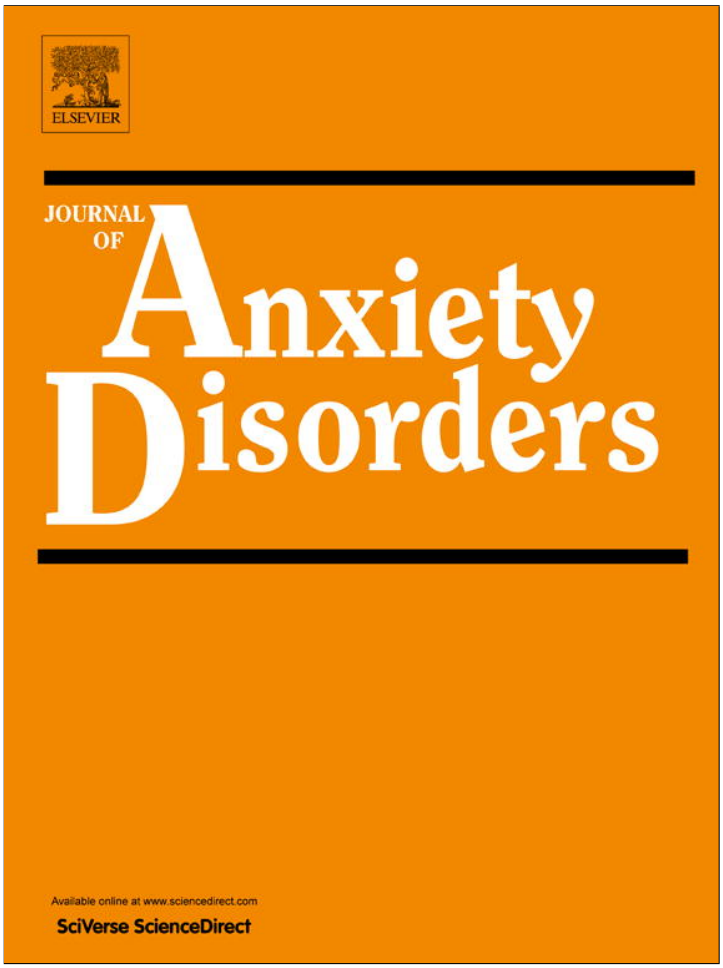

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Analogue trauma results in enhanced encoding of threat information at the expense of neutral information☆

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ABSTRACT

This study investigated whether trauma-related stimuli are preferentially processed at the expense of ongoing processing of neutral stimuli. Participants in the experimental group viewed negative pictures (Trauma) as an analogue trauma induction. Participants in the control group viewed visually similar neutral pictures (Neutral Match). In a Rapid Serial Visual Presentation (RSVP) task participants identified two target pictures. The first target (T1) was a neutral picture, whereas the second target (T2) was a familiar negative or neutral picture or a new neutral or negative picture. In line with hypotheses, only participants in the experimental group showed preferential processing of Trauma pictures. In the experimental group, negative T2 impaired the identification of (neutral) T1 if the T2 immediately followed the T1 in the RSVP stream. The results are consistent with a processing priority of trauma-related information, apparently at the expense of the ongoing processing of neutral information.

1. Introduction

In posttraumatic stress disorder (PTSD), the memory of the traumatic experience is thought to be encoded in such a way that – compared to a non-traumatic memory – it is highly sensitive to automatic activation upon perception of matching stimuli. This means that encounters with situations (either external or internal) that act as trauma reminders are disruptive to ongoing activities and may reflect a trauma-related cognitive bias. *The fear network theory of anxiety* (Foa, Steketee, & Rothbaum, 1989) postulates that a traumatic experience is encoded as a fear network in memory. This network is assumed to include strong associations between the trauma information and individual peri-traumatic responses. When confronted with environmental information that matches the trauma information, the fear network is automatically activated. Similarly, the *perceptual priming hypothesis* (Ehlers & Clark, 2000) postulates that perceptual aspects of the traumatic situation are particularly well encoded, resulting in perceptual priming for trauma-related stimuli. This means that stimuli that are perceptually similar to perceptual information in the trauma memory can act as a trigger to automatically activate the memory. In the present study the preferential encoding of trauma stimuli and its effect on non-trauma processing was further investigated.

These models are supported by laboratory studies in PTSD patients showing implicit and explicit memory bias for trauma-associated materials. For instance, PTSD participants showed increased explicit memory for previously presented trauma-related, but not for other negative, neutral or positive words, compared to controls (Kaspi, McNally, & Amir, 1995; Vrana, Roodman, & Beckham, 1995). Trauma-specific implicit memory biases have been reported in studies using word completion tests for previously presented trauma and non-trauma words (Zeitlin & McNally, 1991) or signal–noise paradigms (Amir, McNally, & Wiegartz, 1996) in PTSD patients versus controls. Moreover, research in healthy control participants has shown an implicit memory bias even for neutral stimuli preceding a traumatic event (Arntz, de Groot, & Kindt, 2005; Ehlers, Michael, Chen, Payne, & Shan, 2006; Michael & Ehlers, 2007).

In sum, trauma-related stimuli seem to be better remembered than neutral or other negative information. This finding appears in studies with direct (explicit memory) as well as indirect (implicit memory) tests. These findings suggest that trauma memory influences the identification of trauma-related stimuli in later encounters. However, the exact process by which trauma-related stimuli are attended to and subsequently encoded or identified cannot be inferred from these studies. In particular, it remains unclear (i) to what degree indeed there is enhanced processing of

☆ This study was conducted at the Radboud University Nijmegen, the Netherlands.

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trauma-related information, and (ii) whether trauma-related stimuli are processed *at the expense* of non-traumatic stimuli. Insight in these issues might also help explain why individuals suffering from PTSD report a feeling of "current threat" and overestimate danger in objectively safe situations. That is, trauma reminders are possibly preferentially encoded and thereby 'confirm' the potential presence of danger. If this preferential processing in turn prevents neutral stimuli (e.g., safety signals) from being encoded this could be interpreted as a confirmation of the absence of safety which might contribute further to feelings of current threat.

