exposure with impaired ability to process contextual information. Specifically, like individuals with PTSD, non-PTSD trauma-exposed individuals fail to react according to contextual demands. In the present study, we explored the process that underlies this impairment. First, we tested the ability of first responders to benefit from contextual primes to improve recognition. Second, we assessed its moderating role in the relationship between traumatic exposure and PTSD symptoms. Fifty-three active-duty firefighters and 33 unexposed civilians matched for age, gender, and years of education participated in the study. All participants completed the contextual priming paradigm, the CAPS-5 clinical interview, and the WAIS-IV vocabulary subtest and were assessed for depression and general traumatic exposure. Repeated traumatic exposure was assessed objectively using the fire-and-rescue-service tracking system. As predicted, we found that trauma-exposed individuals failed to use primes to facilitate rapid and accurate recognition of contextually related objects. Not only did contextual information not improve performance, but it achieved the opposite effect, manifested as negative priming. Hence, context appeared to be an obstacle for trauma-exposed individuals and delayed rapid and accurate recognition. Moreover, impaired ability to process contextual information predicted the tendency to develop PTSD symptoms across repeated exposure to trauma.

1. Introduction

Many individuals are repeatedly exposed to traumatic incidents or experience prolonged stress as part of their everyday life, for example, first responders, civilians living in conflict zones, and individuals who suffer continuous sexual abuse. A growing number of studies suggest that individuals with repeated traumatic exposure may pay a hidden price. Hence, although they do not tend to develop Post-Traumatic Stress Disorder (PTSD) and often show a minimal level of symptoms, they may experience various dysfunctions (e.g., Acheson et al., 2015; Huskey et al., 2022; Kessler et al., 2010; Levy-Gigi & Richter-Levin, 2014; Levy-Gigi et al., 2014). Neuroimaging studies have shown that both PTSD and non-PTSD individuals who experienced repeated traumatic exposure may exhibit deficits in hippocampal structure and function (see Karl et al., 2006; Smith, 2005; Woon et al., 2010 for meta-analyses). Animal and human models propose that such deficits may result in an impaired ability to process contextual information (Acheson et al., 2012, 2015; Flor & Nees, 2014; Goosens, 2011; Liberzon & Abelson, 2016; Moustafa et al., 2013; Pohlack et al., 2015; Rudy, 2009; Shalev et al., 2017; Steiger et al., 2015, for review, see Joshi et al., 2019; Maren et al., 2013). The goal of the present study was to test impairments in processing contextual information in a unique population of active-duty firefighters who experience traumatic events as part of their daily routine and to investigate the possible role of this impairment in the relationship between levels of traumatic exposure and the tendency to develop PTSD symptoms.

A set of studies that aimed to test contextual processing has used the cue-context reversal learning paradigm (Haim-Nachum & Levy-Gigi, 2021; Levy-Gigi & Richter-Levin, 2014; Levy-Gigi et al., 2014; Sopp et al., 2022). In the first phase of this paradigm, the participants first learn a set of positive and negative stimulus-outcome associations (i.e., different boxes, each one has a unique context and a unique cue, half are associated with a positive outcome and half with a negative outcome, for example, an orange box with a car image has gold inside if you open it). In the second phase, the original boxes are presented (positive boxes remain positive and negative remain negative), in addition to new boxes, which share either the same cue or the same context with the original box but have an opposite outcome (a grey box with a car image

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or an orange box with a phone image- both associated with a negative outcome). The results revealed that trauma-exposed individuals show a selective context-related impairment compared to unexposed controls. Specifically, after learning that a specific context is associated with a negative outcome, trauma-exposed individuals struggle to learn that the same context is associated with a positive outcome, even when the context is presented with a new cue. A different study showed that individuals with repeated traumatic exposure are highly alerted independent of the contextual conditions. Hence, they show high alertness not only in high-intensity aversive conditions but also in low-intensity conditions when such behavior is no longer adequate (Levy-Gigi et al., 2016a).

Moreover, it was demonstrated that the impaired ability to behave in accordance with contextual demands is also reflected in difficulty in choosing the most adaptive emotion-regulation strategy that best suits the aversive situation (Levy-Gigi et al., 2016b). Finally, it was found that trauma-exposed individuals struggle to use contextual information to disambiguate cues associated with threat and safety (Acheson et al., 2015; Husky et al., 2022; Kessler et al., 2010; Liberzon & Abelson, 2016; Maren et al., 2013). Taken together, these results may explain, for example, why soldiers who returned from the battlefield may react with fear during a firework display, although they are in a safe, non-threatening environment.

