Childhood abuse is related to working memory impairment for positive emotion in female
university students

Sofie Cromheeke, Laure-Anne Herpoel, Sven C. Mueller

Department of Experimental Clinical and Health Psychology, Ghent University, Belgium

Author note

This research was funded by Ghent University (Multidisciplinary Research Partnership “The integrative neuroscience of behavioural control”)

Correspondence concerning this article should be addressed to Sven C. Mueller, Department of Experimental Clinical and Health Psychology, Ghent University, Henri Dunantlaan 2, 9000 Ghent, Belgium, Email: Sven.Mueller@UGent.be

Abstract

Childhood abuse is an important risk factor for depression, anxiety disorders, and substance use later in life. One possible mechanism underlying this association could be deficits in cognitive processing of emotional information. This study tested the impact of distracting emotional information on working memory performance in 21 young women with a history of sexual and physical abuse during childhood/adolescence (mean age = 20.0 years), and compared their performance to 17 individuals reporting non-abuse related childhood stress (mean age = 19.6 years) and a control group of 17 women without a history of childhood stress (mean age = 20.0 years). During the most difficult distractor condition, working memory accuracy for positive vs. neutral incidental emotional stimuli was reduced in women reporting a history of abuse relative to both control groups (with and without non-abuse related childhood stress). The current results reveal aberrant responses to positive stimuli and are consistent with the notion of persistent influence of childhood abuse on processes critical for emotional well-being and emotion control.

Keywords: sexual abuse, visuospatial working memory, affective, maltreatment, early life stress

Childhood abuse is related to working memory impairment for positive emotion in
female university students

Traumatic events and experience of early stress (ES) during childhood or adolescence, such as parental loss, witnessing violence or sexual or physical abuse have been linked to a variety of adverse health outcomes during the lifespan (McCrory, De Brito, & Viding, 2010). More specifically, these experiences have been shown to be an important risk factor for development of later psychopathology, such as depression, post-traumatic stress disorder, anxiety, and substance abuse (Coffino, 2009; J. G. Green et al., 2010; MacMillan et al., 2001). Importantly, childhood sexual abuse is particularly related to psychopathology even when other adversities and stressors are taken into consideration (Molnar, Buka, & Kessler, 2001). In order to develop interventions aimed at diminishing the adverse effects of such traumatic childhood stress later in life, it is crucial to gain insight into the underlying cognitive mechanisms linking early-life stress to psychopathology.

Current research suggests two possible pathways for reduced health and quality of life in victims of childhood maltreatment. These pathways center around 1), reduced cognitive control and self-regulatory abilities and 2), dysfunctional emotion processing. Although limited, on the one hand, previous work in individuals with experience of ES has documented impairments in cognitive control such as inhibition (Carrion, Garrett, Menon, Weems, & Reiss, 2008; De Bellis, Hooper, Spratt, & Woolley, 2009; Jovanovic et al., 2012; Lewis, Dozier, Ackerman, & Sepulveda-Kozakowski, 2007; Mueller et al., 2012), response shifting (Mueller et al., 2010), and working memory (Majer, Nater, Lin, Capuron, & Reeves, 2010). Due to the frequent co-occurrence of multiple stressors (J. G. Green et al., 2010), most of these previous studies have included individuals with different types of early-life stress, such as neglect and maltreatment (Mueller et al., 2010), emotional abuse, sexual or physical abuse

and/or neglect (Majer et al., 2010) and youth who experienced physical or sexual abuse, or witnessed violence (Carrion et al., 2008). By comparison, only a few of these studies have differentiated between types of stressors and have taken the severity of the early-stress experience into account (De Bellis et al., 2009; Majer et al., 2010). In contrast to the limited work on cognitive impairments in ES, much research has documented detrimental changes in processing emotions after emotional neglect and maltreatment (Maheu et al., 2010; Masten et al., 2008; Tottenham et al., 2010). For example, individuals with a history of maltreatment show abnormalities in emotional face recognition, especially in negatively-valenced faces and exhibit a hyper-responsivity to both angry (Curtis & Cicchetti, 2011; Fries & Pollak, 2004) and fearful faces (Masten et al., 2008).

Even though both pathways, i.e. reduced cognitive control and impaired emotion processing, are important to understand the relationship between ES and psychopathology, increasing efforts, which focus on the tight and dynamic interplay between emotion and cognitive control (Cromheeke & Mueller, 2013; Pessoa, 2009), suggest that these two pathways might not be independent. Diving into this interplay, a study that investigated the effects of reward on cognitive control reported improvements in inhibitory control with reward in healthy adolescents but not adolescents with a history of maltreatment and emotional neglect, which suggests stress-related deficits in the processing of positive information (Mueller et al., 2012). However, apart from studies examining information processing changes associated with reward (e.g. Guyer et al., 2006; Milner et al., 2011; Mueller et al., 2012), no study to our knowledge has investigated how other positive and negative emotional stimuli influence cognitive control processes in individuals reporting severe trauma such as physical and sexual abuse. However, cognitive research suggests a change in the processing of positive and negative child-related schemata in children at-risk for physical abuse relative to low-risk children (Milner et al., 2011). Recent work demonstrated

that the ability to update positive information in working memory was positively linked to life satisfaction and balanced affect (Pe, Koval, & Kuppens, 2013). Such findings might provide important clues to building resilience and establishing effective therapeutic interventions for survivors of abuse and early stress (e.g. Fisher, Chamberlain, & Leve, 2009; Healey & Fisher, 2011; Pe et al., 2013). Since studies investigating emotion-cognition interactions in maltreatment are scarce, evidence in disorders for which individuals with experience of maltreatment have high propensity might provide helpful links.

In a meta-analysis on the emotional Stroop task, depressed individuals, relative to healthy comparisons, exhibited consistent attentional biases for both negative and positive stimuli albeit not as strong in the latter (Epp, Dobson, Dozois, & Frewen, 2012). In-line with this view, remitted depressed individuals show differential neural responses during fMRI to positive (hypoactivation) and negative (hyperactivation) distracting emotion in the prefrontal cortex during a working memory task (Kerestes et al., 2012). In anxious individuals, less evidence is available but shows for example slowed updating of working memory during positive emotion in high anxious vs. low anxious children (Visu-Petra, Tincas, Cheie, & Benga, 2010). These empirical data support suggestions of a link between cognitive control abilities such as working memory and emotion regulation and emotion control processes (Joormann & D'Avanzato, 2010; Joormann & Gotlib, 2008, 2010; Schmeichel & Demaree, 2010; Schmeichel, Volokhov, & Demaree, 2008), further underlining a tight interplay between affective and executive processes.

