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To Be or Not to Be Flexible: Selective impairments as a means to differentiate between depression and PTSD symptoms

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ABSTRACT

During the course of their lives, most individuals experience at least one potentially traumatic event. For some individuals this experience may result in them developing depression and/or post-traumatic stress disorder (PTSD) symptoms. The aim of the present study was to test the interactive effect of traumatic exposure and impaired cognitive flexibility on the tendency to develop either depression or PTSD symptoms. Eighty-two college students (*M* age = 25.32, *SD* age = 4.09) were assessed for exposure to traumatic events, depressive and PTSD symptoms. In addition, they completed a performance-based learning paradigm to evaluate the unique patterns of cognitive flexibility, defined as reduced and enhanced updating of prior knowledge in the face of new information. We predicted and found that for individuals with reduced updating, greater exposure to trauma was associated with elevated depressive symptoms. Contrary to our prediction, for individuals with enhanced updating, greater exposure was associated with elevated PTSD symptoms. While cognitive flexibility is traditionally associated with adaptive outcomes, our results illuminate the important role of a delicate updating balance to adaptively cope with aversive life events. The findings highlight the possible different roles of cognitive flexibility in the development of psychopathology and may serve as a first step toward developing tailored prevention and treatment methods.

Trauma exposure is a major risk factor for developing various mental disorders, with depression (Gabrys et al., 2018; Shapero et al., 2014) and post-traumatic stress disorder (PTSD) (Kliem and Kröger, 2013; Mandavia and Bonanno, 2019) being the most prevalent. Indeed, such exposure almost doubles the risk of depression (Norman et al., 2012) and is the primary criterion for PTSD (APA, 2013). However, the link between levels of trauma exposure and the severity of symptoms is inconsistent. While several studies show an increase in depression and PTSD symptoms following repeated traumatization (Karam et al., 2014; Wang et al., 2010; Wang et al., 2020), others find no such direct effects (see Declercq et al., 2011; Kaurin et al., 2018; Meyer et al., 2012; Pietrzak et al., 2014). This inconsistency might be explained by various differences between individuals, as these influence how and when symptoms appear and progress (Schnell et al., 2020; Wild et al., 2016). One such factor is an individual's level of cognitive flexibility.

Cognitive flexibility is broadly defined as the ability to update beliefs and to modify or adjust behavior in accordance with changes in situational demands (for a review, see Dajani and Uddin, 2015). A major impairment in cognitive flexibility is maladaptive, enhanced or reduced *updating* of prior knowledge in the face of new information (Levy and Wagner, 2011). Following trauma, such an impairment might lead to difficulties in differentiating between threatening and safe signals and conditions. For example, enhanced updating of new negative information might lead a person who has been assaulted in an elevator to avoid using elevators, even in crowded buildings. Reduced updating of new positive information might lead an individual who has been physically attacked to fail to notice demonstrations of affection and perceive every social encounter as hostile.

A growing body of evidence shows that enhanced and reduced updating creates vulnerability to the symptom development of both depression (e.g., Fresco et al., 2006; Gabrys et al., 2018; Hou et al., 2016; Lam et al., 2014; Perini et al., 2019; Stange et al., 2017) and PTSD (Ben-Zion et al., 2018; Brown et al., 2013; Haim-Nachum and Levy-Gigi, 2019; Levy-Gigi et al., 2012) following trauma exposure. Specifically, it has been found that individuals who struggled to adaptively update their behavior to meet new demands were less likely to cope well with traumatic events, and eventually experienced depression, as compared to those who were able to appropriately update and modify their behavior

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to meet their goals (Dickstein et al., 2010; Dombrovski et al., 2010; Janacsek et al., 2018; Joormann and Siemer, 2011; Murphy et al., 2012; Robinson et al., 2012; Stange et al., 2017). Similarly, impaired updating was associated with elevated PTSD symptoms (Daneshvar et al., 2020; Keith et al., 2015), while an adaptive updating following neurocognitive training was correlated with reductions in PTSD symptoms (Ben-Zion et al., 2018; Chaby et al., 2019).

While both depression and PTSD share certain similarities that might explain impaired updating (i.e., rumination in depression and intrusion/hyperarousal in PTSD), there are also differences between the two disorders – both in etiology and symptomatology – that may be associated with distinct updating patterns (e.g., Barrera-Valencia et al., 2017). However, the unique nature of these updating patterns and their relationship with each of these symptoms are not yet clear. The aim of the present study was to test the interactive effect of traumatic exposure and impaired updating on the tendency to develop symptoms of either depression or PTSD. Exploring unique updating patterns, and the associated variations in trajectories following traumatic exposure, might inform both researchers and clinicians about ways to improve diagnostic measures and develop personalized interventions for each of these disorders.

