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Emotional Contrast and Psychological Function Impact Response Inhibition to Threatening Faces

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Abstract

Poor inhibitory control over negative emotional information has been identified as a possible contributor to affective disorders, but the distinct effects of emotional contrast and fearful versus angry faces on response inhibition remain unknown. In the present study, young adults completed an emotional go/no-go task involving happy, neutral, and either fearful or angry faces. Results did not reveal differences in accuracy or speed between angry and fearful face conditions. However, responses were slower and indicated poorer inhibition in blocks where threatening faces were paired with happy, versus neutral, faces. Results may reflect cognitive load of emotional valence contrast, such that higher contrast blocks (containing threatening with happy faces) produced more conflict and required more processing than lower contrast blocks (threatening with neutral faces). Preliminary findings also revealed higher anxiety and depression symptoms corresponded with slower responses and worse accuracy, consistent with patterns of adverse impacts of anxiety and depression on response inhibition to threatening faces, even at subclinical levels of symptomatology.

Keywords

emotional contrast; response inhibition; emotional go/no-go; executive function; threatening faces

Conflict of Interest

The authors declare that they have no conflicts of interest.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

This article does not contain any studies with animals performed by any of the authors.

¹ Target sample size was determined *a priori* to assure that the study was sufficiently well powered to detect interaction effect in the primary analyses, i.e., mixed within-between repeated measures ANOVA with 2 groups (e.g., factor ‘condition’) and 4 measurements (e.g., factor ‘block’). Power analyses calculated based upon a conservative effect size, .01 alpha error probability, and 90% power determined a required total sample size of N=64 (calculated using G*Power 3.1). Estimates were based upon a conservative effect size to increase sensitivity to detect small effects and reduce the possibility of recruiting a sample size under-powered to detect effects. The present sample of N=73 analyzed surpasses that needed to attain sufficient statistical power in this design.

² Participants did not differ between institutions on any psychological measures, ($t_s < 1.56$, $p_s > 0.05$, Cohen’s $d_s < 0.38$). However, there were differences between institutions on two cognitive measures: Color Word Interference (color naming trial; $t(71) = 2.06$, $p = 0.04$, Cohen’s $d = 0.49$) and Trail Making Test (part B; $t(68) = 2.44$, $p = 0.02$, Cohen’s $d = 0.64$). While there were statistical differences between institutions on these two measures, scores were within the normative range and, for the purposes of this study, are not likely to reflect meaningful differences (Delis et al., 2001; Tombaugh, 2004).

³ ERQ Cronbach’s alpha, Reappraisal subscale = 0.75 – 0.82, and Suppression subscale = 0.68 – 0.76 (Gross & John, 2003); MASQ Cronbach’s alphas all > 0.87 (Wardenaar et al., 2010); STAI Cronbach’s alpha, State subscale = 0.48 – 0.85, and Trait subscale = 0.78 – 0.85 (Metzger, 1976); BAI Cronbach’s alpha = 0.94 (Fydrich, Dowdall, & Chambless, 1992); BDI Cronbach’s alpha = 0.81 (Beck, Steer, & Carbin, 1988)

Emotions communicate important information, including the safety or danger of our environment and the people with whom we interact, which facilitates adaptive behavioral responses (Al-Shawaf, Conroy-Beam, Asao, & Buss, 2016). In healthy individuals, positive and negative emotional information have differential impacts on behavioral responses and have been posited to elicit approach and avoidance motivational tendencies, respectively (Elliot, 2008; Elliot, Eder, & Harmon-Jones, 2013), and this pattern was supported by a recent meta-analysis of approach-avoidance tasks (Phaf, Mohr, Rotteveel, & Wicherts, 2014). For example, individuals respond more quickly to positive than negative targets, and make more false alarms (FAs) to happy compared to negative affective word distractors (Albert, López-Martín, & Carretié, 2010; Chiu, Holmes, & Pizzagalli, 2008). Approach-avoidance motivations associated with emotional valence of facial expressions (i.e., how positive or negative) can influence ability to control attention and responses to emotional information. Behavioral results suggest a tendency to approach happy faces, reflected in faster response times (RTs) and worse inhibitory control (e.g., higher FA rates), relative to neutral or negative faces (Hare et al., 2008; Hare, Tottenham, Davidson, Glover, & Casey, 2005; Tottenham, Hare, & Casey, 2011). Inversely, a tendency to avoid negative or threatening faces (e.g., fearful, angry, or sad faces) leads to slower RTs and greater gaze aversion (Hare et al., 2008, 2005; Hunnius, Wit, Vrin, & Hofsten, 2011; Tottenham et al., 2011).