The current study sought to address how emotional stimuli interfere with cognitive control processes, such as working memory, in young women with a history of childhood sexual and physical abuse. To assess specificity of adverse childhood experience on emotion processing, a second group of young women who had experienced other childhood adversities were also included in addition to a control group with no history of ES, given that different

types of childhood stress have been found to result in distinct outcomes (Bruce, Fisher, Pears, & Levine, 2009; McCrory et al., 2010). Based on 1) findings in individuals with mood and anxiety disorders (Joormann & Gotlib, 2008; Stout, Shackman, & Larson, 2013), 2) a high vulnerability of sexually and physically abused individuals to develop such psychopathology (Chou, 2012; J. G. Green et al., 2010) and 3), the severity of childhood sexual/physical abuse relative to other adversities (Molnar et al., 2001), three main predictions were made. First, it was hypothesized that the abuse group would show impaired working memory performance during emotional distractors relative to 1) a neutral condition, 2) individuals reporting a history of non-abuse related childhood stress and 3) healthy comparisons in a visuo-spatial working memory task. Finally, we also predicted that both groups with a history of childhood stress would show higher rates of self-reported psychopathology than the control group.

Method

Participants

First-year university psychology students ($n = 616$) were asked to complete several screening questionnaires in exchange for course credit. For the present purposes, students were asked to indicate the number of stressors they had encountered during childhood and/or adolescence (0, 1, 2 or more). Due to ethical reasons, no questions were asked regarding the specificity of stressors at that moment. To recruit female participants with a history of physical/sexual abuse, we invited individuals who reported two or more early life stressors on the initial screening ($n = 78$) into the laboratory, of whom 40 voluntarily agreed to participate in the study and fill in additional questionnaires. All participants came from a homogenous background in Flanders and were of Caucasian ethnicity. To assess the nature of the stressors more specifically, upon visiting the laboratory participants completed the Stressful Life Events Screening Questionnaire (SLESQ)(Goodman, Corcoran, Turner, Yuan, & Green, 1998), a 13-item self-report measure to determine exposure to eleven specific and two general categories of events (e.g. life-threatening accident, sexual, physical, or emotional abuse). For each category, participants were asked to indicate whether they had experienced such an event and, if they responded 'yes', to specify the event (e.g. age, frequency, duration). The SLESQ has a good test-retest reliability (median $\kappa = .73$) and adequate convergent validity (median $\kappa = .64$) (Goodman et al., 1998). In the current sample, the internal consistency of the SLESQ was acceptable ($\alpha = .6$). To assess sexual and physical abuse specifically, the questionnaire includes the following items: “1) *At any time, has anyone (parent, other family member, romantic partner, stranger or someone else) ever physically forced you to have intercourse, or to have oral or anal sex against your wishes, or when you were helpless, such as being asleep or intoxicated?* 2) *Other than experiences mentioned in earlier questions, has anyone ever touched private parts of your body, made you touch their body, or tried to make you to*

have sex against your wishes?, 3) *When you were a child, did a parent, caregiver or other person ever slap you repeatedly, beat you, or otherwise attack or harm you?*”. For the abuse group, only female students who had reported either sexual abuse ($n = 10$), physical abuse ($n = 4$), or a combination of both ($n = 7$) were selected (Total $N = 21$, mean age (M_{age}) = 20.0 years, standard deviation (SD) = 1.9). Students reporting other experiences of childhood stress, such as illness or accidents, were included in the non-abuse stress group ($n = 17$, $M_{age} = 19.6$ years, $SD = 1.1$). The control group consisted of 17 female students ($n = 17$, $M_{age} = 20.2$ years, $SD = 1.7$) who did not report any prior or current stressful life events in the SLESQ (details of experienced stressors in Table 1). All participants agreed to voluntarily take part in the experiment in exchange for course credits or monetary compensation. The study was approved by the ethical committee of the Faculty of Psychology and Educational Sciences at Ghent University.

To assess the presence of psychopathology, participants completed the Dutch version of the Adult Self Report (ASR)(Achenbach & Rescorla, 2003), a screening instrument measuring mental health problems (internalizing and externalizing), resulting in scores on both syndrome scales and DSM (Diagnostic and Statistical Manual of Mental Disorders) scales. The ASR has a good reliability and content validity, and excellent internal consistency ($\alpha = .94$ (Evers, van Vliet-Mulder, & Groot, 2005); $\alpha = .95$ in the current sample). T-scores higher than 63 on the subscales Internalizing problems, Externalizing problems and Total problems are considered clinical. Current levels of depression and anxiety were assessed with the Beck Depression Inventory (Beck, Erbaugh, Ward, Mock, & Mendelsohn, 1961) and State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970) (Table 2). Both the BDI-II-NL and STAI-NL have good validity and excellent internal consistency ($\alpha = 0.88$ and $\alpha = 0.9$ respectively (Evers et al., 2005); in the current sample: $\alpha = 0.93$ for BDI, $\alpha = 0.92$ for STAI-State, $\alpha = .94$ for STAI Trait). Since resilience has been shown to moderate the

presence and severity of depression following childhood trauma (Wingo et al., 2010), we also included the Resilience Scale (RS-NL; Wagnild & Young, 1993), a 25-item questionnaire with good internal consistency ($\alpha = 0.85$; in the current sample: $\alpha = 0.80$), test-retest reliability ($r = 0.9$) and acceptable construct validity (Portzky, Wagnild, De Bacquer, & Audenaert, 2010).

Stimuli and material

Images of 44 different actors (24 male, 20 female) were selected from the NimStim face stimulus database (Tottenham et al., 2009) and the Radboud Faces Database (Langner et al., 2010). Each actor posed three emotional expressions (neutral, happy, angry) with closed mouth, resulting in a total of 132 faces. Only pictures with emotion ratings of 70% or higher (mean emotion rating: 94%) for all three emotions were selected (Langner et al., 2010; Tottenham et al., 2009). To avoid confounds based on external features, background and hair were removed, and images were gray-scaled (256 gray levels) using Adobe Photoshop 5.0. The faces were displayed on a black background at 160x200 pixels, corresponding to approximately 4x5cm. At the beginning of the experiment 30 individuals (15 male, 15 female) were randomly chosen from the selection of 44 actors. Each actor only expressed one emotion throughout the task, resulting in 10 individuals per emotion (five male, five female). The task consisted of 120 trials divided into four blocks of 30 trials each. Within each block, every actor was shown once. After completing the task, participants were asked to fill in the questionnaires.