To achieve our aim, we have used a well-validated cognitive flexibility paradigm, which has a unique partial reversal design (Haim-Nachum and Levy-Gigi, 2019; Levy-Gigi et al., 2011, 2015; Levy-Gigi and Kéri, 2015; Zabag et al., 2020). This paradigm enables the detection of selective impairments in updating positive and negative outcomes, as well as the differentiation between impairments in updating target and context related information. Target information is the central element that falls within the focus of attention (in the current task – pictures of certain objects), whereas contextual information refers to elements that are in the periphery of the attention (in the current task – the background color of the pictures (see Fig. 1) (Mayes et al., 1992; Murnane et al., 1999).

Previous studies that used the same paradigm demonstrated selective impairments in individuals with depression and PTSD symptoms (Levy-Gigi and Kéri, 2015; Levy-Gigi et al., 2015). Specifically, both depression and PTSD were associated with intact positive to negative updating and impaired negative to positive updating. However, depression was associated with reduced updating of target, but not context related information, whereas PTSD was associated with reduced updating of context-, but not target related information.

To our knowledge, the current study is the first to test associations between levels of trauma exposure and trauma-related symptoms while directly comparing trajectories of depression and PTSD as a function of

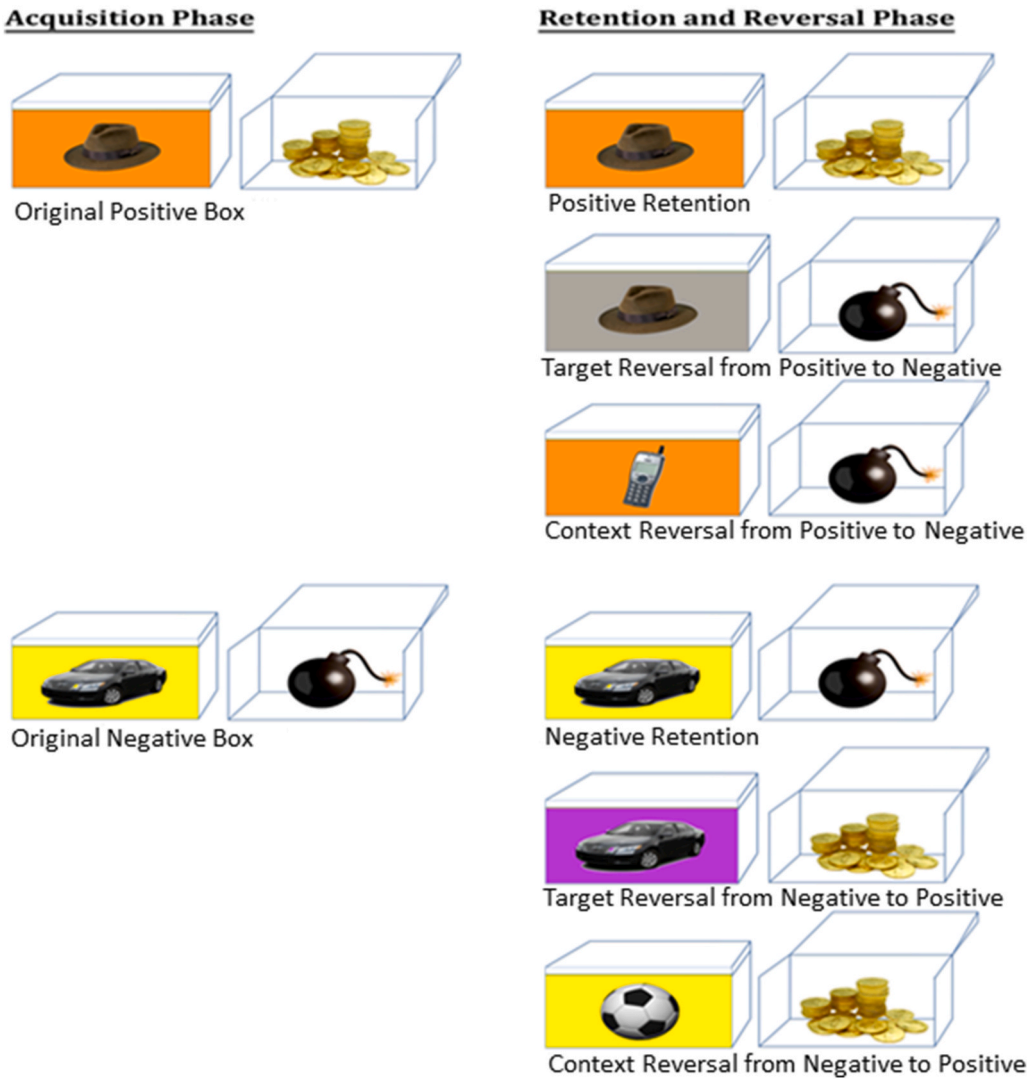

Fig. 1. Example of acquisition, retention, and reversal trials in the two phases of the cognitive flexibility paradigm. This Figure is being reproduced with the permission of the copyright holder Neuropsychology. *Reference of the original source:* Levy-Gigi et al. (2015). *Reduced hippocampal volume is associated with overgeneralization of negative context in individuals with PTSD. Neuropsychology 29(1),151–161.*

updating patterns. We expected no statistically significant baseline differences in learning and retaining information as a function of trauma-exposure, depression and PTSD symptoms. However, we anticipated significant differences in the ability to update existing information. Specifically, we postulated that trauma exposure would selectively interact with reduced updating of negative to positive target related information to predict depressive, but not PTSD, symptoms. On the other hand, we hypothesized that traumatic exposure would selectively interact with reduced updating of negative to positive context-related information to predict PTSD, but not depressive, symptoms.

1. Methods

1.1. Participants

The sample size was calculated using G*Power software (Faul et al., 2007). Based on the effect size that was found in a previous related study (Haim-Nachum and Levy-Gigi, 2019), we conducted *a-priori* power analysis for determining the sample size for a moderation analysis. This revealed a need for 75 participants for the detection of a medium-sized effect (Cohen's $f^2 = 0.15$), with a 5% significance level (α) and 85% power level (1-β) (Cohen, 1992). The estimated sample size was increased by 10% to account for potential equipment failure. Using on-campus advertisements, we recruited 83 Israeli college students to participate in the study for course credit (see Table 1). All participants had completed mandatory military service (time in service ranges between 24 and 36 months), and reported either military-related or non-military-related trauma exposure. Inclusion criteria were: (i) 18–45 years of age; (ii) accurate or corrected vision. Exclusion criteria were: (i) present or previous diagnosis of psychopathology other than depression and PTSD; (ii) substance dependence or abuse within the past 6 