These studies clearly demonstrate the difficulty of individuals with repeated traumatic exposure to modify their behavior in accordance with changing contextual demands. However, the specific nature of this deficit and its possible relationship with PTSD symptoms severity deserves further investigation. Specifically, it is unclear whether this deficit relates to a preliminary impairment in encoding contextual information or a subsequent impairment in integrating contextual information with additional relevant knowledge. To tease apart these different aspects of contextual processing, we compared the performance of individuals with repeated traumatic exposure and unexposed controls on a contextual priming paradigm.

In this paradigm, the prime and target images are presented one after the other (see Fig. 1). We used three types of prime-target pairs: (1) context-related pairs- the prime and the target images were from the same thematic world; for example, if the prime was an image of a toque, the target image was an oven. (2) context-unrelated pairs- the prime and the target images were from different thematic worlds, for example, a toque and a zebra. (3) prime-non-object pairs- in this case, the prime image, e.g., a toque, was followed by a target image of an obscure shape. The participants had to indicate whether the target image was a common object or an abstract non-object image (see Fig. 1). Since the identification of different stimuli (i.e., objects or words) is strongly related to the contextual scenes in which they are likely to occur (Bar, 2004; Biederman, 1981; Chaigneau et al., 2009; Heit, 1996; Palmer, 1975; Smith et al., 2018), we expect to find facilitated recognition (i.e., priming effect), demonstrated by shorter reaction time to context related, compared to unrelated images (Meyer & Schvaneveldt, 1971).

This paradigm allows the differentiation between various impairments in contextual processing. If the contextual information (i.e., the prime) is encoded and well-integrated in the memory framework, it will activate context-related associations (Antes et al., 1981; Bar, 2004; Bar & Aminoff, 2003; McCauley et al., 1980), which will fasten the recognition of the related target image (Bar, 2004), demonstrating a prime effect. If the prime is not encoded, we will see no differences in reaction time between context-related and unrelated images. Finally, if the context is encoded but not well integrated, unrelated images will be recognized faster than related ones.

To the best of our knowledge, our study is the first to test **contextual** priming in trauma-exposed individuals. Previous studies that tested the priming effect in trauma-exposed individuals have used different variations of the word-stem completion task (Ehring & Ehlers, 2011; Lyttle et al., 2010; Michael et al., 2005). In this task, trauma-related and unrelated aversive words were matched with neutral words with the same frequency and initial letters (e.g., victim-vicar). In the first phase of the word-stem completion task, the participants see the word pairs. In the second phase, they see the stems of the presented words (e.g., vic) and need to complete them. The results reveal a higher completion rate (i.e., priming effect) for trauma-related words. While important, this paradigm does not allow controlling for possible effects of explicit memory