Procedure

The sequence of the Spatial Emotional Match To Sample (SEMTOS) task, modeled after a non-emotional variant of Awh et al. (Awh, Jonides, & Reuter-Lorenz, 1998), during a

single trial was as follows (Figure 1): a) A yellow fixation cross was shown at the beginning of the trial for 1 sec, b) the memory cue (a happy, angry or neutral face) appeared for 400 ms in one of 24 possible locations. The locations were equally spaced on an imaginary concentric circle with a radius of 250 pixels. To prevent verbal coding of locations, every possible location was located at least 10° clockwise or counterclockwise from the cardinal axes, c) during a retention interval of 5000 ms, a red or blue color probe was shown for 1000 ms. Participants were asked to indicate the color of this stimulus by pressing the red or blue button ('w' or 'x' on the keyboard, covered with red and blue stickers, respectively) with the left hand. The interval between the end of the memory cue and the appearance of the color probe varied randomly between 1000 ms and 3000 ms, d) after the retention interval, the face was shown again for 1500 ms. Participants had to indicate whether this memory probe had the same location as the memory cue that was shown at the beginning of the trial. They were instructed to press "=" for match trials and "≠" for miss trials (":" and "=" on the keyboard, covered with stickers of = and ≠, respectively), using their right hand.

Before starting the experiment, both the memory and the color discrimination tasks were practiced separately first, and then together. Each practice block consisted of 10 trials. Participants only continued to the next block if they had an accuracy rate of at least 60%. They were asked to look at the fixation cross at the beginning of each trial, when the fixation cross turned yellow. For both the memory probe and color probe, only responses within a response window of 2000 ms were registered. Participants were instructed to respond as quickly as possible, but without compromising accuracy. They did not receive feedback about their performance on either task.

The location of the memory probes matched the memorized location on 40% of the trials (*match* trials). When the locations did not match (*miss* trials), the distance between the memory cue and probe was varied systematically between 15° (*Miss1*), 20° (*Miss2*) and 25°

(*Miss3*) clockwise or counterclockwise on the imaginary concentric circle, respectively. The emotional expression and gender of the faces was counterbalanced across these conditions. The distance between the memory cue and the color probe varied systematically. Color probes were shown either near (40° on the imaginary circle) or far (160° on the imaginary circle), and either clockwise or counterclockwise from the memorized location.

-----Figure 1 about here please -----

Statistical analysis

A 4 x 3 x 3 repeated measures analysis of covariance (ANCOVA) on responses to the memory probe was conducted with Location (*Match, Miss1, Miss2, Miss3*) and Emotional expression (*angry, happy, neutral*) as within-subjects factors and Group (*abuse, stress, and control group*) as between-subjects factor. The ANCOVA was run twice, once for accuracy (% correct) and once for reaction times (in ms). Significant interactions or main effects were followed-up with pairwise comparisons, paired samples t-tests, or univariate analyses, as appropriate. Mean reaction times were based on correct trials. Reaction times of less than 100 ms were excluded as anticipatory responses. Additional correlational analyses (Pearson's r) were carried out to investigate the association of the behavioural findings with results of mood state and psychopathology as well as individual factors of abuse (e.g., age of onset, duration, frequency of abuse). Measures of effect size are reported as Cohen's d or partial eta squared (as appropriate).

Results

-----Table 1 about here please -----

-----Table 2 about here please -----

Questionnaire results

Table 1 shows details of the type and number of stressors reported by the control, stress and abuse group. Groups differed significantly on the mean number of stressors with the abuse group reporting more stressors than the stress group, and both the abuse and stress group reporting more stressors than the control group ($p < .001$ for all pairwise comparisons, Bonferroni corrected). Table 2 shows the demographic and psychopathology indicators by the control, stress and abuse group. Age or resilience scores did not differ between groups. However, significant group differences were found on trait levels of anxiety, state levels of anxiety, and symptoms of depression. Post-hoc tests indicated that both the stress and abuse group scored higher than controls on trait ($p = .005$ and $p = .001$, respectively) and state anxiety ($p = .026$ and $p = .028$, respectively). The abuse group also reported more symptoms of depression than controls ($p < .001$), while the difference between the stress and control group on this measure approached conventional levels of significance ($p = .059$). In terms of psychopathology, while none of the participants in the control group met clinical cut-off scores, eight out of 17 women in the stress group and eight out of 21 women in the abuse group scored within the clinical range on internalizing and externalizing scales, a difference that was significant, $\chi^2(2, N = 54) = 111.06, p = .004$. Participants also differed on the total psychopathology (ASR) scores, with women in the abuse and stress group scoring significantly higher than control women ($p < .001$ and $p = .003$, respectively). Given the group differences in levels of depression and anxiety, these variables were added as covariates

in the subsequent analyses (but we do not discuss them as they were not the focus of our hypotheses).

Accuracy

As expected, the three-way Location by Emotion by Group interaction was significant, $F(12, 300) = 2.02, p = .023$, partial $\eta^2 = .08$. To follow-up this interaction, the analyses were re-run split at the level of Group (Figure 2, Table 3). Location significantly interacted with Emotion in the abuse, $F(6, 108) = 2.32, p = .04$, partial $\eta^2 = .11$, and the stress group, $F(6, 84) = 2.42, p = .03$, partial $\eta^2 = .15$. In the control group, however, this interaction was not significant..

The Emotion by Location interaction in the abuse group showed that in the most difficult distractor condition, the Miss1 trials, women with a history of abuse performed significantly worse for happy compared to neutral faces ($p = .022$)(see Figure 2A). By comparison, an impact of affective valence was not present in Match trials or in easier to detect Miss2 or Miss3 trials. In the stress group, follow-up analyses for each location separately did not yield any significant main effects of emotion, although there was a slight trend in the Miss3 trials, $F(2, 32) = 2.61, p = .09$, partial $\eta^2 = .14$). In addition, the main ANCOVA analysis also revealed a significant main effect of Location, $F(3, 150) = 74.58, p < .001$, partial $\eta^2 = .60$, which indicated a higher accuracy for match trials and trials farthest from the target (Miss3) than for distractors closer to the target (Miss1 and Miss2 trials) (all pairwise comparisons $p < .001$, Bonferroni corrected) regardless of Group.