months; (iii) past experience of concussion or other clinically significant head injuries, including loss of consciousness for over 10 min; (iv) a history of neurological disorders such as epilepsy, multiple sclerosis, stroke, or encephalitis. One participant was excluded due to a history of concussion. In accordance with the latest version of the Declaration of Helsinki (WMA, 2013), informed consent was obtained at the beginning of the experiment after the nature of the procedure was fully explained, and participants were debriefed at the end of the study. Participants were assured that they could not be identified via the paper and that we had fully anonymized them. The study procedure and methods were approved by the Institutional Review Board of Bar-Ilan University.

2. Measurements

2.1. Cognitive flexibility paradigm

In this well-validated paradigm (Levy-Gigi et al., 2014, 2015), participants view a series of boxes on a computer screen. On each box, the image of a target object (e.g., a hat) is placed against a background context (different colors, e.g., orange; see Fig. 1). Participants are asked to either open the box or leave it closed. When opened, each box is associated with a specific outcome (positive, i.e., gold coins, or negative, i.e., a bomb) that leads to either a gain or loss of 25 points, respectively. The paradigm has two phases: an *acquisition phase* followed by a *retention and updating phase*. In the acquisition phase, participants learn by trial and error to predict and act on the outcome of four different boxes (i.e., open the two positive boxes and leave the two negative boxes closed). Each of the four boxes has a unique target and context pairing and a matched outcome (e.g., a box with a hat on an orange background has gold coins inside it whereas a box with a car on a yellow background has a bomb inside it). The outcome of each box is counterbalanced across participants. To complete the acquisition phase and move on to the retention and updating phase, participants need to reach a criterion of six consecutive correct responses within a minimum of 40 trials. Participants who do not achieve this within the minimum, receive an additional 16 trials. If participants have not yet completed the acquisition by that point, they are opted out of the experiment. Correct responses are opening positive boxes or leaving negative boxes closed; incorrect responses are opening negative boxes or leaving positive boxes closed. If this criterion is accomplished, the retention and updating phase starts immediately without any signaled switch or delay. In this phase, participants see the original positive and negative boxes (e.g., a *hat* on an *orange* background has *gold* inside) in addition to two new types of boxes: one shares the same target with the original box but has a new, different context (e.g., a *hat* on a gray background) and the other shares the same context but has a new, different target (e.g., a phone on an *orange* background). The new boxes are associated with the opposite outcome relative to the original boxes (i.e., if the box with the *hat* on the *orange* background has *gold* inside, then the boxes with the *hat* on a *gray* background and a *phone* on the *orange* background will have a *bomb* inside and vice versa). Therefore, to successfully learn these new associations, participants need to reverse and update the association rule of either the original target or the original context. Boxes in this phase are presented in 10 blocks of 12 boxes each (two boxes from each of the following conditions: positive/negative retention, positive/negative target updating, positive/negative context updating). Boxes in each block are presented in a random order. This adds up to a total of 120 trials, 20 trials per condition.