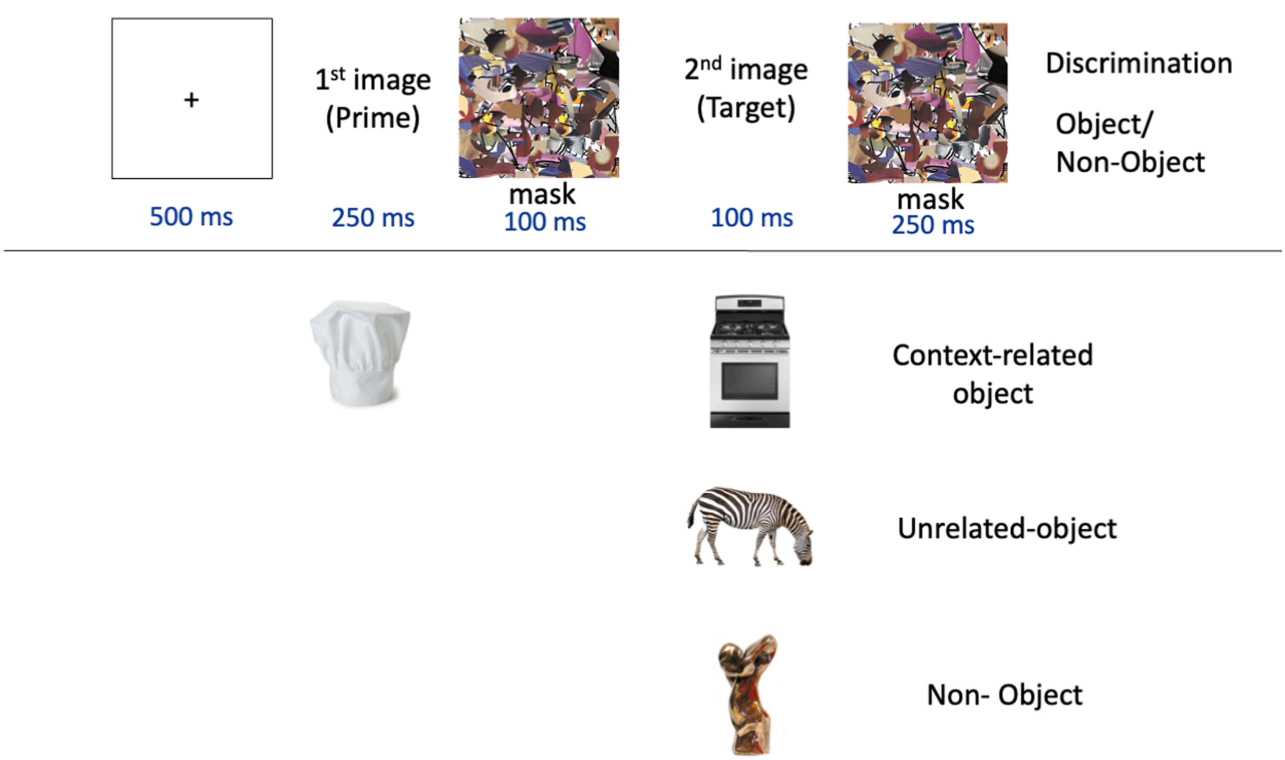

Fig. 1. Illustration of the Contextual Priming paradigm.

traces of the trauma-related words (e.g., Jacoby et al., 1993; Tulving et al., 1982). Hence, it is impossible to make significant conclusions regarding the role and impact of contextual processing. On the other hand, the contextual priming paradigm uses neutral images that eliminate possible effects of explicit memory and allow the assessment of a general (non-trauma-related) contextual priming deficit.

Our first aim was to explore whether repeated traumatic exposure impairs the ability to process contextual information. This was done by comparing the performance of trauma-exposed and unexposed individuals. If both trauma-exposed and unexposed participants show a priming effect, traumatic exposure does not affect encoding and integrating contextual information when neutral images are presented. If trauma-exposed individuals do not show a priming effect, it may suggest that they fail to encode and integrate contextual information. Finally, suppose the reaction time to unrelated images is faster than related images; it will imply that traumatic exposure is associated with a selective impairment in integrating contextual information, whereas the encoding of this information is intact.

Our second aim was to test whether the ability to process contextual information may help explain the illusive relationship between repeated traumatic exposure and the tendency to develop PTSD symptoms. Despite the well-known negative ramifications of repeated traumatic exposure, the direct link between levels of exposure and PTSD severity is unclear. Some studies show that continual exposure to trauma is associated with greater symptom severity; others reveal that such exposure encourages adaptation and promotes resilience (see Greene et al., 2018 for review). One explanation for these contradicting findings is that other variables moderate the relationship between repeated traumatic exposure and PTSD severity. Here we suggest that one possible moderator relates to the ability to process contextual information. This influence will be measured above and beyond the effect of other established correlates of PTSD symptoms, including general (non-duty related) traumatic exposure, depressive symptoms, and IQ scores which have been previously associated with PTSD symptoms (e.g., Breslau, Chen, & Luo, 2013; Brewin, Andrews, & Valentine, 2000; Heim & Nemeroff, 2001; Kolkow et al., 2007; Orr et al., 2012). Based on previous results (Levy-Gigi et al., 2014, 2016a, 2016b), we anticipated that while trauma-exposed individuals with impaired ability to benefit from contextual priming will show an increased level of PTSD symptoms across exposure time, trauma-exposed individuals who can benefit from contextual priming will show no such connection.

The current study focuses on a unique population of active-duty firefighters repeatedly exposed to various potentially traumatic events as part of their daily routine (Levy-Gigi et al., 2011). Like other studies, to discriminate the effect of repeated traumatic exposure from the possible effects of threshold PTSD, we focused only on non-PTSD participants (Haim-Nachum et al., 2022; Haim-Nachum & Levy-Gigi, 2019, 2020, 2021; Levy-Gigi et al., 2014; Levy-Gigi & Richter-Levin, 2014; Sopp et al., 2022). To distinguish the effect of duty-related traumatic exposure and eliminate the effects of the participants' backgrounds, we measured and controlled the exposure to general potential traumatic events (for a similar method, see Levy-Gigi et al., 2011). Finally, since depression and IQ are significantly correlated with the severity of PTSD symptoms and may affect the ability of individuals to complete a performance-based paradigm, we also controlled for their effect. Hence the reported results are above and beyond these possible individual differences.