Rapid Serial Visual Presentation (RSVP) paradigms appear ideal to investigate whether trauma-related stimuli are indeed preferentially encoded at the expense of proper encoding of competing neutral stimuli. In the typical RSVP task, participants view a stream of stimuli (e.g., digits, words, or pictures), rapidly presented one after another, at the center of the screen. The instruction is to detect and identify two targets, T1 and T2, appearing within the stream. The targets usually differ from distracter items on one feature dimension, for instance picture format or print color. It has been shown that if the second target is presented within a certain time after the first target, usually ranging from 200 to 500 ms after T1 termination, people typically fail to correctly identify the T2 (e.g., Raymond, Shapiro, & Arnell, 1992; Weichselgartner & Sperling, 1987). This deficit in the identification of T2 has been called the *attentional blink* (AB). Note that presentation times for stimuli vary between studies. Often used presentation times are 80 ms or 100 ms. The *two-stage model for multiple target detection* (Chun & Potter, 1995) postulates that the AB is associated with capacity limitations at the second of two processing stages required for target identification. It postulates a very broad but coarse first processing phase which allows the rough detection of target-defining features. At a second processing stage, a more valid and durable object representation is created, involving consolidation in working memory and full identification of the object. Because this second stage represents a serial process, no other item can enter before the target under process is identified.

Studies using affective rather than neutral T2 stimuli showed that the AB effects are smaller for affectively arousing than for neutral verbs (Keil & Ihssen, 2004), indicating that emotional information is preferentially processed. In a similar vein, it has been demonstrated that the AB effect was attenuated for affectively arousing pictorial stimuli such as emotional faces (e.g., de Jong, Koster, van Wees, & Martens, 2009; Fox, Russo, & Georgiou, 2005), aversively conditioned neutral faces (Milders, Sahraie, Logan, & Donnellon, 2006) or fear-relevant stimuli such as spiders (Reinecke, Rinck, & Becker, 2008). There also is evidence that the AB is sensitive for individual differences in anxiety. For example, it has been shown that the AB for spiders is further reduced in spider phobic individuals (Reinecke et al., 2008; see also Fox et al., 2005).

Interestingly, there is not only evidence that threatening stimuli are more likely to be identified even if presented during the attentional blink period (see above), but also that this preferential processing may come at the cost of ongoing processing of neutral stimuli. For example, in a study of social phobia, de Jong and Martens (2007) found a hampered identification of T1 happy faces in trials where the T2 was an angry face. It thus appears that threatening stimuli not only have a low threshold of identification (attenuating the AB), but may also have a prioritized access to the limited cognitive resources that are required for correct identification of visual stimuli during a particular time window. So far, no study has investigated the role of preferential processing and potential disruption of ongoing processing of neutral stimuli in the context of (analogue) trauma. This study aimed at closing this gap in trauma research.

For optimal experimental control, an analogue trauma design with healthy participants was chosen (Holmes & Bourne, 2008). An analogue trauma is induced by presenting film clips (e.g., Brewin & Saunders, 2001; Holmes, Brewin, & Hennessy, 2004) or pictures (e.g., Ehlers et al., 2006; Michael & Ehlers, 2007; Pearson & Sawyer, 2011) showing a traumatic event according to the DSM-IV-TR (American Psychiatric Association, 2000). There is ample evidence that an analogue trauma can reliably induce PTSD-like symptoms such as intrusions, cognitive avoidance and emotional impact, at a lower intensity (Holmes & Bourne, 2008). During the training phase, participants all viewed one set of neutral pictures followed by either negative (analogue trauma) pictures in the experimental group or additional neutral pictures in the control group. These negative and neutral pictures were identical except for the central feature that was threat-related in the experimental group and neutral or positive in the control group (e.g., a baby corpse in a grave versus a gold bar in the same grave). Following this training phase, participants worked on a RSVP task involving the rapid presentation of a series of images. Participants were instructed to detect and identify two targets, identifiable by a brighter picture background. The first target was always a neutral picture to be classified as a landscape or architectural scene (cf. Most, Chun, & Widders, 2005). The second target belonged to one of five categories: (1) a neutral picture viewed by both groups during the training phase (Neutral Familiar), (2) a negative picture viewed only by the experimental group (Trauma), (3) a neutral picture matching the Trauma pictures on visual features except the central object viewed only by the control group (Neutral Match), (4) a new negative picture (New Negative) or (5) a new neutral picture (New Neutral). Our first research question was whether participants in the experimental group would show enhanced identification of 'trauma'-associated T2 targets compared to controls (i.e., attenuated AB for trauma stimuli). Our second question aimed at whether such a preference would be related to an interruption of neutral target processing, reflected in decreased T1 accuracy when presenting 'trauma'-associated stimuli afterwards. Our specific hypotheses related to the research questions are best explained in terms of the experimental task and are therefore presented at the end of Section 2.

2. Method

This study was approved by the Ethical Committee of Behavioural Science Research of the Radboud University Nijmegen (ECG09032009).

2.1. Participants

Participants were Dutch speaking female university students ($N = 81$). They were screened for panic attacks, panic disorder, PTSD, major depressive episode (current and lifetime), psychotic episode (current and lifetime), blood phobia and history of fainting, and were excluded from the study if any criterion was present. Participants received course credit for participation. The RSVP task was presented with Matlab software (Psychophysics Toolbox; Brainard, 1997; Pelli, 1997). Other measures were presented with Inquisit 3.0.3.2 (Millisecond Software) on a PC.

2.2. Materials

2.2.1. Anxiety and mood

The Dutch version of the State-Trait Anxiety Inventory (Zelfbeoordelingsvragenlijst; Van der Ploeg, 1980) was used to assess trait (STAI-T) and state anxiety (STAI-S). The STAI has 40 items (20 for trait anxiety and 20 for state anxiety) that are rated on a 4-point scale (1 = almost never, 4 = almost always). The STAI-T has a high test–retest reliability (.75) and internal consistency ($\alpha = .85$; Van der Ploeg, 1980). The STAI-S, being a state measure, has an appropriately lower test–retest reliability (.25) and high internal

consistency (α = .88; Van der Ploeg, 1980). Negative mood was measured with a self-report questionnaire (MoodQ; Holmes et al., 2004). This questionnaire includes current happiness, anxiety, horror, depressed mood, and anger, rated on an 11-point scale (0 = not at all, 10 = extremely). Scores were summed (happiness reversed).