-----Figure 2 about here please -----

To further assess the difference in responding to Miss1 happy faces in the abuse group, difference scores of emotional valence [Neutral – Happy] and [Neutral - Angry] were calculated (Figure 3). Confirming the findings from the main analysis, the [Neutral – Happy] accuracy difference score was significantly different from 0 in the abuse group, $t(20) = 2.48$, $p = .022$, $d = 0.56$, but not in the stress group or the control group. By comparison, the [Neutral - Angry] accuracy difference score in the Miss1 trials did not differ significantly from 0 in the abuse or control group..

-----Figure 3 about here please -----

Reaction time

Reaction time analysis only yielded a main effect of location, $F(3, 147) = 16.17$, $p < .001$, partial $\eta^2 = .25$. Pairwise comparisons showed that participants were faster for match trials than for Miss1 ($p < .001$) and Miss2 ($p < .001$) trials. They were also faster for easier to perform Miss3 trials than for relatively more difficult Miss1 ($p < .001$) and Miss2 ($p = .002$) trials. The three-way interaction was not significant but approached conventional levels of significance, $F(12, 294) = 1.60$, $p = .09$, partial $\eta^2 = .06$ (Figure 2B). No other main effects or interactions were significant (Table 3).

-----Table 3 about here please -----

Exploratory analyses of abuse type, duration, onset, and psychopathology

Because total psychopathology scores were higher in the stress and abuse compared to the control group, we investigated whether the accuracy difference that was found between

the happy and neutral faces in the Miss1 condition was due to behaviour problems. The [Neutral - Happy] accuracy difference was not significantly correlated with the Total Psychopathology score (ASR), nor did it differ between participants who scored in the (sub)clinical range and participants with scores in the normal range.. When looking at the abuse, stress and control group separately, no significant correlations were found between the [Neutral - Happy] accuracy difference and the Total score, and Internalizing or Externalizing subscales in either group (all $p > .05$).

Additionally, we tested the association between the [Neutral - Happy] accuracy difference and details of the abuse, but no significant correlations were found with age of onset, duration, or frequency of abuse.. We also explored whether adding age of onset, duration, and frequency of abuse as covariates had any impact on the three-way Location by Emotion by Group interaction in the abuse group. However, the three-way interaction was still significant, $F(6, 90) = 2.21$, $p = .049$, partial $\eta^2 = .13$, suggesting little impact of abuse details on the main finding. Moreover, details of the abuse experience did not significantly interact with the factors Location and Emotion.

Discussion

The present study sought to provide evidence for the persistent influence of childhood maltreatment on neuropsychological functions later in life. To this goal, the influence of emotional distraction on working memory, a function implicated in emotion regulation and emotion control (Joormann & D'Avanzato, 2010; Joormann & Gotlib, 2008, 2010; Schmeichel & Demaree, 2010; Schmeichel et al., 2008) was assessed in female survivors of childhood trauma (physical and/or sexual abuse) or experience of non-abuse related childhood stress. Two main findings pertinent to the study goal emerged. First, as hypothesized, affective valence interrupted effective working memory performance in female university students with a history of abuse. However, contrary to the hypotheses, this interruption only occurred for positive but not negative faces. Second, no interference effect was found for participants without a history of abuse or participants with non-abuse related childhood stress.

While much previous research has documented perturbed processing of, and heightened sensitivity to, negative emotional faces in individuals with a history of abuse (Gibb, Schofield, & Coles, 2009; Masten et al., 2008; Tottenham et al., 2011), findings of effects of positive emotion on cognitive performance in this population are scarce. Indeed, the main finding of the current study demonstrated impaired working memory performance during positive faces in women with a history of abuse relative to women with non-abuse related childhood stress or women without childhood stress. Such data suggest a detrimental impact of incidental (i.e., irrelevant) positive information on working memory accuracy. Of note, this detrimental impact was only apparent in the most difficult distractor condition (close proximity between target and distractor) but not in easier to perform distractor conditions. On the easier working memory conditions, all groups performed equally well and were insensitive to distracting affective information. Although two recent neurobiological studies failed to find differential amygdala activation for happy compared to neutral faces in

relation to childhood trauma (Dannowski et al., 2012; van Harmelen et al., 2013), these studies did not take the relationship between emotional valence and skills subserving emotion regulation into account. An interesting study by Tottenham et al. (2011) that examined the influence of amygdala activity for fearful compared to neutral faces during inhibitory control in previously institutionalized children did unfortunately not examine happy faces. However, parallel research in reward processing has documented reduced reward sensitivity in individuals with a history of abuse (Guyer et al., 2006), also failing to elevate inhibitory control performance (Mueller et al., 2012). Thus, a question for future work concerns the implications of reduced processing of positive emotion for cognitive and emotion control after ES.

Based on evidence in individuals with depression or anxiety (Epp et al., 2012; Kerestes et al., 2012; Levens & Gotlib, 2010; Visu-Petra et al., 2010) and research on emotion processing in ES (Maheu et al., 2010; Masten et al., 2008; Tottenham et al., 2011), we also expected to find an effect in negative faces. However, negative incidental emotion did not seem to impair working memory in any group. One interesting theoretical conjecture regarding the selective effect of positive stimuli could be linked to resilience. All participants in the current study were university students, thus potentially showing a selectivity bias of individuals being able to attend university despite the early trauma. Such a notion would be supported by the idea that positive emotions aid high-resilient individuals to recover from stress (Ong, Bergeman, Bisconti, & Wallace, 2006) and enhance coping resources (Tugade, Fredrickson, & Feldman Barrett (2004). High resilience also moderates depression scores in maltreated individuals (Wingo et al., 2010) supported by psychophysiological data, which shows that hemispheric asymmetry in the EEG distinguished between resilient and non-resilient children (Curtis & Cicchetti, 2007). Thus, given that there were no significant differences between the three groups of the current study on measures of resilience, it is

conceivable that a selective effect of positive emotion might be limited to high resilient relative to low resilient individuals. However, as we had no *a priori* expectations with regard to this measure, current work in our laboratory is following-up on this intriguing possibility.