2. Methods and materials

2.1. Participants

The sample size was calculated using G*Power software (Faul et al., 2007). Based on a previous study that tested contextual processing in a similar population (Levy-Gigi, Richter-Levin, & Kéri, 2014), we conducted a-priori power analysis for repeated measures ANOVA. This revealed a need for 80 participants based on the ability to detect a medium-size effect (Cohen's f=.25) in the study, with a 5 % significance level (α) and 80 % power level (1-β) (Cohen, 1992). Based on these results, 89 individuals were recruited to participate in the study. Exclusion criteria included any current DSM-5 psychopathology, including PTSD, and any history of psychiatric or neurological disorders, alcohol abuse, or dependence.

Three firefighters were excluded from the sample due to a clear diagnosis of PTSD. The remaining 86 volunteers (53 active-duty firefighters and 33 unexposed civilians matched for age, gender, and years of education) participated in the study. See Table 1 for a detailed description of the sample. Firefighters were randomly recruited from six fire stations in south Israel, all located in a similar setting within a radius of 35 miles. All firefighters reported multiple exposures to DSM-5 Criterion A events (see more details in the following section on traumatic exposure). The unexposed group included thirty-three civilians who work in a data-mining company. They were recruited by a clinical psychologist that interviewed them to ensure no past exposure to DSM-5 criteria A events. The investigation was carried out in accordance with the Declaration of Helsinki. The study design was reviewed and approved by the Bar-Ilan University ethical committee (Approval #90). All participants provided written informed consent at the beginning of the experiment after the nature of the procedure was fully explained.

2.2. Measures

2.2.1. The contextual priming paradigm

The paradigm includes 80 sets of pictures. Each set contained a prime (image of different common objects, e.g., a toque) and three target images: (1) an image of a context-related object (e.g., an oven); (2) an image of a context-unrelated object (a zebra); and (3) an abstract image (see Fig. 1). In each trial, the participants briefly saw the prime, followed by one of the three target images (either context-related, unrelated, or abstract images, see Fig. 1). The aim of the participant was to judge if the target image showed a common object or a non-object (i.e., an abstract image). Participants completed eight practice trials (2 contextual trials, two unrelated trials, and four non-object trials) before starting the actual task, which included a total of 240 trials (80 context-related pairs, 80 unrelated pairs, and 80 prime-abstract image pairs) that were presented in random order. The dependent variable was the reaction time of the correct discrimination trials in each of the three experimental conditions (context-related, context-unrelated, non-object).

Table 1
Demographic characteristics, cognitive assessment, and clinical symptoms (Means and Standard Deviations) of the trauma-exposed firefighters and the unexposed matched- controls.

	Trauma-exposed firefighters (N = 53)	Unexposed controls (N = 33)	Comparison between the groups
Age (years)	35.77 (8.76)	35.24 (4.0)	$t = .33; p = .74$
Male/female	48/5	30/3	
Education (years)	12.57 (1.17)	12.73 (1.1)	$t = -.64; p = .53$
IQ Scaled Scores	10.1 (1.94)	10.55 (1.33)	$t = -1.27; p = .21$
Medications* (N)	4/53	2/33	
In-Service Time (years)	7.53 (8.1)	N/A	
PTSD Symptoms	24.11 (21.64)	N/A	
Depressive Symptoms	4.55 (6.92)	6.64 (5.73)	$t = -1.45; p = .15$

*4 trauma- exposed participants and 2 unexposed control participants received benzodiazepine.
PTSD symptoms as measured by the Clinician Administrated PTSD Scale (CAPS-5); Depressive symptoms as measured by the Beck Depression Inventory (BDI-II), IQ scores as estimated by the WAIS-IV vocabulary subtest.

2.2.2. Traumatic exposure

To evaluate the accumulative symptomatic effect of repeated traumatic exposure during active fire and rescue service, we applied an innovative approach that concentrates on two types of measures (see also Levy-Gigi et al., 2016a). First, we took advantage of the new fire-and-rescue-service tracking system, which documents the number, type, and severity of traumatic events that each active-duty firefighter experiences daily. Second, we administered the life stressful events questionnaire (Vrana & Lauterbach, 1994), which inquired about types of traumatic events unrelated to active duty (e.g., death of a family member, history of domestic violence). The questionnaire provides discriminant information regarding duty-related traumatic exposure measures. Taken together, these two measures allow for assessing duty-related traumatic exposure while controlling for possible effects related to the type and occurrences of traumatic events that are not part of active service or precede the active-duty period of the participants.