2.2.2. Attention and attentional control

Attention for the pictures in the induction phase was rated on an 11-point scale from 0 (not at all) to 10 (completely) (Holmes et al., 2004). Earlier research with a variation on the RSVP task and negative pictures showed that the ability to focus one's attention and the ability to shift one's attention between tasks can be important in RSVP performance (Verwoerd, Wessel, de Jong, & Nieuwenhuis, 2009). Therefore, we included the Dutch version of the Attentional Control Scale (Derryberry & Reed, 2002; Verwoerd, de Jong, & Wessel, 2006). The ACS contains 20 items and consists of two subscales: Attentional Focus (9 items) and Attentional Shifting (11 items). Items describe situations in which attention needs to be focused on a task (e.g., "My concentration is good even if there is music in the room around me") or in which attention needs to be shifted between tasks (e.g., "It is easy for me to alternate between two different tasks"). Items are rated on a 4-point scale (1 = almost never, 4 = always). Internal consistencies in a Dutch sample were moderate to high (α = .79 for Attentional Focus and .67 for Attentional Shifting; Verwoerd et al., 2009). Convergent validity is good, as shown by a study in which attentional control measured with the ACS showed a similar pattern in attentional bias as a behavioral measure of attention (Derryberry & Reed, 2002).

2.2.3. Induction

The pictures for the induction phase and RSVP task were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2001) and internet (see Section 2.2.4 for more details). Pictures in the induction phase were presented with a light grey frame for 5 s on a computer screen, with 1 s in between pictures during which the screen was white. Both groups first viewed the same four neutral pictures. Participants in the experimental group then viewed four negative pictures. Participants in the control group viewed four neutral pictures that were matched to the negative pictures except for the main object (e.g., the pre-matched IAPS nr. 3005.1 and 3005.2: baby in dirt or gold bar in dirt). Each participant viewed 8 pictures in total. Participants were instructed to view the pictures as if they were bystanders at the scene and not to disengage from the pictures in any way.

2.2.4. RSVP task

Pictures were selected from the IAPS system except pictures from the T2 category Neutral Familiar and the distracter items that were selected from the internet. A pilot study with 20 participants who did not participate in the experiment assessed the arousal and valence ratings for the internet pictures according to the IAPS scales. Pictures that matched the ratings for the selected IAPS pictures were included in our study. The average valence (1–9, most negative to most positive valence) and arousal (1–9, lowest to highest arousal) ratings for the five picture categories were as follows: Trauma: 2.10 and 6.24, Neutral Match: 5.81 and 4.43, Neutral Familiar: 5.86 and 3.00, New Neutral: 5.87 and 3.00, New Negative: 1.83 and 6.35, respectively. The distracter pictures were all neutral or slightly positive, with an average valence of 5.15 and arousal of 3.18.[1]

During the RSVP task participants were presented with a temporal string of 15 pictures including T1, T2 and 13 distracters. Targets were presented with a bright grey frame whereas distracters had a dark grey frame. Distracter items were randomly selected from a pool of 40 neutral pictures that were not presented in the induction phase. T1 targets were selected from a pool of 32 neutral pictures. Half of these depicted landscapes, the other half architectural scenes (Verwoerd et al., 2009). Landscape and architecture items were each displayed 50% of the time. T2 items were the four negative pictures viewed by the experimental group during the induction phase (Trauma T2), the four neutral pictures viewed by the neutral group in the induction phase (Neutral Match), the four neutral pictures viewed by both groups during the induction phase (Neutral Familiar), four new negative pictures (New Negative), and four new neutral pictures (New Neutral). T2 depicted each of the five picture categories equally often. Trial by trial, the position of T1 within the temporal string was randomly determined, occurring in equal frequency at the string positions 3–9. T2 appeared at a lag of 1, 2 or 6. These lags were chosen to reflect the Attentional Blink window found for neutral and non-complex material (Chun & Potter, 1995). The remaining 13 positions within the picture string were randomly filled with distracter items. To prevent salience effects (uncontrolled for by the IAPS ratings) all stimuli in the RSVP task were presented in sepia color. Pictures were presented in a 19 cm × 19 cm size (Verwoerd et al., 2009).

Participants completed 6 practice trials and 360 experimental trials. Each combination of factors, 2 (T1 categories) × 5 (T2 categories) × 3 (lag) × 6 (T1 string positions), was presented twice in the RSVP task.[2] The specific pictures for each assigned T1 and T2 category, however, were randomly selected from that category. For example, the trial combination of a Landscape T1, Trauma T2, Lag 1, and T1 position 6 was presented twice. However, a different Landscape picture could be selected from the 16 available Landscape T1 pictures during the second presentation. Similarly, a different Trauma T2 could be selected from the four available pictures during the second presentation of this trial combination. Each trial started with the presentation of a centered black fixation cross for 500 ms. Then, the temporal 15 picture string was presented with a stimulus duration of 80 ms without interstimulus interval. Participants were instructed to attend to the string and to identify the two target pictures marked by a bright grey frame. After the RSVP string, a blank grey screen appeared for 1000 ms to prevent memory masking. Then, two response menus were presented for 5000 ms maximum. The first asked for T2 identification whereas the second asked for T1 identification (Reinecke et al., 2008). The response menu for T2 consisted of a comparison of the central feature of two pictures. One response option represented the central feature of the presented T2; whereas the other option represented a central feature of a random other T2 picture. For example, "Was it a baby or a fire?". The central feature of every T2 picture was identified beforehand by three raters on the basis of consensus. Participants were required to indicate whether T1 depicted a landscape or architecture (Verwoerd et al., 2009). Guessing was explicitly discouraged; however, a forced-choice format was used. Participants started a new trial through button press and could pace their breaks. Fig. 1 presents an example of an RSVP trial.

2.3. Procedure

After screening and signing an informed consent form, participants filled in the STAI-T, STAI-S and the mood questionnaire. Next, participants were randomly assigned to the experimental or control group and viewed the appropriate pictures in the induction phase.

[1] All pictures and their ratings are available from the corresponding author.

[2] Importantly, following from our design, each combination of (T1 category × T2 category × Lag position) was repeated 10 times, in which the string position of T1 varied over 6 positions.