Fearful and angry faces are both examples of threatening stimuli, defined as negatively-valenced signals predictive of adverse physical or emotional effects (Hedger, Gray, Garner, & Adams, 2016), although each type of expression may have a qualitatively unique relationship with approach-avoidance motivation (Adams, Ambady, Macrae, & Kleck, 2006). While fearful and angry faces both elicit avoidance responses, delayed disengagement, and automatic neural signals, there may be qualitative differences in avoidance motivation related to their unique environmental signals. Fearful faces signal an indirect threat in the environment, while angry faces signal a direct socio-relational threat to the receiver (Hedger et al., 2016; Juncai, Jing, & Rongb, 2017; Pichon, de Gelder, & Grèzes, 2009). Furthermore, fearful faces may be perceived as less threatening than angry faces given findings that prosocial behavior is associated with increased recognition of fearful faces (Kaltwasser, Hildebrandt, Wilhelm, & Sommer, 2017). Concerning cognitive processing, studies of healthy participants indicate that when compared to fearful faces, angry faces involve less automatic processing, requiring greater neural resources and contextual information (Juncai et al., 2017; Pichon et al., 2009). It has been suggested that while detection of fearful faces requires the perceiver to shift attention away from the fearful face to the novel, dangerous stimulus in the environment, detection of angry faces requires the perceiver to override habituation of attention so as to maintain focus on the threat of the angry face itself (Juncai et al., 2017; Stoyanova, Pratt, & Anderson, 2007). In other words, angry faces require increased cognitive processing compared to fearful faces, which may manifest as added cognitive load that adversely impacts response inhibition.

Moreover, emotional stimuli inherently increase cognitive load in that they are highly motivationally salient and attract attention from task demands (Zhang & Lu, 2012). For example, samples of healthy individuals have demonstrated that higher (versus lower) arousal emotional faces increase RTs and stopping latencies in stop-signal tasks (Padmala &

Pessoa, 2010; Sagaspe, Schwartz, & Vuilleumier, 2011; Verbruggen & De Houwer, 2007). High cognitive load in the form of emotional conflict also adversely impacts RTs and accuracy; emotional Stroop tasks involving the simultaneous presentation of incongruent emotional faces, words, or images elicit greater conflict resolution demands and require increased cognitive processing compared to congruent trials. Emotional conflict (i.e., incongruent trials) leads to slower RTs and lower accuracy, which can resolve in subsequent trials through adaptive anticipatory mechanisms (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006; Shen, Xue, Wang, & Qiu, 2013; Xue, Ren, Kong, Liu, & Qiu, 2015).

In addition to within-trial emotional conflict arising from simultaneous presentation of contrasting valence or arousal signals within a stimulus, sequential presentation of contrasting stimuli increases emotional conflict trial-to-trial, and likewise increases cognitive load. Studies of emotional contrast sequentially presenting affective words in the context of contrasting emotional or neutral sentences or word lists indicate that greater contrast between consecutive words attracts more attention and engages more neural resources (Maratos, Dolan, Morris, Henson, & Rugg, 2001; Schmidt, 2012). Attention to emotionally contrasting sequential verbal information impacts cognitive processing, but the effects of such trial-to-trial contrast on responses to emotional faces have not been assessed. Electrophysiological evidence has demonstrated that emotional faces affect processing at earlier stages than emotional words (Frühholz, Jellinghaus, & Herrmann, 2011), suggesting that contrast in faces may have robust downstream effects on later processing, such as emotion recognition and evaluation, and behavioral responses. For the present study, we define “emotional contrast” as the trial-to-trial contrast in emotional valence of facial expressions, related to but unique from “emotional conflict” as defined by studies of emotional Stroop tasks where the incongruity occurs within a trial (Etkin et al., 2006; Frings, Englert, Wentura, & Bermeitinger, 2010). Assessing executive control over responses to contrasting emotional faces will clarify the context and extent to which emotional stimuli increase cognitive load.