2.2.3. PTSD assessment

Trauma-exposed participants were interviewed using the Clinician Administrated PTSD Scale (CAPS-5) (Weathers et al., 2013) to assess subthreshold PTSD symptoms.

2.2.4. Control variables

To control for possible effects of depression and IQ, the participants completed (1) The Beck Depression Inventory (BDI–II; Beck et al., 1996, Cronbach's α = .89). (2) The vocabulary subtest of the Wechsler Adult Intelligence Scale IV (WAIS-IV) that highly correlates with general IQ scores (Wechsler, 2008).

2.3. Procedure

The experimenter met the participants, described the aim of the study, and asked them to sign a written consent form. All the participants were screened for psychopathology using the Structured Clinical Interview for *Diagnostic and Statistical Manual for Mental Disorders-Forth Edition* (SCID-5 RV, First et al., 1996). Then they went over the instructions for the contextual priming task. The experimenter ensured the participant knew the response keys and stayed in the room during the 8-trail practice phase. The experiment began at the end of the practice phase after the experimenter ensured that the participants fully understood the task. After completing the task, the participants filled out the self-report questionnaires. The experimenter conducted the vocabulary subtest. Clinical interviews were conducted by a well-trained and regularly supervised clinical psychologist.

2.4. Data analysis

We used SPSS (version 27) software (SPSS Inc., IL, USA). All data were checked for normality of distribution using Kolmogorov–Smirnov tests. Data from trials where the RT was faster than 100 ms or slower than 3000 ms (less than 0.1 % of the trials) were excluded from the analysis. We used repeated measures ANOVA with follow-up paired samples t-tests to assess the priming effect in trauma-exposed and unexposed individuals. We used Hayes's moderator macro (2013) to assess the moderating role of contextual processing in the relationship between traumatic exposure and PTSD symptom severity.

3. Results

3.1. Differences in the ability to process contextual information

We conducted a Group (trauma-exposed firefighters vs. unexposed controls) by Target Type (context-related vs. context-unrelated) repeated-measures ANOVA on the reaction time in correct discrimination trials. Age, gender, and education served as covariates. The results are presented in Fig. 2. We revealed a significant interaction between

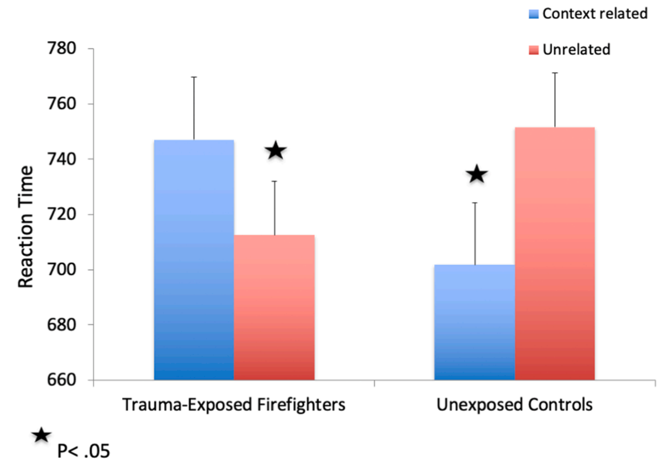

Fig. 2. Reaction time in correct discrimination trials as a function of Group (trauma- exposed firefighters vs. unexposed matched controls) and Prime Type (context related vs. Unrelated objects).

Priming Type and Group (F(1,81) = 9.45, p = .003, η_p^2 = .10). Follow-up paired samples t-test with Bonferroni correction (α = .025) revealed that in unexposed controls reaction time for context-related images is significantly shorter compared to the reaction time to unrelated images (t(32) = 2.13, p = .04). On the other hand, in trauma-exposed firefighters, the reaction time for context-related images is significantly longer compared to unrelated images (t(52) = −2.14, p = .04). These results indicate that while unexposed controls can benefit from context-related priming, individuals with repeated traumatic exposure display the opposite effect. Specifically, it takes them longer to react to context-related compared to context-unrelated images. Hence, while their ability to encode contextual information remained intact, they failed to integrate contextual information to guide behavior.

3.2. The moderating role of the ability to integrate contextual information

To examine our prediction regarding the moderating role of the ability to integrate contextual information in the relationship between repeated traumatic exposure and PTSD symptoms, we employed Hayes's (2013) PROCESS macro using 5000 bootstraps resampling for the calculation of confidence intervals (model 1) (For the advantages of using this macro see Hayes, 2009) on the trauma-exposed participants. Repeated traumatic exposure, contextual priming, and PTSD symptoms were treated as independent, moderator, and outcome variables. General traumatic exposure, depression, and IQ served as the control variables.