An alternative explanation for the lack of a difference between angry and neutral faces might be differences in interpretation of neutral and negative faces in affected and comparison participants. Previous studies have found that neutral faces are not always perceived as emotionally neutral in individuals with, or at-risk for, psychopathology. Masten et al. (2008) used a morphed facial identification task to examine processing of facial emotions in maltreated children. Compared to controls, maltreated children (with and without Posttraumatic stress disorder) showed a heightened ability to identify fearful faces when they were morphed with neutral faces (50% neutral, 50% fearful). Additionally, depression-prone individuals misinterpret neutral faces as being sad more often than healthy controls (Leppanen, Milders, Bell, Terriere, & Hietanen, 2004). In the current study, participants in the abuse and stress group reported more depressive symptoms than healthy comparisons, which could suggest that a negative interpretation bias might increase elaboration of neutral faces and consequently improve working memory performance for neutral and negative faces together. More work on distinguishing between these possibilities is required.

As alluded to earlier, cognitive biases have been implicated in several psychopathological disorders, such as depression or anxiety disorders. For example, depression is associated with interpretation biases towards negative stimuli (Gotlib et al., 2004; Joormann & Gotlib, 2008; Levens & Gotlib, 2010), with an increased interest in therapies targeting such biases (Baert, De Raedt, Schacht, & Koster, 2010; Beard, Sawyer, & Hofmann, 2012; Britton et al., 2013; Schweizer & Dalgleish, 2011; Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013). A recent study on the effect of emotional working memory training in a healthy population yielded promising results, since the training

improved not only performance on the emotional working memory task but also on a transfer task measuring emotional regulation capacity (Schweizer et al., 2013). In addition, Pe et al. (2013) found beneficial effects on well-being when positive material was updated in working memory. Future research could examine the effectiveness of bias training when training either positive or negative information in individuals with a history of abuse.

Some limitations of the present study require discussion. One limitation certainly concerns the small sample size, even though a gradual effect of location distance on accuracy and sensitivity to incidental emotion suggests that the study group was sensitive to the task. However, due to the small sample size, the additional correlational analyses relating the [Neutral - Happy] accuracy difference in Miss1 trials to questionnaire results and details of abuse history should be considered exploratory. Secondly, while restricting the study to female participants might limit generalizability to men with a history of childhood abuse, it also constitutes a strength by excluding any possible confound of sex. A third limitation concerns the use of self-report measures. Even though the SLESQ is a well-validated instrument (Goodman et al., 1998; B. L. Green, Chung, Daroowalla, Kaltman, & DeBenedictis, 2006), we cannot exclude the possibility of recall bias. For the assessment of psychopathology, we also used a self-report measure, i.e. the ASR (Achenbach & Rescorla, 2003), instead of a structured psychiatric interview. However, the emphasis of the current study was on the experience of abuse on cognitive mechanisms of emotional processing rather than clinical psychopathology. In addition, the ASR is a reliable and valid (Achenbach & Rescorla, 2003) instrument and is frequently used to assess psychopathology in young adults (Hack et al., 2004; Reef, Diamantopoulou, van Meurs, Verhulst, & van der Ende, 2010). Moreover, it detected significant differences between the two groups in experienced pathology on several scales of the ASR. Finally, because of time constraints and in order to avoid fatigue in participants, we decided to only use one positive and one negative emotional

expression in the task. Even though sad faces are often used in depression research, we opted for angry faces given the heightened sensitivity of traumatized individuals to threatening information (Gibb et al., 2009; Johnson, Gibb, & McGear, 2010; Pine et al., 2005; Pollak & Tolley-Schell, 2003). Future work could examine sensitivity to other emotional expressions.

Conclusion

The present study highlights interfering effects of positive emotion on working memory performance in women with a history of abuse relative to women with other childhood stressors or comparisons without a history of ES. These findings aim to increase awareness of history of abuse among female university students and the impact it might have on cognitive skills related to emotion control. Larger and more strongly powered studies are needed to replicate this finding to investigate how individual differences and abuse characteristics influence working memory impairment for positive information.

References

- Achenbach, T. M., & Rescorla, L. A. (2003). *Manual for the ASEBA Adult Forms & Profiles*. Burlington, VT: University of Vermont, Research Center for Children, Youth, & Families.
- Awh, E., Jonides, J., & Reuter-Lorenz, P. A. (1998). Rehearsal in spatial working memory. *Journal of Experimental Psychology: Human Perception and Performance*, 24(3), 780.
- Baert, S., De Raedt, R., Schacht, R., & Koster, E. H. (2010). Attentional bias training in depression: therapeutic effects depend on depression severity. *Journal of behavior therapy and experimental psychiatry*, 41(3), 265-274. doi: 10.1016/j.jbtep.2010.02.004
- Beard, C., Sawyer, A. T., & Hofmann, S. G. (2012). Efficacy of attention bias modification using threat and appetitive stimuli: a meta-analytic review. *Behav Ther*, 43(4), 724-740. doi: 10.1016/j.beth.2012.01.002
- Beck, A. T., Erbaugh, J., Ward, C. H., Mock, J., & Mendelsohn, M. (1961). An Inventory for Measuring Depression. *Archives of general psychiatry*, 4(6), 561-&.
- Britton, J. C., Bar-Haim, Y., Clementi, M. A., Sankin, L. S., Chen, G., Shechner, T., . . . Pine, D. S. (2013). Training-associated changes and stability of attention bias in youth: Implications for Attention Bias Modification Treatment for pediatric anxiety. *Dev Cogn Neurosci*, 4, 52-64. doi: 10.1016/j.dcn.2012.11.001
- Bruce, J., Fisher, P. A., Pears, K. C., & Levine, S. (2009). Morning cortisol Levels in preschool-aged foster children: differential effects of maltreatment type. *Developmental psychobiology*, 51(1), 14-23. doi: 10.1002/dev.20333