Table 1
Demographic characteristics and clinical measures of the participants (Means and standard deviations/frequency).

Variable	*Mean*	*SD*	*Range*
Age (years)	25.32	4.09	20–38
Male/Female (Ns)	20/62		
Education (years)	14.76	2.05	12–20
Depression	6.69	4.88	0–20
PTSD	26.68	10.17	16–69
Traumatic events	2.43	1.51	1–8

N = 82.
Note. The values for Male/Female represent frequencies. Depression was measured using the BDI-II; PTSD scores were estimated by the PCL-5; exposure to traumatic events was assessed using the TEQ.
*Independent *t*-test results revealed no significant differences between updating levels and depression and PTSD symptoms as a function of gender (all *ps* > .05).

3. Self-report questionnaires

The participants completed the following self-report questionnaires to measure clinical symptoms: (1) The revised version of the *Beck Depression Inventory (BDI–II;* Beck et al., 1996*),* a 21-item instrument (internal consistency α = 0.93, in the current study a = 0.91) that assesses symptoms of depression and rates items' occurrence over the past two weeks. Each item is measured on a scale from 0 to 3, with total scores ranging from 0 to 63; higher scores indicate greater levels of depression. This tool has high reliability and high structural and content validity (for review, see Wang and Gorenstein, 2013). Similar to other studies which tested sub-clinical individuals following trauma exposure, 12.2% of the participants in the current study reported mild to moderate levels of depression (14–20 symptoms), and 87.8% reported lower levels of depression (0–13 symptoms) (see de Sá Junior et al., 2018; Levy-Gigi et al., 2016; Musallam et al., 2005; Reyes-Rodríguez et al., 2013). (2) *The Posttraumatic Stress Disorder Checklist (PCL-5;* Weathers et al., 1994*),* a 20-item self-report questionnaire (internal consistency α = 0.90, in the current study a = 0.91) that assesses the DSM-5 symptoms of PTSD over the past month, using a five-point scale ranging from 0 = "not at all" to 4 = "extremely". This is a sound measure that has strong psychometric properties, including convergent and discriminant validity and test-retest reliability (Blevins et al., 2015). Using a PCL-5 cut-point of 31 (see Ashbaugh et al., 2016; Bovin et al., 2016), responses in our study showed that 32.97% of participants met the criteria for probable PTSD.

(3) The *Traumatic Events Questionnaire* (Vrana and Lauterbach, 1994), an 11-item questionnaire (internal consistency α = 0.91, in the current study a = 0.86) that includes specific types of potentially traumatic events to assess lifetime exposure. The TEQ is a valid and reliable assessment of traumatic events with good psychometric properties (Crawford et al., 2008); it shows strong correlations with reports from structured clinical interviews screening for traumatic events and has strong associations with PTSD symptoms. Responses to this questionnaire showed that all participants were exposed to trauma, 32.9% experienced one event, 28.1% experienced two, 19.5% experienced three, 11% experienced four, and the remaining 8.5% experienced between five and eight events (for frequencies of the different trauma types endorsed, see Table 2). TEQ served as the basis for PTSD symptoms inquiry, and participants who reported experiencing more than one event were instructed to anchor their responses on the PCL-5 to the most distressing event.

4. Data analysis

Statistical analyses were performed using the SPSS version 25 software (SPSS Inc., Chicago, IL). We utilized Pearson's correlations to test associations between updating, trauma exposure, clinical symptoms, and demographics (see Table 3). We applied repeated measures ANOVA on the percentage of the correct responses in the acquisition and retention phases to explore the effects of trauma exposure, depression, and PTSD symptoms on baseline differences in learning. The Hayes (2013) PROCESS macro was used to test the moderating role of enhanced and reduced updating in the relationship between traumatic events and clinical symptoms of depression or PTSD. Cases with missing data were deleted list-wise. All statistical tests used α of 0.05 with a two-sided *a-priori* hypothesis.