The estimated coefficients of the main findings and their significance levels are described in Table 2. The general model was significant (R^2 = .39, F (6, 46) = 4.92, p = .001). Core analyses revealed that consistent with previous findings, general traumatic exposure had a significant main effect on the level of PTSD symptoms (Brewin et al., 2000; Heim & Nemeroff, 2001). However, there was no main effect of contextual processing and repeated traumatic exposure. Importantly, consistent with our hypothesis, there was a significant interaction between repeated traumatic exposure and contextual priming. This interaction accounted for an additional 6.3 % of the variance above and beyond the variance explained by the main effect and depressive symptoms, IQ scores, and general traumatic exposure, which are established correlates of PTSD.

To interpret the interactive effect of repeated traumatic exposure and contextual priming on PTSD symptoms, we computed bootstrapping confidence intervals (95 %), evaluating the magnitude of the relationship between repeated traumatic exposure and PTSD symptoms for individuals with low (−1 SD) and high contextual priming (+1 SD). As

Table 2
Estimated coefficients, standard errors, and 95 % confidence intervals for control, independent and moderator variables in the model predicting PTSD symptoms in trauma-exposed firefighters.

Variables	B	*S.E*	*t* value	*p* value	95 % Confidence interval Low	High
Control Variables						
General Traumatic Exposure	4.73	1.62	2.99	.01	1.48	7.98
Depressive Symptoms	.38	.50	.76	.45	-.62	1.38
IQ Scores	-2.21	1.76	-1.25	.22	-5.75	1.33
Predictors Repeated Traumatic Exposure	.01	.01	1.51	.14	-.004	.03
Contextual Priming	.01	.02	.29	.77	-.05	.06
Traumatic Exposure X Contextual Priming	-.0001	.00	-2.18	.03	-.0003	.00
Traumatic Exposure X Contextual Priming (Without control variables)	-.0001	.00	-2.13	.03	-.0003	.00

B, unstandardized estimated coefficient; S.E., standard error; Depressive symptoms as measured by the Beck Depression Inventory (BDI-II), IQ scores as estimated by the WAIS-IV vocabulary subtest.

expected, the results revealed a significant positive relationship between repeated traumatic exposure and PTSD symptoms for individuals with a low ability to benefit from contextual priming (β = .02, CI 95 % [.003,.04], $t(52) = 2.37$, $p = .02$). However, no relationship between repeated traumatic exposure and PTSD was found among individuals with a high ability to benefit from contextual information (β = −.004, CI 95 % [−.03,.02], $t(52) = -.33$, $p = .74$). These results indicate that among individuals with low (but not high) ability to benefit from contextual information an increase in traumatic exposure is associated with enhanced PTSD symptomatology.

Two additional points are worth noting. First, the interaction between repeated traumatic exposure and contextual priming was not restricted to a model that includes measures of depressive symptoms, IQ scores, and general traumatic exposure as control variables. Specifically, it was also evident when these control variables were not included (Table 2), accounting for 7.2 % of the variance above and beyond the variance explained by the main effects. Second, given our conceptual focus on trauma, it was important to show that the interaction between contextual priming and repeated traumatic exposure was specific to PTSD and not depressive symptoms, especially given the high correlation between these two pathologies in our sample. To that end, we ran a similar analysis to the main analysis, in which depressive symptoms served as the dependent variable, and PTSD symptoms were entered as a control variable. In this analysis, the model was insignificant, and there was no interaction between contextual priming and repeated traumatic exposure ($F(1,48)= .62$, $p = .44$).

4. Discussion

The present study aimed to investigate the ability of individuals with repeated traumatic exposure to process contextual information and its moderating role in the relationship between traumatic exposure and PTSD symptoms. To that end, we concentrated on a unique population of active-duty firefighters. First, we compared their performance on a contextual priming paradigm with the performance of unexposed matched controls. Second, we examined whether their performance interacts with levels of traumatic exposure to predict PTSD symptoms severity.

The results revealed that individuals with repeated traumatic exposure could encode contextual primes; however, as opposed to unexposed controls, they could not use them to facilitate subsequent rapid recognition of related objects. The results align with our previous findings in individuals with repeated traumatic exposure that demonstrated an impaired ability to process contextual information and react accordingly. Specifically, after learning that a certain contextual condition is negative, they struggle to learn that the same context changes its valance (Levy-Gigi & Richter-Levin, 2014; Levy-Gigi et al., 2014; Sopp et al., 2022). In addition, they fail to modify their behavior according to negative intensity levels and react similarly in aversive conditions with either high or low intensity (Levy-Gigi et al., 2016a, 2016b).