- Carrion, V. G., Garrett, A., Menon, V., Weems, C. F., & Reiss, A. L. (2008). Posttraumatic stress symptoms and brain function during a response-inhibition task: an fMRI study in youth. *Depression and anxiety*, 25(6), 514-526. doi: 10.1002/da.20346
- Chou, K. L. (2012). Childhood sexual abuse and psychiatric disorders in middle-aged and older adults: evidence from the 2007 Adult Psychiatric Morbidity Survey. *The Journal of clinical psychiatry*, 73(11), e1365-1371. doi: 10.4088/JCP.12m07946
- Coffino, B. (2009). The role of childhood parent figure loss in the etiology of adult depression: findings from a prospective longitudinal study. *Attach Hum Dev*, 11(5), 445-470. doi: 10.1080/14616730903135993
- Cromheeke, S., & Mueller, S. C. (2013). Probing emotional influences on cognitive control: an ALE meta-analysis of cognition emotion interactions. *Brain structure & function*. doi: 10.1007/s00429-013-0549-z
- Curtis, W. J., & Cicchetti, D. (2011). Affective facial expression processing in young children who have experienced maltreatment during the first year of life: An event-related potential study. *Development and Psychopathology*, 23(2), 373-395. doi: 10.1017/S0954579411000125
- Dannlowski, U., Kugel, H., Huber, F., Stuhrmann, A., Redlich, R., Grotegerd, D., . . . Suslow, T. (2012). Childhood maltreatment is associated with an automatic negative emotion processing bias in the amygdala. *Human brain mapping*. doi: 10.1002/hbm.22112
- De Bellis, M., Hooper, S. R., Spratt, E. G., & Woolley, D. P. (2009). Neuropsychological findings in childhood neglect and their relationships to pediatric PTSD. *J Int Neuropsychol Soc*, 15(6), 868-878. doi: 10.1017/S1355617709990464
- Epp, A. M., Dobson, K. S., Dozois, D. J. A., & Frewen, P. A. (2012). A systematic meta-analysis of the Stroop task in depression. *Clinical psychology review*, 32(4), 316-328. doi: DOI 10.1016/j.cpr.2012.02.005

- Evers, A., van Vliet-Mulder, J. C., & Groot, C. J. (2005). *Documentatie van tests en testresearch in Nederland, deel I en II*. Assen: Van Gorcum.
- Fisher, P. A., Chamberlain, P., & Leve, L. D. (2009). Improving the lives of foster children through evidenced-based interventions. *Vulnerable Child Youth Stud*, 4(2), 122-127. doi: 10.1080/17450120902887368
- Fries, A. B. W., & Pollak, S. D. (2004). Emotion understanding in postinstitutionalized eastern European children. *Development and Psychopathology*, 16(2), 355-369. doi: Doi 10.1017/S0954579404044554
- Gibb, B. E., Schofield, C. A., & Coles, M. E. (2009). Reported history of childhood abuse and young adults' information-processing biases for facial displays of emotion. *Child Maltreatment*, 14(2), 148-156.
- Goodman, L. A., Corcoran, C., Turner, K., Yuan, N., & Green, B. L. (1998). Assessing traumatic event exposure: General issues and preliminary findings for the Stressful Life Events Screening Questionnaire. *Journal of traumatic stress*, 11(3), 521-542.
- Gotlib, I. H., Kasch, K. L., Traill, S., Joormann, J., Arnow, B. A., & Johnson, S. L. (2004). Coherence and specificity of information-processing biases in depression and social phobia. *J Abnorm Psychol*, 113(3), 386-398. doi: 10.1037/0021-843X.113.3.386
- Green, B. L., Chung, J. Y., Daroowalla, A., Kaltman, S., & DeBenedictis, C. (2006). Evaluating the cultural validity of the stressful life events screening questionnaire. *Violence against Women*, 12(12), 1191-1213. doi: Doi 10.1177/1077801206294534
- Green, J. G., McLaughlin, K. A., Berglund, P. A., Gruber, M. J., Sampson, N. A., Zaslavsky, A. M., & Kessler, R. C. (2010). Childhood adversities and adult psychiatric disorders in the national comorbidity survey replication I: associations with first onset of DSM-IV disorders. *Archives of general psychiatry*, 67(2), 113-123. doi: 10.1001/archgenpsychiatry.2009.186

- Guyer, A. E., Kaufman, J., Hodgdon, H. B., Masten, C. L., Jazbec, S., Pine, D. S., & Ernst, M. (2006). Behavioral alterations in reward system function: the role of childhood maltreatment and psychopathology. *Journal of the American Academy of Child and Adolescent Psychiatry*, 45(9), 1059-1067. doi: 10.1097/01.chi.0000227882.50404.11
- Hack, M., Youngstrom, E. A., Cartar, L., Schluchter, M., Taylor, H. G., Flannery, D., . . . Borawski, E. (2004). Behavioral outcomes and evidence of psychopathology among very low birth weight infants at age 20 years. *Pediatrics*, 114(4), 932-940. doi: 10.1542/peds.2003-1017-L
- Healey, C. V., & Fisher, P. A. (2011). Children in Foster Care and the Development of Favorable Outcomes. *Child Youth Serv Rev*, 33(10), 1822-1830. doi: 10.1016/j.chilyouth.2011.05.007
- Johnson, A. L., Gibb, B. E., & McGeary, J. (2010). Reports of Childhood Physical Abuse, 5-HTTLPR Genotype, and Women's Attentional Biases for Angry Faces. *Cognitive Therapy and Research*, 34(4), 380-387. doi: DOI 10.1007/s10608-009-9269-3
- Joormann, J., & D'Avanzato, C. (2010). Emotion regulation in depression: Examining the role of cognitive processes. *Cognition & emotion*, 24(6), 913-939. Doi 10.1080/02699931003784939
- Joormann, J., & Gotlib, I. H. (2008). Updating the contents of working memory in depression: interference from irrelevant negative material. *J Abnorm Psychol*, 117(1), 182-192. doi: 10.1037/0021-843X.117.1.182
- Joormann, J., & Gotlib, I. H. (2010). Emotion regulation in depression: relation to cognitive inhibition. *Cognition & emotion*, 24(2), 281-298. doi: 10.1080/02699930903407948
- Jovanovic, T., Ely, T., Fani, N., Glover, E. M., Gutman, D., Tone, E. B., . . . Ressler, K. J. (2012). Reduced neural activation during an inhibition task is associated with impaired