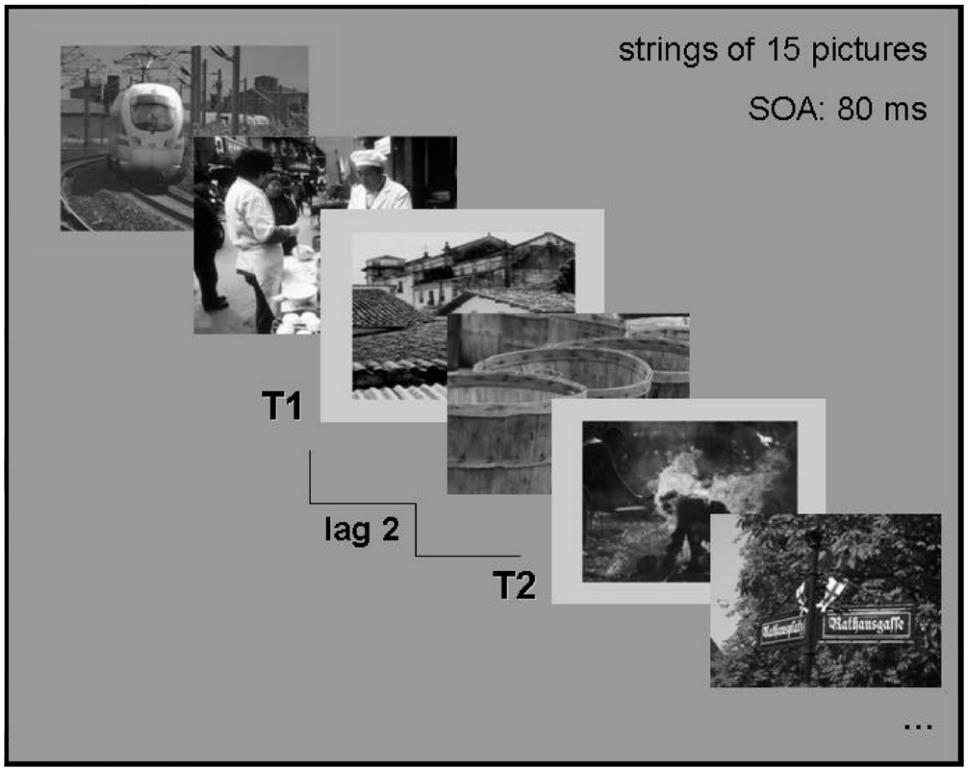

Fig. 1. An example of an RSVP trial, with targets being presented with a lag of 2.

The STAI-S and the MoodQ were completed again. As we wanted to prevent that any group effects on the RSVP task could simply be explained by group differences in negative mood, we ensured that there were no mood differences between the groups at the start of the RSVP task. To accomplish this, participants worked on a word search puzzle for 10 min after the induction phase picture viewing. The STAI-S and the MoodQ were administered and the experimenter checked whether participants' mood had returned to baseline levels. If a participant reported elevated negative mood, the distraction task was extended by 5 min and the STAI-S and MoodQ were administered again. Next, participants worked on the RSVP task. Finally, participants were debriefed, thanked, and assigned course credit.

2.4. Hypotheses

Our first research question was whether there would be differences in T2 identification accuracy between the experimental and control group. Our hypotheses were as follows: (1) *Threat bias:* in line with PTSD models (Ehlers & Clark, 2000; Foa et al., 1989), participants in the experimental group have a higher identification accuracy for Trauma T2 compared to participants in the control group; (2) *Exclusion familiarity effect:* participants in the experimental group have a higher identification accuracy for Trauma T2 than for Neutral Familiar pictures, confirming that enhanced identification of Trauma T2 is not due to mere familiarity effects; (3) *Visual features effect:* perceptual priming studies (Ehlers et al., 2006; Michael & Ehlers, 2007) suggest that matching visual features activate the analogue trauma associations in memory and lead to better target identification. Therefore, we expected that participants in the experimental group have higher identification accuracy for Neutral Match pictures than for the Neutral Familiar and New Neutral pictures; (4) *Conceptual features effect:* following the fear network model (Foa et al., 1989), stimuli that are associated with the trauma on a conceptual level (i.e., negative/threat) may trigger the trauma memory network. We hypothesized that participants in the experimental group have higher identification accuracy for New Negative pictures than for the Neutral Familiar and New Neutral pictures; (5) *Control effects:* a familiarity effect (enhanced identification of Neutral Familiar and Neutral Match pictures over New Neutral T2 pictures) or a general priority of threat processing (Trauma and New Negative pictures over other T2) may be present in the control group.

Our second research question was whether there is an interference effect of Trauma T2 on T1 identification in the experimental group relative to the control group. We hypothesized that there would be an *interruption of neutral processing:* the priority of processing Trauma T2 in the experimental group will interfere with the ongoing processing of (neutral) T1. T1 identification accuracy will be lower in trials with Trauma T2 compared to other T2 trials in the experimental group compared to the control group.

3. Results

3.1. Outliers, demand and statistical approach

We followed the outlier procedure described by Tabachnick and Fidell (1996). No multivariate outliers were detected (with Mahalanobis distances). All variables were checked for univariate outliers across and within groups. There were four univariate outliers that were adjusted appropriately. Two participants indicated low attention for the pictures in the induction phase (scores 2 and 5) and were excluded from analysis.

All tests were done with an alpha level of .05. Effect sizes are reported in Cohen's *d* (for simple *t*-tests) or *f* (for ANOVAs). Self-report data are reported in Table 1, experimental data in Table 2. As is the standard for the analysis of RSVP effects, T2 accuracy was analyzed only for trials in which T1 was identified correctly. T1 accuracy was analyzed only for trials in which T2 was correctly identified. Comparisons between groups were done with

Table 1
Descriptive statistics of self-report data across and within the experimental and the control group.

Measure		Control group		Experimental group		Total	
		M	*SD*	*M*	*SD*	*M*	*SD*
ACS		54.38	7.69	54.05	7.37	54.22	7.49
STAI-T		36.93	7.31	34.03	4.83	35.49	6.34
MoodQ	Baseline	6.88	3.74	5.38	3.35	6.14	3.61
	Post induction	6.70	3.68	15.46	8.73	11.03	7.96
	Post distracter	4.88	2.85	5.26	2.80	5.06	2.81
STAI-S	Baseline	32.08	5.77	30.49	4.29	31.29	5.12
	Post induction	32.60	7.39	65.67	7.05	34.11	7.34
	Post distracter	30.15	5.89	31.10	4.74	30.62	5.34
Attention for pictures		8.25	0.98	8.82	1.23	8.53	1.14

independent samples *t*-tests or ANCOVA. Effects within groups were tested with paired samples *t*-tests or repeated-measures ANOVA with Bonferroni corrections if the within-subjects factor contained more than two levels.

3.2. Randomization and compliance

The two groups were comparable on age, $p = .20$, overall $M = 20.29$, $SD = 1.86$; educational level, $p = .37$, with 89.9% university, 7.6% college, and 2.5% lower education; overall attentional control (ACS), $p = .85$; Attentional Focusing, $p = .27$; Attentional Shifting, $p = .52$; and baseline state anxiety (STAI-S), $p = .17$.