Most importantly, our results shed new light on the nature of this impairment. Specifically, we showed that contextual primes not only lacked any facilitation effect in trauma-exposed participants but also impaired object recognition. Specifically, whereas unexposed controls recognized context-related images faster than context-unrelated images, individuals with repeated traumatic exposure displayed an opposite pattern, with better recognition of context-unrelated than related objects. The fact that contextual primes altered recognition may suggest that both groups could encode the contextual information and activate a context frame after viewing the contextual prime. For example, among all the participants, an image of a toque activated other context-related images such as oven, stove, dinner, etc. However, while unexposed individuals could use this frame to facilitate recognition of context-related objects, trauma-exposed individuals failed to integrate it with related available information adequately. Hence, the recognition of context-related objects was delayed.

These results indicate that context may be a barrier for individuals with repeated traumatic exposure. Specifically, the contextual information slows down instead of promoting rapid and accurate categorization and discrimination of related objects. Possible support for this view may come from the elemental representation model (Rudy, 2009; Rudy et al., 2004). According to this model, a hippocampal deficit may facilitate elemental instead of conjunctive representations of past aversive experiences. Hence, elements present together with aversive events are encoded individually and become independently associated with the contextual situation. Since our participants were exposed to many traumatic events in various contextual conditions, this representation may characterize their entire perception. Hence, instead of having typical contextual frames (e.g., toque, oven, stove, dinner), they have extended frames that include other elements which do not naturally belong to them. Therefore, each contextual prime may activate an extremely wide range of elements. These elements may increase the attentional load and, as a result, may impede rapid recognition.

Alternatively, it is possible that presenting context-related information results in a negative priming effect (Mayr & Buchner, 2007). According to the episodic retrieval model, in conditions of negative priming effect, the primes suppress the retrieval of context-related information and flag the brain 'do-not-respond.' Hence, when the brain reacts to this information, the tag causes a conflict that delays subsequent recognition, as observed in the current study. However, why would individuals with repeated traumatic exposure suppress context-related information? One potential answer may relate to the professional demands of the firefighters who participated in this study. These individuals must function in aversive conditions, including fires, car accidents, and terror attacks (Supplemental Table 1). In these conditions, it is important to suppress irrelevant contextual information to achieve optimal functioning. For example, thoughts about the identity of the victims, their suffering, and the sorrow that might be caused to their relatives may impair the ability to function professionally at the incident scene. Suppressing this contextual information may represent a normal and adaptive reaction to abnormal situations. However, it might be overgeneralized to other neutral, everyday situations where it is no longer adequate. This view is in line with other studies, which showed inappropriate overgeneralization in both individuals with PTSD (Acheson et al., 2012, 2015; Levy-Gigi et al., 2012, 2015) and non-PTSD individuals with repeated traumatic exposure (Haim-Nachum & Levy-Gigi, 2021; Levy-Gigi & Richter-Levin, 2014; Levy-Gigi et al., 2014, 2016a; Sopp et al., 2022; Zabag et al., 2020).

To the best of our knowledge, this is the first study to test contextual priming in trauma-exposed individuals. Previous studies which used the word-stem completion task revealed an increased priming effect for trauma-related words (Lyttle et al., 2010; Michael et al., 2005). This may suggest that the traumatic experience and its related context improve performance. However, it does not allow the evaluation of contextual processing in neutral conditions. Moreover, since the participants encoded the trauma-related words before the completion task, the results may reflect cognitive mechanisms other than contextual processing. The task that was used in the current study enables a focused examination of contextual processing. Moreover, trauma-exposed individuals showed altered performance while using neutral primes. These results add to previous findings which showed impaired performance in neutral contextual conditions, suggesting an overall effect on the ability of trauma-exposed individuals to process contextual information adequately (Levy-Gigi et al., 2014, 2015; Levy-Gigi & Richter-Levin, 2014, Haim-Nachum et al., 2022).

Importantly, the impaired ability to process contextual information affected the well-being of our trauma-exposed participants by moderating the relationship between traumatic exposure and PTSD symptoms. Specifically, we found that firefighters with low, but not high, ability to process contextual information showed a significant positive association between levels of traumatic exposure and PTSD symptoms. Hence, these firefighters were more prone to develop PTSD symptoms over repeated exposure to trauma. The interactive relationship between traumatic exposure and the ability to process contextual information was significant even when we controlled for individual differences in exposure to general traumatic life events, depression severity, and IQ scores. Moreover, we showed considerable specificity as it was associated with PTSD and not depressive symptoms.