- fear inhibition in a traumatized civilian sample. *Cortex; a journal devoted to the study of the nervous system and behavior*. doi: 10.1016/j.cortex.2012.08.011
- Kerestes, R., Ladouceur, C. D., Meda, S., Nathan, P. J., Blumberg, H. P., Maloney, K., . . . Phillips, M. L. (2012). Abnormal prefrontal activity subserving attentional control of emotion in remitted depressed patients during a working memory task with emotional distracters. *Psychological medicine*, 42(1), 29-40. doi: Doi 10.1017/S0033291711001097
- Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H. J., Hawk, S. T., & van Knippenberg, A. (2010). Presentation and validation of the Radboud Faces Database. *Cognition & emotion*, 24(8), 1377-1388.
- Leppanen, J. M., Milders, M., Bell, J. S., Terriere, E., & Hietanen, J. K. (2004). Depression biases the recognition of emotionally neutral faces. *Psychiatry research*, 128(2), 123-133. doi: 10.1016/j.psychres.2004.05.020
- Levens, S. M., & Gotlib, I. H. (2010). Updating Positive and Negative Stimuli in Working Memory in Depression. *Journal of Experimental Psychology-General*, 139(4), 654-664. doi: Doi 10.1037/A0020283
- Lewis, E. E., Dozier, M., Ackerman, J., & Sepulveda-Kozakowski, S. (2007). The effect of placement instability on adopted children's inhibitory control abilities and oppositional behavior. *Dev Psychol*, 43(6), 1415-1427. doi: 10.1037/0012-1649.43.6.1415
- MacMillan, H. L., Fleming, J. E., Streiner, D. L., Lin, E., Boyle, M. H., Jamieson, E., . . . Beardslee, W. R. (2001). Childhood abuse and lifetime psychopathology in a community sample. *The American journal of psychiatry*, 158(11), 1878-1883.
- Maheu, F. S., Dozier, M., Guyer, A. E., Mandell, D., Peloso, E., Poeth, K., . . . Ernst, M. (2010). A preliminary study of medial temporal lobe function in youths with a history

- of caregiver deprivation and emotional neglect. *Cognitive, affective & behavioral neuroscience*, 10(1), 34-49. doi: 10.3758/CABN.10.1.34
- Majer, M., Nater, U. M., Lin, J. M., Capuron, L., & Reeves, W. C. (2010). Association of childhood trauma with cognitive function in healthy adults: a pilot study. *BMC Neurol*, 10, 61. doi: 10.1186/1471-2377-10-61
- Masten, C. L., Guyer, A. E., Hodgdon, H. B., McClure, E. B., Charney, D. S., Ernst, M., . . . Monk, C. S. (2008). Recognition of facial emotions among maltreated children with high rates of post-traumatic stress disorder. *Child Abuse Negl*, 32(1), 139-153. doi: 10.1016/j.chiabu.2007.09.006
- McCrory, E., De Brito, S. A., & Viding, E. (2010). Research review: the neurobiology and genetics of maltreatment and adversity. *Journal of child psychology and psychiatry, and allied disciplines*, 51(10), 1079-1095. doi: 10.1111/j.1469-7610.2010.02271.x
- Milner, J. S., Rabenhorst, M. M., McCanne, T. R., Crouch, J. L., Skowronski, J. J., Fleming, M. T., . . . Risser, H. J. (2011). Event-related potentials: search for positive and negative child-related schemata in individuals at low and high risk for child physical abuse. *Child Abuse Negl*, 35(4), 249-266. doi: 10.1016/j.chiabu.2011.01.002
- Mueller, S. C., Hardin, M. G., Korelitz, K., Daniele, T., Bemis, J., Dozier, M., . . . Ernst, M. (2012). Incentive effect on inhibitory control in adolescents with early-life stress: an antisaccade study. *Child Abuse Negl*, 36(3), 217-225. doi: 10.1016/j.chiabu.2011.10.010
- Mueller, S. C., Maheu, F. S., Dozier, M., Peloso, E., Mandell, D., Leibenluft, E., . . . Ernst, M. (2010). Early-life stress is associated with impairment in cognitive control in adolescence: an fMRI study. *Neuropsychologia*, 48(10), 3037-3044. doi: S0028-3932(10)00242-3 [pii] 10.1016/j.neuropsychologia.2010.06.013

- Pe, M. L., Koval, P., & Kuppens, P. (2013). Executive well-being: updating of positive stimuli in working memory is associated with subjective well-being. *Cognition*, 126(2), 335-340. doi: 10.1016/j.cognition.2012.10.002
- Pessoa, L. (2009). How do emotion and motivation direct executive control? *Trends in cognitive sciences*, 13(4), 160-166. doi: 10.1016/j.tics.2009.01.006
- Pine, D. S., Mogg, K., Bradley, B. P., Montgomery, L., Monk, C. S., McClure, E., . . . Kaufman, J. (2005). Attention bias to threat in maltreated children: implications for vulnerability to stress-related psychopathology. *The American journal of psychiatry*, 162(2), 291-296. doi: 10.1176/appi.ajp.162.2.291
- Pollak, S. D., & Tolley-Schell, S. A. (2003). Selective attention to facial emotion in physically abused children. *J Abnorm Psychol*, 112(3), 323-338.
- Portzky, M., Wagnild, G., De Bacquer, D., & Audenaert, K. (2010). Psychometric evaluation of the Dutch Resilience Scale RS-nl on 3265 healthy participants: a confirmation of the association between age and resilience found with the Swedish version. *Scand J Caring Sci*, 24 Suppl 1, 86-92. doi: 10.1111/j.1471-6712.2010.00841.x
- Reef, J., Diamantopoulou, S., van Meurs, I., Verhulst, F., & van der Ende, J. (2010). Predicting adult emotional and behavioral problems from externalizing problem trajectories in a 24-year longitudinal study. *European child & adolescent psychiatry*, 19(7), 577-585. doi: 10.1007/s00787-010-0088-6
- Schmeichel, B. J., & Demaree, H. A. (2010). Working memory capacity and spontaneous emotion regulation: high capacity predicts self-enhancement in response to negative feedback. *Emotion*, 10(5), 739-744. doi: 10.1037/a0019355
- Schmeichel, B. J., Volokhov, R. N., & Demaree, H. A. (2008). Working memory capacity and the self-regulation of emotional expression and experience. *Journal of personality and social psychology*, 95(6), 1526-1540. doi: 10.1037/a0013345

Schweizer, S., & Dalgleish, T. (2011). Emotional working memory capacity in posttraumatic stress disorder (PTSD). *Behaviour research and therapy*, 49(8), 498-504. doi:

10.1016/j.brat.2011.05.007

Schweizer, S., Grahn, J., Hampshire, A., Mobbs, D., & Dalgleish, T. (2013). Training the emotional brain: improving affective control through emotional working memory training. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, 33(12), 5301-5311. doi: 10.1523/JNEUROSCI.2593-12.2013

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). The state-trait anxiety inventory. *Palo Alto, Calif: Consulting Psychologists Press Inc.*