Trait anxiety (STAI-T) was significantly higher in the control group than in the experimental group, corrected $t(67.80) = 2.08$, $p = .04$, $d = 0.48$. There was a trend towards a more negative mood (MoodQ) at baseline in the control group, $t(77) = 1.86$, $p = .07$, $d = 0.42$. Participants in the experimental group reported more attention for pictures in the induction phase than participants in the control group, $t(77) = 2.28$, $p = .03$, $d = 0.51$. These group differences were controlled for in the experimental analyses by including trait anxiety, baseline negative mood, and attention ratings as covariates (overall effect sizes were small, i.e., $<f = .10$).

3.3. Manipulation check

3.3.1. Emotional impact

A 2 Group (control, experimental) × 2 Time (baseline, post-induction) repeated measures ANOVA was performed with negative mood (MoodQ) as the dependent variable. There was a significant main effect of Time, $F(1, 77) = 52.71$, $p < .001$, $f = 0.83$, and Group, $F(1, 77) = 13.48$, $p < .001$, $f = .42$, and a significant Group × Time interaction, $F(1, 77) = 56.50$, $p < .001$, $f = 0.85$. In the control group, there was no significant change in negative mood from baseline to post-induction, $p = .69$ but negative mood increased significantly in the experimental group, $t(38) = 7.71$, $p < .001$, $d = 0.83$. Post-induction scores were significantly higher in the experimental group than the control group, corrected $t(50.83) = 5.79$, $p < .001$, $d = 1.41$.

A significant main effect of Time, $F(1, 77) = 22.83$, $p < .001$, $f = 0.55$, and a significant Group × Time interaction, $F(1, 77) = 15.20$, $p < .001$, $f = 0.44$, but no significant effect of Group, $F(1, 77) = 0.34$, $p = .56$, emerged for state anxiety (STAI-S). There was no significant change in state anxiety from baseline to post-induction in the control group, $p = .53$, but there was a significant increase in state anxiety in the experimental group, $t(38) = 6.08$, $p < .001$, $d = 0.91$. Post-induction state anxiety was marginally higher in the experimental group than in the control group, $t(77) = 1.89$, $p = .06$, $d = 0.43$. In sum, the pictures in the induction phase for the experimental group increased negative mood as intended whereas pictures in the induction phase for the control group did not have a significant emotional impact.

3.3.2. Return to baseline

To ensure mood had returned to baseline levels after the distracter puzzle a 2 Group (control, experimental) × 2 Time (baseline, post-distracter) repeated measures ANOVA was performed with negative mood (MoodQ) as the dependent variable. There was a significant main effect of Time, $F(1, 77) = 11.36$, $p < .01$, $f = 0.38$, and a significant Group × Time interaction, $F(1, 77) = 8.79$, $p < .01$, $f = 0.34$, but no significant effect of Group, $p = .40$. The control group reported a decrease in negative mood from baseline to post-distracter, $t(39) = 5.19$, $p < .001$, $d = 0.30$. In the experimental group there was no difference in negative mood between baseline and post-distracter, $p = .80$. The groups were comparable on negative mood after the distracter puzzle, $p = .55$.

A significant Group × Time interaction, $F(1, 77) = 9.12$, $p < .01$, $f = 0.34$, but no significant main effect of Group, $p = .77$, or Time, $p = .12$, emerged for state anxiety (STAI-S). State anxiety was significantly lower after the distracter puzzle than at baseline in the control group, $t(39) = 3.10$, $p < .01$, $d = 0.33$, and state anxiety was comparable between baseline and post-distracter in the experimental group, $p = .28$. The groups were comparable on state anxiety

Table 2
Means and standard deviations for the experimental effects. Upper panel: T2 report accuracy in T1-correct trials. Lower panel: T1 report accuracy in T2-correct trials.

Picture category	Experimental group			Control group		
	Lag 1	Lag 2	Lag 6	Lag 1	Lag 2	Lag 6
T2 identification accuracy						
Trauma	.70 (.15)	.73 (.17)	.71 (.17)	.62 (.21)	.61 (.19)	.61 (.18)
Neutral Match	.64 (.17)	.65 (.15)	.70 (.14)	.63 (.14)	.64 (.17)	.64 (.17)
Neutral Familiar	.65 (.16)	.65 (.18)	.65 (.17)	.70 (.13)	.67 (.14)	.63 (.16)
New Negative	.65 (.18)	.64 (.16)	.66 (.18)	.63 (.17)	.60 (.17)	.61 (.18)
New Neutral	.83 (.10)	.81 (.14)	.80 (.14)	.79 (.12)	.79 (.13)	.75 (.14)
T1 identification accuracy						
Trauma	.50 (.13)	.52 (.11)	.55 (.13)	.56 (.14)	.53 (.15)	.51 (.16)
Neutral Match	.53 (.15)	.49 (.12)	.57 (.14)	.49 (.14)	.52 (.11)	.53 (.14)
Neutral Familiar	.54 (.14)	.55 (.14)	.55 (.14)	.51 (.13)	.55 (.14)	.53 (.12)
New Negative	.50 (.14)	.54 (.14)	.55 (.13)	.56 (.14)	.49 (.13)	.54 (.13)
New Neutral	.56 (.11)	.55 (.13)	.55 (.13)	.49 (.09)	.56 (.12)	.52 (.13)

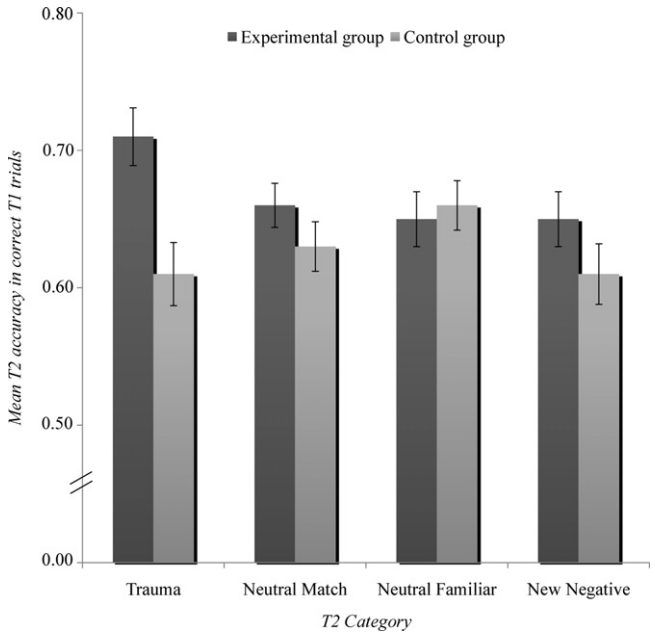

Fig. 2. Mean T2 identification accuracy across lags for correct T1 trials for each T2 category split by group.

after the distracter puzzle, $p = .43$. In sum, the groups were comparable on mood at the start of the RSVP task.