The study has important clinical implications. First, it suggests that the contextual priming paradigm provides a more sensitive tool for evaluating clinical and subclinical levels of PTSD rather than relying exclusively on the formal dichotomic diagnostic criteria of the DSM. Specifically, impairment in contextual processing predicted continuous levels of PTSD symptoms. Our approach also represents a general shift in the field that looks at clinical disorders as continuous rather than dichotomous entities (e.g., Cuthbert & Kozak, 2013). As such, the paradigm may function as a complimentary screening tool when recruiting individuals to professions that are expected to involve repeated exposure to trauma.

Second, the findings suggest that inappropriate processing of contextual information plays a significant role in PTSD etiology and symptomology, explaining why trauma-exposed individuals demonstrate inappropriate fear generalization and threat detection. This may have therapeutic implications where improving contextual processing during treatment may result in better responses that can buffer the deleterious consequences of traumatic events.

Finally, the results of the current study are especially important in light of the approach, which emphasizes the resilience of trauma-exposed individuals (e.g., Bonanno et al., 2004; Galatzer-Levy et al., 2018). This approach received extensive support from studies that showed a relatively low prevalence of PTSD diagnosis in first-responders (Chang et al., 2008; Del Ben et al., 2006; Fushimi, 2012; Myers et al., 2013; Soo et al., 2011; see Orr et al., 2012; Pole et al., 2009 for prospective studies). However, our results add to growing evidence suggesting that although not diagnosed with PTSD, individuals with repeated traumatic exposure do pay the price, demonstrated by their failure to adequately process contextual information (Haim Nachum & Levy-Gigi, 2021; Hennig-Fast et al., 2009; Levy-Gigi & Richter- Levin, 2014; Levy-Gigi et al., 2014, 2016a, 2016b; Steudte-Schmiedgen et al., 2014; Sopp et al., 2022).

The current study has several limitations. First, it was designed to detect possible effects of repeated traumatic exposure among active-duty, highly functioning first responders. To focus on the unique effect of repeated traumatic exposure, we excluded trauma-exposed individuals diagnosed with PTSD. Previous findings suggest that individuals with PTSD show similar impairments (Acheson et al., 2012; Levy-Gigi et al., 2012; Levy-Gigi & Kéri, 2012; Zabag et al., 2020); however, future studies may aim to directly compare the performance of threshold and subthreshold PTSD individuals who experienced repeated traumatic exposure on the contextual priming paradigm. This may allow conclusive results regarding the effects of repeated traumatic exposure and PTSD diagnosis on contextual processing. In addition, due to the size of our sample, we could not evaluate the possible associations between performance and specific clusters of PTSD symptoms (e.g., Levy-Gigi & Kéri, 2012; Kostek et al., 2014). Future studies with larger enrollment may aim to investigate this connection further.

Moreover, since we compared active-duty firefighters to unexposed civilians, it is possible that variables related to job selection and not traumatic exposure affected our results (for further discussion, see Levy-Gigi, Richter-Levin & Kéri, 2014). To minimize possible differences, the two groups were matched for age, gender, and education. Future prospective studies may aim to test firefighters' trainees before traumatic exposure and follow them through service to tease apart possible effects of job selection and traumatic exposure. Finally, the cross-sectional examination of individuals with repeated traumatic exposure does not allow testing whether the impaired ability to process contextual information functions as an antecedent or consequence of PTSD symptoms. However, it is important to note that whether the impaired ability to process contextual information is an antecedent or consequence of PTSD, our study provides proof that it is an important variable in the relationship between traumatic exposure and PTSD symptoms. Nevertheless, a longitudinal study is needed to establish its causal role as a vulnerability or consequential factor.

In conclusion, the present study supports the proposal of impaired contextual processing in individuals with repeated traumatic exposure. Specifically, it shows that while they can encode and activate contextual information, it may function as a barrier and impede the rapid recognition of related objects. Moreover, the results suggest that impaired contextual processing plays a moderating role in the relationship between repeated traumatic exposure and levels of PTSD symptoms. These findings help better understand the failure of trauma-exposed individuals to react in accordance with changing situational demands and emphasize its significant impact on the probability of developing PTSD symptoms across repeated exposure to trauma.

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CRediT authorship contribution statement

ELG Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Formal Analyses, Writing - original draft; ES Project administration, Visualization; MB Conceptualization, Formal Analyses. All authors review & editing the final version of the manuscript.

Declaration of Competing Interest

The authors report no conflict of interest. The authors alone are responsible for the content and writing of the paper.

Data Availability

The authors do not have permission to share data.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.janxdis.2023.102765.

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