Stout, D. M., Shackman, A. J., & Larson, C. L. (2013). Failure to filter: anxious individuals show inefficient gating of threat from working memory of threat from working memory. *Frontiers in human neuroscience*, 7. doi: Artn 58 Doi

10.3389/Fnhum.2013.00058

Tottenham, N., Hare, T. A., Millner, A., Gilhooly, T., Zevin, J. D., & Casey, B. J. (2011). Elevated amygdala response to faces following early deprivation. *Developmental science*, 14(2), 190-204. doi: DOI 10.1111/j.1467-7687.2010.00971.x

Tottenham, N., Hare, T. A., Quinn, B. T., McCarry, T. W., Nurse, M., Gilhooly, T., . . . Casey, B. J. (2010). Prolonged institutional rearing is associated with atypically large amygdala volume and difficulties in emotion regulation. *Developmental science*, 13(1), 46-61. doi: DOI 10.1111/j.1467-7687.2009.00852.x

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., . . . Nelson, C. (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry research*, 168(3), 242-249. doi:

10.1016/j.psychres.2008.05.006

van Harmelen, A. L., van Tol, M. J., Demenescu, L. R., van der Wee, N. J., Veltman, D. J.,

Aleman, A., . . . Elzinga, B. M. (2013). Enhanced amygdala reactivity to emotional faces in adults reporting childhood emotional maltreatment. *Social cognitive and affective neuroscience*, 8(4), 362-369. doi: 10.1093/scan/nss007

Visu-Petra, L., Tincas, I., Cheie, L., & Benga, O. (2010). Anxiety and visual-spatial memory updating in young children: An investigation using emotional facial expressions.

Cognition & emotion, 24(2), 223-240. doi: Pii 917893044 Doi 10.1080/02699930903387546

Table 1

Detailed information on reported stressors as assessed with the Stressful Life Events

Screening Questionnaire (SLESQ) for the control, stress, and abuse group, separately

SLESQ item	Controls (n = 17)	Stress group (n = 17)	Abuse group (n = 21)
Life-threatening illness/accident	0	3	7
Robbery/mugging	0	1	2
Death of a close friend/relative	0	5	6
Sexual abuse with physical force	0	0	12
Sexual abuse without physical force	0	0	7
Childhood physical abuse	0	0	11
Adulthood physical abuse	0	2	4
Emotional abuse	0	6	12
Threatened with a weapon	0	0	1
Witnessed violence or physical/sexual abuse	0	2	8
Other experiences of serious injury or life in danger	0	0	2
Other frightening experiences ^a	0	7	8

^aExamples include a car accident, witnessing an explosion, suicide attempt of a parent, life-threatening illness of a parent.

Table 2

Demographic information and mean scores (SD) on the measures of anxiety (STAI), depression (BDI), total psychopathology (ASR), mean number of stressors, and resilience score

Variable	Control group (n = 17)	Stress group (n = 17)	Abuse group (n = 21)	p- value	Effect size partial η^2
Age	20.21 (1.73)	19.56 (1.13)	20.04 (1.93)	.50	.03
Depression ^a	-.51 (.54)	.32 (1.08)	1.04 (1.49)	.001	.25
State anxiety ^a	-.42 (.87)	.43 (1.03)	.38 (1.26)	.04	.12
Trait anxiety ^a	-.49 (.75)	.63 (1.28)	.77 (1.21)	.002	.21
Total Psychopathology ^b	45.35 (4.12)	56.62 (9.08)	59.2 (11.81)	< .001	.32
Number of stressors	0 (0)	1.41 (0.94)	3.81 (1.25)	< .001	.76
Resilience ^b	49.35 (6.69)	47.88 (7.87)	45.86 (8.65)	.39	.04

^az-scores are shown for BDI, STAI-state, and STAI-trait.

^bT-scores are used.

Table 3

Mean (Standard Deviations) reaction times (in msec) and accuracy (in % correct) for the control, stress, and abuse group

	Control group (n = 17)		Stress group (n = 17)		Abuse group (n = 21)	
	Mean RT ^a (SD)	Mean Acc ^b (SD)	Mean RT ^a (SD)	Mean Acc ^b (SD)	Mean RT ^a (SD)	Mean Acc ^b (SD)
Angry Match	791 (216)	87 (13)	740 (121)	82 (14)	807 (122)	87(12)
Happy Match	796 (117)	88 (11)	748 (118)	83 (12)	753 (99)	88 (11)
Neutral Match	785 (127)	86 (11)	772 (122)	80 (14)	774 (126)	86 (13)
Angry Miss1	861 (141)	54 (25)	821 (155)	61 (23)	848 (136)	60 (17)
Happy Miss1	864 (107)	61 (23)	800 (126)	57 (23)	918 (173)	52 (21)
Neutral Miss1	872 (129)	59 (16)	787 (122)	56 (19)	844 (98)	64 (19)
Angry Miss2	840 (149)	75 (18)	767 (148)	69 (25)	830 (101)	76 (14)
Happy Miss2	846 (135)	75 (19)	750 (122)	76 (20)	859 (98)	71 (19)
Neutral Miss2	834 (134)	76 (17)	746 (91)	72 (21)	848 (131)	75 (14)
Angry Miss3	805 (124)	87 (10)	712 (86)	85(16)	810 (114)	86 (15)
Happy Miss3	775 (125)	82 (16)	770 (120)	76 (16)	817 (107)	86 (16)
Neutral Miss3	813 (105)	84 (18)	750 (138)	83 (15)	825 (118)	85 (15)

^aRT = reaction time.

^bAcc = accuracy.

Figure 1. Overview of a typical trial in the SEMTOS task

Figure 2. A. Accuracy scores (% correct) for the control (left panel), no-abuse stress group (middle panel), and abuse group (right panel) split by emotional valence and location. B. Reaction times (ms) for the control (left panel), no-stress abuse group (middle panel), and abuse group (right panel), split by emotional valence and location of the stimuli. Full lines indicate match trials, dotted lines are Miss1 trials, dashed lines are Miss2 trials and the combined dashed/dotted lines are Miss3 trials. Error bars denote SEM. Asterisk indicates significance, $p < .05$

Figure 3. Accuracy difference scores (%) for the Miss1 condition in both the abuse and control group. Positive scores indicate a higher accuracy for neutral faces compared to either happy (left panel) or angry (right panel) faces. The figure illustrates the decreased accuracy for happy compared to neutral faces (in the Miss1 condition) in the abuse group. Error bars denote SEM. Asterisk indicates significance, $p < .05$