5. Results

5.1. Acquisition and retention of stimulus-outcome associations

Based on median scores, we created two groups for trauma exposure, depression, and PTSD symptoms. We conducted repeated measures ANOVA on the percentage of correct responses with Trauma Exposure, Depression, and PTSD Symptoms as the between-subject factors and Acquisition and Retention as the within-subject factors. As predicted, there were no statistically significant differences in performance-based learning in the acquisition phase $F(1, 80) = 0.99$, $p = .32$; $F(1, 80) = 0.55$, $p = .46$; $F(1, 80) = 0.41$, $p = .52$, as a function of trauma exposure, depression, and PTSD symptoms, respectively. Similarly, there were no significant differences in the retention phase $F(1, 80) = 0.71$, $p = .40$; $F(1, 80) = 1.37$, $p = .25$; $F(1, 80) = 1.55$, $p = .22$, as a function of trauma exposure, depression, and PTSD symptom levels, respectively. These results indicate that the participants were equally able to learn and retain stimulus-outcome associations independent of their trauma exposure, depression and PTSD symptom levels.

Table 2
Prevalence of different traumatic events (N = 82).

Type of traumatic event	Prevalence	
	n	%
(Violent/unexpected) death of a loved one	34	27.64
Combat	20	16.26
Adult abusive relationship/beaten up by a partner	13	10.57
Terror attacks (civilians in war zones)	12	9.76
Severe accidents or self-injuries	11	8.94
Child abuse/beaten up by caregiver	8	6.5
Sexual assault (forced sexual activity)	5	4.07
Witnessing someone being seriously injured/killed	5	4.07
Other traumatic events	**15**	**12.19**
Total	**123**	**100**

6. Target and context updating

To examine the moderating role of updating in the relationship between exposure to traumatic events and level of depressive and PTSD symptoms, we employed Hayes (2013) PROCESS macro using 5000 bootstrap resampling for a calculation of confidence intervals. ***In the first model***, exposure to traumatic events, target updating, and level of depressive symptom were treated as independent, moderator, and outcome variables, respectively, while controlling for level of PTSD symptoms. The results of the analyses are presented in Table 4. The general model was significant ($R^2 = 0.34$, $F(4,77) = 9.81$, $p < .001$). There were no main effects of trauma exposure and target updating on the level of depressive symptoms, ($t(82) = 1.28$, $p = .20$; $t(82) = 0.34$, $p = .73$, for exposure and target updating, respectively). However, there was a significant interaction of traumatic exposure and target updating on the level of depressive symptoms ($t(82) = -2.18$, $p = .03$) (Fig. 2). This effect accounted for an additional 4.1% of the variance. In order to interpret this interaction, we computed bootstrapping confidence intervals (95%), evaluating the magnitude of the relationship between trauma exposure and the level of depressive symptoms for individuals with reduced and enhanced target updating (−/+1 *SD*). The results revealed a significant positive relationship between trauma exposure and the level of depressive symptoms for individuals with reduced (−1 *SD*) target updating, $\beta = 1.09$, $t(82) = 2.61$, $p = .01$, CI 95% [0.26, 1.92]. No such relationship was found in individuals with average, $\beta = 0.40$, $t(82) = 1.28$, $p = .20$, CI 95% [-0.22, 1.03], or enhanced levels (+1 *SD*) of target updating, $\beta = -0.29$, $t(82) = -0.61$, $p = .54$, CI 95% [-1.23, 0.65]. These findings indicate that among individuals with reduced negative to positive target updating, increased trauma exposure was associated with more depressive symptoms. However, for individuals with average or enhanced negative to positive target updating, such an increase in exposure did not affect the level of depressive symptoms. A similar model, which used PTSD as a dependent variable while controlling for level of depression symptoms, reached no significant results (all *ps* >. 05).