3.4. Data inspection

A 2 Group (control, experimental) × 5 Picture (Trauma, Neutral Match, New Negative, New Neutral, Neutral Familiar) × 3 Lag (1, 2, 6) ANOVA revealed that the main effect of Lag on T2 identification accuracy was not significant nor were any of the interactions including Lag, all $p > .05$. Accordingly, T2 identification scores were collapsed across lags.

Paired-samples *t*-tests revealed significantly higher identification rates for the New Neutral T2 pictures compared to all other T2 pictures, smallest $t(78) = 8.28$, highest $p < .01$. This suggests that, despite pilot testing and using sepia color, New Neutral pictures were unintentionally more easily identified than pictures from other T2 categories. As the New Neutral category apparently did not represent the intended control condition, it was omitted from further analyses.

3.5. Research Question 1: Do participants in the experimental group show a different pattern of identification accuracy for the T2 stimuli than participants in the control group?

Here, the following hypotheses were tested: (1) Threat bias, (2) Exclusion familiarity effect, (3) Visual features effect, (4) Conceptual features effect, and (5) Control effects. First a 2 Group (control, experimental) × 4 Picture (Trauma, Neutral Match, Neutral Familiar, New Negative) repeated measures ANCOVA was done, with Group as the between-subjects factor, Picture as the within-subjects factor, trait anxiety, baseline negative mood and attention ratings as covariates (results not reported), and identification accuracy for T2 as the dependent variable. The Group × Picture interaction relevant for our research question was significant, $F(3, 72) = 2.93$, $p = .04$, $f = 0.35$. RSVP effects on T2 identification accuracy for both groups are shown in Fig. 2.

3.5.1. Threat bias

It was expected that participants in the experimental group would have higher identification accuracy for Trauma T2 compared to participants in the control group. To test this, a one-way ANCOVA was performed with Group as the between subject factor and identification accuracy for Trauma T2 as the dependent variable. In line with our hypothesis, identification accuracy for Trauma T2 was significantly higher in the experimental group than the control group, $F(1, 74) = 5.66$, $p = .02$, $f = 0.28$.

3.5.2. Exclusion familiarity effect

It was expected that participants in the experimental group would have higher identification accuracy for Trauma T2 than for Neutral Familiar T2. This was tested with paired-samples *t*-tests within the experimental group. In line with our hypothesis, identification accuracy for Trauma T2 was significantly higher than for Neutral Familiar T2 in the experimental group, $t(38) = 3.03$, $p < .01$, $d = 0.46$. This pattern was reversed in the control group, $t(39) = 2.01$, $p = .05$, $d = 0.38$, where identification accuracy for Neutral Familiar T2 was significantly higher than for Trauma T2.

3.5.3. Visual features effect

We expected that participants in the experimental group would have higher identification accuracy for Neutral Match T2 than for Neutral Familiar and New Neutral T2. The hypothesis was tested within the experimental group without the New Neutral category (see Section 3.4) using a paired-samples *t*-test. The hypothesis was not supported as there were no significant differences in identification accuracy between Neutral Match and Neutral Familiar T2 in the experimental group, $t(38) = 0.78$, $p = .44$.

3.5.4. Conceptual features effect

We expected that participants in the experimental group would have higher identification accuracy for New Negative T2 than for Neutral Familiar and New Neutral T2. The hypothesis was tested within the experimental group without the New Neutral category (see Section 3.4) using a paired-samples *t*-test. The hypothesis was not supported as there were no significant differences in identification accuracy for New Negative and Neutral Familiar T2 in the experimental group, $t(38) = 0.02$, $p = .98$.

3.5.5. Control effects

As the Neutral New category could not be used, familiarity (identification accuracy for Neutral Familiar and Neutral Match versus New Neutral T2) and general threat effects (identification accuracy for Trauma and New Negative versus other T2; see page 12, Hypotheses) in the control condition could not be tested. Therefore, we simply tested a main effect of T2 category on T2 identification accuracy in the control condition (excluding the New Neutral category). A repeated-measures ANOVA with picture type as the within-subjects factor showed no significant effect of picture type on T2 identification accuracy in the control condition, $F(3, 37) = 1.73$, $p = .18$.

3.6. Research Question 2: Is there an interference effect of Trauma T2 on the processing of T1 stimuli in the experimental group compared to the control group?

Here, the *interruption of neutral processing* hypothesis was tested. First, a 2 Group (control, experimental) × 3 Lag (1, 2, 6) × 4 Picture (Trauma, Neutral Match, New Negative, Neutral Familiar) repeated measures ANCOVA was done with Group as a between subjects factor, Lag and Picture as within-subjects factors, trait anxiety, baseline negative mood and attention ratings covariates (results not reported), and T1 identification accuracy the

dependent variable. The relevant Group × Lag × Picture interaction was significant, $F(6, 69) = 3.55$, $p < .01$, $f = 0.56$.

We hypothesized that identification accuracy for T1 stimuli in trials with Trauma T2 would be lower in the experimental group than in the control group. The three-way interaction was further analyzed with a 2 Group (control, experimental) × 3 Lag (1, 2, 6) ANCOVA with Group as the between-subject factor, Lag as the within-subject factor, and T1 accuracy in Trauma T2 trials as the dependent factor. The Group × Lag interaction showed a non-significant trend, $F(2, 73) = 2.81$, $p = .07$, $f = 0.28$. This trend was followed up by one-way ANCOVAs per Lag, showing lower identification accuracy in the experimental group than the control group for T1 in trials with Trauma T2 at Lag 1, $F(1, 74) = 9.47$, $p < .01$, $f = 0.37$; but not at Lag 2 or 6, both $p > .05$. This indicates that the relatively strong interfering effect in the experimental group was only evident when the Trauma T2 was presented in short temporal proximity of the neutral T1.

The same analysis, now testing the interfering influence of the New Negative T2 stimuli showed a similar Group × Lag interaction for T1 identification accuracy, $F(2, 73) = 3.52$, $p = .04$, $f = 0.31$. One-way ANCOVAs per Lag indicated a significantly lower T1 identification accuracy in the experimental group for trials with New Negative T2 compared to the control group at Lag 1, $F(1, 74) = 4.88$, $p = .03$, $f = 0.26$, but not at Lag 2 or 6, both $p > .05$.

The Group × Lag interactions (and Lag or Group main effects) for T1 identification accuracy in trials with Neutral Match or Neutral Familiar T2 pictures were not significant, largest $F(2, 73) = 1.39$, smallest $p = .20$. Fig. 3 presents T1 identification accuracy for RSVP trials with Trauma T2 and New Negative T2 for the experimental and control group.