In the second model, trauma exposure, context-related updating, and level of PTSD symptom were treated as independent, moderator, and outcome variables, respectively, while controlling for level of depressive symptoms. The results are presented in Table 5. The general model was significant ($R^2 = 0.33$, $F(4,77) = 9.34$, $p < .001$). There were no main effects of trauma exposure and context-related updating on the level of PTSD symptoms, ($t(82) = 1.34$, $p = .18$; $t(82) = -0.02$, $p = .98$ for exposure and context-related updating, respectively). However, there was a significant interaction of trauma exposure and context-related updating on the level of PTSD symptoms ($t(82) = 2.11$, $p = .04$) (Fig. 3). This effect accounted for an additional 4.1% of the variance. In order to interpret this interaction, we computed bootstrapping confidence intervals (95%), evaluating the magnitude of the relationship between trauma exposure and the level of PTSD symptoms for individuals with reduced and enhanced context-related updating (−/+1 *SD*). The results revealed a significant positive relationship between trauma exposure and the level of PTSD symptoms for individuals with enhanced (+1 *SD*) levels of context-related updating, $\beta = 2.32$, $t(82) = 2.4$, $p = .02$, CI 95% [0.40, 4.23]. No such relationship was found in individuals with average, $\beta = 0.89$, $t(82) = 1.34$, $p = .18$, CI 95% [-0.43, 2.21], or reduced levels (−1 *SD*) of context-related updating, $\beta = -0.54$, $t(82) = -0.58$, $p = .56$, CI 95% [-2.38, 1.31]. These findings indicate that among individuals with average or reduced negative to positive context updating, an increase in the trauma exposure did not affect the level of PTSD symptoms. However, for individuals with enhanced negative to positive context updating, such an increase in exposure level was associated with elevated PTSD symptoms. A similar model, which used depression as a dependent variable while controlling for level of PTSD symptoms, reached no significant results (all *ps* >. 05).

Table 3
Zero-order correlations between demographics, cognitive flexibility, clinical symptoms, and trauma exposure.

Variable	1	2	3	4	5	6	7	8
1. Age	1							
2. Gender	-.15	1						
3. Education	.60***	.06	1					
4. Target updating	-.10	-.15	-.06	1				
5. Context updating	-.17	-.15	-.29**	.40***	1			
6. Depressive symptoms	-.08	-.06	-.21	.09	.09	1		
7. PTSD symptoms	-.09	-.07	-.17	.07	.03	.52***	1	
8. Trauma exposure	.15	-.10	-.04	-.04	-.10	.27**	.26*	1

Note. N = 82, Gender: Male = 0, Female = 1, $*p < .05$; $**p \leq 01$; $***p \leq .001$.

Table 4
Estimated Coefficients, Standard Errors and 95% Confidence Intervals for Independent and Moderator Variables in the model predicting Depressive symptoms.

Variables	*B*	*SE*	*t* value	95% CI	
				Low	High
Control variables					
PTSD symptoms	.24	.05	5.1***	.14	.33
Predictors					
Traumatic events	.40	.31	1.28	-.22	1.03
Target updating	.01	.01	.34	-.02	.04
Traumatic events x Target updating	-.02	.01	−2.18*	-.04	-.00

N = 82, CI = Confidence Intervals, $*p < .05$; $***p < .001$.

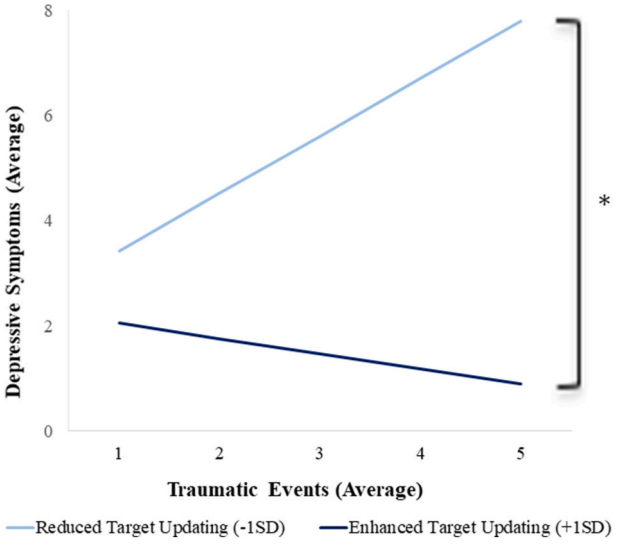

Fig. 2. Level of depressive symptoms as a function of exposure to traumatic events and target-updating (reduced vs. enhanced).

Table 5
Estimated Coefficients, Standard Errors and 95% Confidence Intervals for Independent and Moderator Variables in the model predicting PTSD symptoms.

Variables	*B*	*SE*	*t* value	95% CI	
				Low	High
Control variables					
Depressive symptoms	1.04	.20	5.09***	.63	1.44
Predictors					
Traumatic events	.89	.66	1.34	-.43	2.21
Context updating	-.00	.03	-.02	-.07	.07
Traumatic events x Context updating	.05	.02	2.11*	.00	.10

N = 82, CI = Confidence Intervals, $*p < .05$; $***p < .001$.