3.7. Attentional control and identification accuracy

In the experimental group, attentional control (ACS) was positively related to T2 identification accuracy for Trauma pictures, $r = .35$, $p = .03$, and T1 accuracy for trials with New Negative T2 pictures, $r = .33$, $p = .04$. These correlations appeared to be driven by the Attentional Shifting subscale, $r = .44$, $p = .01$, and $r = .34$, $p = .04$, respectively. The Attentional Focus subscale was not significantly related to RSVP performance. Attentional control was not significantly related to any RSVP parameter in the control group.

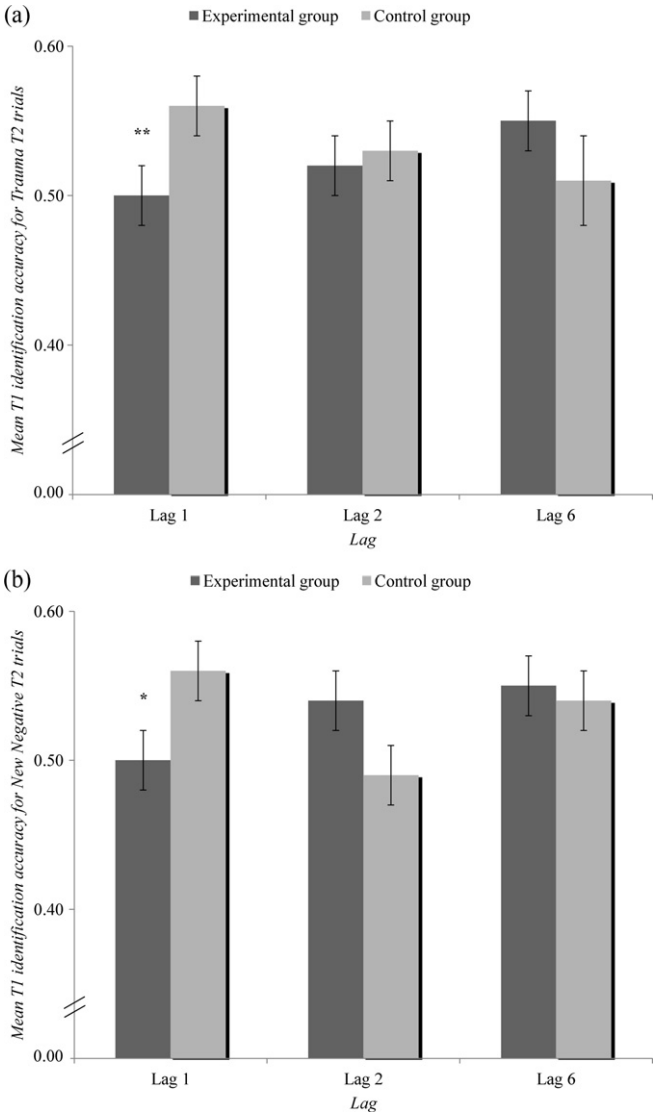

Fig. 3. (a) Mean T1 identification accuracy per lag for RSVP trials with correctly identified Trauma T2 compared between the experimental and control group (**significant at .01 level). (b) Mean T1 identification accuracy per lag for RSVP trials with correctly identified New Negative T2 compared between the experimental and control group (*significant at .05 level).

4. Discussion

The present study aimed to experimentally investigate whether (analogue) traumatic stimuli are preferentially processed and to explore whether such processing priority would be associated with a disruption of ongoing processing of neutral stimuli. First, we were interested in whether previous exposure to negative pictures would increase identification of these pictures in an RSVP task. Second, we were interested in whether enhanced identification would interfere with report accuracy of previously presented neutral stimuli.

Our results supported the processing priority of 'trauma' stimuli after an analogue trauma induction. That is, Trauma T2 were better identified in the experimental group than in the control group (*Threat bias*). As identification accuracy for Trauma T2 was higher than for Neutral Familiar T2 in the experimental group, whereas T2 identification was comparable for all T2 categories in the control group, the priority encoding was likely due to the analogue trauma and not because of mere familiarity or a general arousal/valence effect (*Exclusion familiarity effect*). Our results are in line with earlier priming studies in the context of analogue trauma (Ehlers et al., 2006; Arntz et al., 2005), that showed better implicit memory for 'trauma' related stimuli after viewing a negative slide show. Our study extends these findings by showing that a priming effect also emerged for stimuli that are presented with suboptimal (80 ms) presentation times. That is, the prioritized encoding of threat stimuli may occur at a relatively automatic level. This interpretation is in line with the fear network theory (Foa et al., 1989) and the perceptual priming hypothesis (Ehlers & Clark, 2000). In contrast to our hypotheses, T2 pictures sharing visual (Neutral Match) or conceptual (New Negative) features with the analogue trauma induction stimuli (Trauma pictures) were not better identified (*Visual features effect*/*Conceptual features effect*). However, the Neutral New T2 category was unavailable for reliable comparison and the Neutral Match and New Negative T2 could only be compared against the Neutral Familiar T2. For the visual features effect, this means that visual features in a neutral condition that resemble the trauma memory (i.e., the Neutral Match T2) may have enhanced identification – as compared to new neutral information (i.e., the New Neutral T2) – to the same extent that familiar neutral information would (i.e., the Neutral Familiar T2). It may also mean that visual features shared by the trauma memory do not receive priority processing, and neither does previously encoded information. In other words, at this

stage it is unclear whether no effects were present or whether both Neutral Match T2 and Neutral Familiar T2 received priority processing. The same reasoning applies to the conceptual features effect. The New Negative T2 could have received priority processing compared to new *neutral* information (i.e., New Neutral T2) to the same extent that familiar neutral information (i.e., the Neutral Familiar T2) would receive priority processing to *unfamiliar* neutral information (i.e., New Neutral T2). It remains unclear whether there was a conceptual features effect that was undetected because of a familiarity effect, or whether neither of these were present. Thus, we were unable to reliably falsify the visual features and conceptual features effect.

The Group × Lag interaction for T1 identification accuracy in trials with Trauma T2 (*Interruption of neutral processing*) did not reach the conventional level of significance but did show a trend in the predicted direction ($p = .07$). It is likely that the effect size of the interaction effect was relatively small because the trauma induced interfering effect of Trauma T2 on T1 identification was as expected only evident when the Trauma T2 was presented in short temporal proximity of the neutral T1. Accordingly, a subsequent analysis that was restricted to Lag 1 showed that the presentation of the Trauma T2 resulted in a significantly stronger interference effect in the experimental group compared to the control group, whereas such a difference was absent for Lags 2 and 6. However, because the Group × Lag effect did not reach the conventional level of significance, it requires further replication to see whether it indeed represents a robust phenomenon. Interestingly, the analyses regarding the interfering effects of the New Negative pictures on T1 identification showed a similar pattern. In fact, the pattern of results was even more pronounced reflected by the finding that the Group × Lag interaction effectively reached significance. Subsequent analyses per Lag again showed that T1 identification was only impaired in the experimental group compared to the control group at Lag 1, but not at Lags 2 and 6. Thus, only if the New Negative picture immediately followed the T1 did a relatively strong interference effect occur in the experimental group. Taken together, this pattern of findings may be explained in the two-stage model for multiple target detection (Chun & Potter, 1995). The 'trauma' information in memory was automatically activated on encounter with a matching stimulus and was processed at the expense of the neutral stimulus. The fact that we did not find an interference effect at Lag 2 and 6 suggests that T1 was processed relatively quickly, before T1 entered the two-stage processing. The finding that an interference effect was induced by New Negative T2 pictures suggests that the interference may have generalized to some extent on a conceptual (threat) level.

The enhanced processing of 'trauma' stimuli at the expense of ongoing neutral processing is clinically relevant. Automatic processing of trauma reminders at the expense of safety signals is thought to maintain PTSD (e.g., Ehlers & Clark, 2000; Ehlers, Clark, Hackmann, McManus, & Fennell, 2005). That is, a relatively strong cognitive bias toward trauma-reminders and away from neutral stimuli (in the absence of actual danger) may create or maintain an exaggerated perception of threat. Further, the finding that conceptually related "trauma" stimuli hamper ongoing neutral processing without enhanced identification of the stimulus may be related to the concept of "current threat" reported by PTSD patients (Ehlers & Clark, 2000) by prohibiting the identification of safe (neutral) signals. An interesting avenue for future research would be to aim to distinguish between literal safety signals (i.e., trauma disconfirming) and other neutral stimuli. For example, our RSVP experiment could be repeated with the Neutral Match and Neutral New pictures as T1 stimuli to test the extent to which their identification accuracy is affected by Trauma T2.

The attentional control (ACS) measure was included primarily as a randomization check. The RSVP effects reported in this paper cannot be accounted for by individual differences in attentional control, as the experimental and control group were comparable on this variable. Interestingly, specifically within the experimental condition, the Attentional Shifting subscale was related to indices of preferential processing bias. Attentional shifting was positively related to identification accuracy for Trauma T2 suggesting that attentional shifting may be a risk factor for a memory or attentional bias after (analogue) trauma exposure. However, this correlation should be considered with care as the ACS has only moderate to high reliability and replication is required. Attentional shifting was also positively related to T1 identification accuracy in trials with New Negative T2. This suggests that attentional shifting may protect against the generalization of interference of ongoing processing of neutral stimuli in the presence of a conceptual threat stimulus.

Our study has several limitations. The most obvious is the use of an analogue trauma induction with negative pictures. This prohibits a straightforward generalization of our results to actual trauma and PTSD. However, using distressing stimuli is an often used and fruitful way to simulate trauma-related processes under highly controlled circumstances allowing for causal investigations. The use of healthy female student participants prohibits the generalization of our effects to other populations. Although our sample limits our conclusions, at this point, however, there are no scientific reports on gender effects in emotional RSVP. Further, in a non-student population effects would hypothetically be more (and not less) pronounced as the variation in cognitive control would be presumably greater. Second, the New Neutral pictures were not usable as a control condition as they were unintentionally easier identified by the participants despite pilot testing. This prevented us from testing whether the enhanced identification was also present for stimuli sharing conceptual (negative) or visual features with the Trauma pictures. Third, despite randomization, some unexpected group differences emerged (trait anxiety, baseline negative mood and attention). In the analyses these variables were statistically controlled for so as to reduce any distortions on our main effects. However, future studies may want to consider a matching procedure rather than randomization for group allocation. Fourth, we did not find a Lag effect for T2 identification in any T2 category. This is in contrast with earlier studies of the Attentional Blink (AB) effect using neutral stimuli (e.g., Raymond et al., 1992; Weichselgartner & Sperling, 1987) or phobic pictures with only a central object (Reinecke et al., 2008). One explanation is that our stimuli were too complex or too emotional to be able to detect clear AB effects. Any enhancement or interference may have lasted during a large part of one RSVP trial thereby erasing lag effects. The absence of an AB effect is not detrimental to the theoretical implications of our results as such an effect has not been put forward by cognitive models of PTSD. Finally, the order of the response menus may have influenced our results. T2 was always asked for first and so the time that T1 needed to be remembered was always longer. Inspection of the identification rates suggests that this may have resulted in overall lower identification accuracy for T1. However, the comparison between T1 and T2 identification was not relevant for our hypotheses.

To summarize, the present study found evidence for enhanced encoding of threat information after an analogue trauma induction. This processing priority of 'trauma' related stimuli occurred at the expense of the ongoing processing of neutral stimuli. This effect could not be accounted for by mere familiarity, general valence/arousal, or state mood effects. The enhancement effect supports cognitive models of PTSD (e.g., Ehlers & Clark, 2000; Foa et al., 1989) and is in line with earlier priming studies with analogue trauma induction (Arntz et al., 2005; Ehlers et al., 2006) and implicit memory bias studies in trauma survivors (e.g., Amir et al., 1996; Zeitlin & McNally, 1991). Our results extend these models

by showing that prioritized processing of 'trauma' related stimuli may be accompanied by the interference of the ongoing processing of neutral stimuli. Further, neutral processing was also interrupted when a New Negative T2 appeared in the RSVP stream. Although this picture category did not benefit from priority encoding as such, it did have an effect on the processing of ongoing neutral stimuli. These findings are clinically relevant. By processing trauma-related stimuli at the expense of neutral stimuli current threat in a given situation may be overestimated, whereas safety signals might not be acknowledged. Future research may consider including measures of PTSD symptoms (e.g., avoidance, intrusive memories, risk assessment) to further investigate a link with clinical symptomatology. Finally, we found suggestive evidence for a role of attentional shifting in both the enhancement as well as interference effect. Future research on the relation between attentional shifting and the risk and/or protective effects of this ability (e.g., Verwoerd et al., 2009), and its potential clinical implications in terms of attentional training interventions (e.g., Verwoerd, Wessel, & de Jong, 2012), would be highly interesting.

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