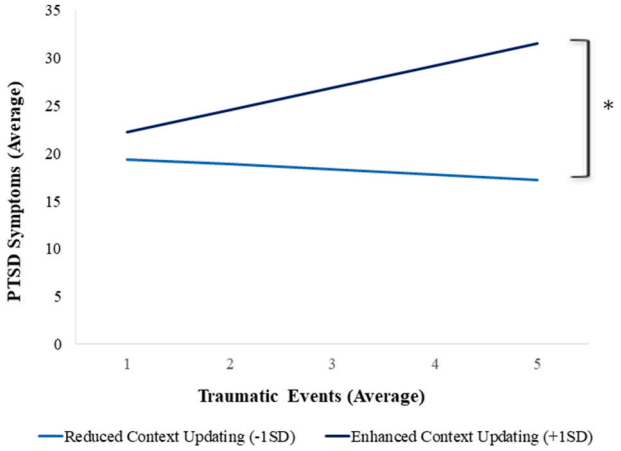

Fig. 3. Level of post-traumatic stress disorder (PTSD) symptoms as a function of exposure to traumatic events and context-updating (reduced vs. enhanced).

7. Discussion

The aim of the present study was to test whether traumatic exposure interacts with selective impairments in cognitive flexibility, to predict the tendency to develop either depression or PTSD symptoms. We differentiated between reduced and enhanced updating of target and context-related information. In line with our prediction, we found that for individuals with reduced negative to positive target, but not context, updating, greater traumatic exposure was associated with higher levels of depressive symptoms. Specifically, they struggled to learn that a previously negative target was later associated with a positive outcome even when it was presented in a new context. These findings are in line with previous evidence which showed faster attending away from negative target-related information in depressed individuals (Hauschildt et al., 2013; Wittekind et al., 2015; for a review, see Bistricky et al., 2011), and selective associations between depression and impaired updating of target related information (Levy-Gigi and Kéri, 2015).

The results support existing findings, which show that individuals with depression are less sensitive to contextual information (Msetfi et al., 2007, 2013; Whitmer and Gotlib, 2013). Such individuals struggle to maintain context information over time (Msetfi et al., 2009) and fail to show valence-alteration when observing stimuli of different valence (Rottenberg et al., 2005). Hence, they react in a similar manner independent of the contextual environment. The results of the present study suggest that insensitivity to contextual information may lead to reduced updating of target-related information. For example, both the presence of a real gun in a battlefield and a fake gun in a costume party may trigger fear reaction among individuals with such impairment.

In contrast to our prediction, for individuals with enhanced, but not reduced, negative to positive context-related updating, greater traumatic exposure was associated with higher levels of PTSD symptoms. Specifically, they struggled to learn that a previously negative context

was later associated with a positive outcome, even when it was presented with a new target. Impaired processing of context related information is a well-observed phenomenon in individuals with PTSD (for review, see Liberzon and Abelson, 2016). Animal models of PTSD reveal that trauma-related hippocampal deficits lead to elemental rather than conjunctive processing of aversive events. Imagine an animal that received a shock in a specific cage. Instead of encoding all individual features present in the environment as a whole (e.g., the cage and all the related features need to be present in order to signal a sense of danger), each element presented in the aversive event becomes independently associated with it (e.g., the structure of the cage, its size, color and smell are all associated with the traumatic shock independently) (for review, see Rudy et al., 2004; Rudy, 2009). Similarly, human models suggest that deficits in hippocampal structure and function impair the integration and processing of context-related information (Acheson et al., 2012; Shalev et al., 2018; Levy-Gigi et al., 2015). Imagine a soldier who participated in a combat in an anemone field. Elemental processing of contextual information may result in associations between each contextual element with the traumatic event. Hence, this person may react with fear even when smelling anemones in his safe, well-familiar hometown.

While the results of the current study provide additional support for the association between PTSD and impaired processing of contextual information, the nature of the observed impairment is different. When testing individuals diagnosed with PTSD, such impaired processing was reflected in reduced rather than enhanced updating of context-related information (Levy-Gigi et al., 2012, 2015; Zabag et al., 2020). Hence, PTSD individuals struggle to learn that a previously negative context has become positive. In the current study, we found an opposite pattern in the sub-clinical non-PTSD traumatized individuals. Specifically, they showed enhanced updating of new positive information. These results may reflect a broader difficulty to hold on to negative feelings, thoughts, and beliefs, which may result in a tendency to update these to positive ones fast. Since this updating pattern is positively associated with levels of PTSD symptoms, it may indicate an inability to allocate sufficient time/attention for adaptively processing those negative feelings (Bar--Haim et al., 2010; Wald et al., 2011). These results are in line with studies on emotion regulation showing that disengagement with negative thoughts may result in maladaptive coping, in the long term (Sheppes and Gross, 2012; Wilson and Gilbert, 2008). Specifically, while bereaved individuals may initially benefit from avoiding thoughts about their loss or not allowing themselves to take the time to grieve, this persistent avoidance may impede their ability to adjust to their new life circumstances and experience more symptoms in the long run (Shear et al., 2007).

Taken together, the results of the present study demonstrate a crucial dissociative role of cognitive flexibility in the development of depression and PTSD symptoms following traumatic exposure. This is done while innovatively highlighting different forms of cognitive flexibility (e.g., Hefer and Dreisbach, 2017; Haim-Nachum and Levy-Gigi, in press). Whereas reduced updating may signal rigidity, enhanced updating may signal heightened reactivity in the presence of new contradictory information.

Moreover, in contrast to the more common view (Genet et al., 2013; for reviews, see Cheng et al., 2014; Koster et al., 2017; Morris and Mansell, 2018), we suggest that both reduced **and** enhanced updating may be associated with clinical symptoms following trauma exposure. These findings emphasize the need for reaching a delicate updating balance in order to achieve adaptive behaviors when coping with aversive life changes (Kim et al., 2020; Kube et al., 2019; for review, see Kube and Rozenkrantz, 2020).

In addition, the different impairments of individuals with depression and PTSD symptoms provide support for previous studies arguing that cognitive flexibility updating deficits vary across disorders (Gloster et al., 2011). For example, it has been shown that individuals with bipolar disorder demonstrate reduced positive to negative updating (Feiss et al., 2017). Individuals with social anxiety, on the other hand, showed reduced negative to positive updating during affiliative interactions (Beltzer et al., 2019), but enhanced negative updating in social-ranked related encounters (Haker et al., 2014).

Finally, the current results not only demonstrate that depression and PTSD are associated with different impairments, but they also serve as a proof-of-concept, suggesting that such impairments can be used to predict distinct effects of trauma exposure. From a diagnostic perspective, our findings contribute to the understanding of the differences between depression and PTSD by identifying possible risk factors (i.e., cognitive flexibility updating tendencies) that could better predict individual differences in response to trauma. From a clinical perspective, they may offer insights regarding the conditions needed for individuals with symptoms of depression and PTSD to cope better with trauma, and can serve to improve existing diagnostic measures and inform current treatment. This may be achieved by shifting focus from general trauma treatments to more personalized methods aiming to train depressive individuals with target updating and PTSD patients with context updating skills. However, it should be noted that measuring this relationship at one point in time does not allow determining whether enhanced and reduced updating function as an antecedent or consequence of depressive and PTSD symptoms. Future longitudinal studies are needed in order to derive a more nuanced understanding of the relationship between trauma exposure and these symptoms, and to reach conclusions regarding causality.

While providing new insights and contributing to the existing literature, the study has several limitations. First, we referred to cognitive flexibility as a possible mechanism and focused on the level of depression and PTSD symptoms as a continuum, refraining from the traditional dichotomous approach. While such an investigation is in line with the more recent dimensional approach to psychopathology (for review see Carcone and Ruocco, 2017), which allows not only for the assessment of the presence or absence of pathology, but also for the assessment of the mechanisms involved in the maintenance and development of these symptoms, it is yet unclear whether fully diagnosed individuals would show similar patterns. Future studies may thus aim to compare updating patterns of fully diagnosed individuals with depression, PTSD, and comorbid depression-PTSD.

While providing important insights regarding the role of cognitive flexibility in the relationship between trauma exposure and symptoms of depression and PTSD, the interaction effects found for both types of symptoms are small. Future studies may aim to include a larger sample to support the current results and to test the effect of possible individual differences such as the type of trauma (e.g., interpersonal vs. general trauma; combat vs. non-combat related exposure) and the setting of the exposure (e.g., work-related; first responders vs. civilians).

To summarize, the current study offers a novel perspective for understanding how different cognitive flexibility mechanisms may confer vulnerability to – or may protect against the experience of – depression and PTSD symptoms following exposure to trauma. Awareness of these mechanisms and of the critical balance between them is highly significant. Specifically, while adequate updating may serve as a shield in the face of aversive events, reduced or enhanced levels of this trait might be associated with clinical symptoms, calling for the development of tailored prevention and treatment methods.

Author contributions

Conceptualization: ELG; Data Curation: SHN; Formal Analyses: SHN; Funding: ELG; Supervision: ELG; Visualization: SHN; Writing – original draft: SHN and ELG; Writing – review & editing: SHN and ELG.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon request.

Declaration of competing interest

None.

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