Psychological dysfunction (e.g., anxiety and depression) can also influence affective processing and responding, and has a strong relationship with poor control over responses to emotional information and attentional biases, particularly in the context of threatening faces (Joormann & Gotlib, 2010; Mogg, Millar, & Bradley, 2000). Young adults with higher trait anxiety demonstrate difficulty disengaging from both angry and fearful faces (Leleu, Douilliez, & Rusinek, 2014). Furthermore, state, trait, and induced anxiety in nonclinical samples appears to modulate effects of approach-avoidance motivation for angry faces; elevated anxiety predicts poor inhibitory control for angry compared to happy or neutral faces, and delayed disengagement from angry faces (Fox, Russo, & Dutton, 2002; Pacheco-Unguetti, Acosta, Lupiáñez, Román, & Derakshan, 2012). Individuals reporting high trait anxiety, but without psychiatric diagnoses, also demonstrate impaired inhibition to fearful face distractors, particularly under conditions of higher cognitive load (Ladouceur et al., 2009). In the context of mood disorders, the literature has reported that clinically depressed individuals have impaired recognition of negative and positive emotions except for sadness (Dalili, Penton-Voak, Harmer, & Munafò, 2015). Sad faces also evoke greater neural activation in individuals with depression compared to non-depressed individuals (Elliott, Rubinsztein, Sahakian, & Dolan, 2002). Taken together, the literature suggests anxiety is

particularly relevant to response inhibition in the context of threatening faces, but the effects of depressive symptoms on response inhibition in the context of threatening faces remain unexamined.

To summarize, previous studies assessing response inhibition have largely measured responses in nonclinical samples and employed computerized tasks requiring participants to inhibit responses to emotional faces or words. The literature on facial expressions specifically demonstrates that several factors impact behavioral control over responses to emotional faces: the degree of emotional valence and arousal of the face, cognitive load (e.g., emotional conflict), and psychological function. Past research indicates fearful and angry faces can differentially influence neural and behavioral response patterns. Moreover, cognitive load and symptoms of anxiety strongly correspond with poorer inhibition and slower RTs. However, there are open questions about the impact of trial-to-trial emotional contrast and depressive symptoms on both response inhibition and approach-avoidance motivation toward threatening faces. We aim to fill several gaps in the literature of threatening face processing. First, we illuminate the impact of trial-to-trial emotional valence contrast on cognitive load – beyond that of emotional conflict within-trial (e.g., Stroop-like effects). We report such trial-to-trial contrast between emotional (threatening) faces – beyond studies of sequentially contrasting words. Lastly, we expand the literature of mood and emotional processing, particularly addressing gaps in understanding the impact of subthreshold depressive symptoms on response inhibition to threatening faces.

In the present study, young adult participants completed an emotional go/no-go task employing happy, neutral, and either fearful or angry target and distractor faces, and self-report measures of mood, anxiety, and emotion regulation. The primary outcome measures were task response inhibition accuracy (FAs = incorrect responses to distractors) and speed (RTs to targets). We assessed task responses between participants who viewed one of the two types of threatening faces (either fearful or angry faces), and between task blocks of target/distractor faces. We hypothesized that participants who completed task blocks with angry faces would show (1a) poorer inhibition accuracy and (1b) slower RTs compared to participants who completed task blocks with fearful faces. We also expected (2a) poorer response inhibition accuracy and (2b) slower RTs in blocks inducing higher cognitive load (i.e., from greater emotional contrast within blocks pairing threatening with happy faces compared to blocks pairing threatening with neutral faces (lower contrast)). Finally, although this was a nonclinical sample, we expected individuals with higher self-reported symptoms of anxiety and depression and maladaptive emotion regulation strategies would demonstrate (3a) poorer inhibition accuracy and (3b) slower RTs.

Method

Participants

Eighty-one native English-speaking undergraduate student participants were recruited following pre-screening for the following exclusion criteria: uncorrected vision or hearing problems, diagnosis or treatment of any psychiatric or neurological conditions, Autism Spectrum Disorder, ADHD, colorblindness, and history of severe head injury or substance abuse. The sample had an age range of 18 – 23 years ($M(SD) = 18.88(1.02)$), and an

education range of 12 – 15 years ($M(SD) = 12.65(0.87)$, $N_{\text{male}} = 40$, $N_{\text{female}} = 41$). Participants were assigned to either the ‘fear’ or ‘angry’ condition (conditions described in more detail in Procedure below). Three participants were excluded for not following task instructions, another for a consistent software recording error, and one individual did not pass in-person screening for eligibility criteria. Two additional participants were excluded from all analyses because responses on a self-report measure of depression indicated severe depression (Beck Depression Inventory [BDI]>29; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). One additional participant was excluded from all analyses for unreliable responses due to extremely slow RTs ($z\text{-score} > 3.00$). The final sample included 39 participants in the fear condition ($N_{\text{male}} = 20$, $N_{\text{female}} = 19$, $M(SD)_{\text{age}} = 18.90(1.05)$, $M(SD)_{\text{edu}} = 12.67(0.96)$), and 34 in the angry condition ($N_{\text{male}} = 17$, $N_{\text{female}} = 17$, $M(SD)_{\text{age}} = 18.85(1.08)$, $M(SD)_{\text{edu}} = 12.68(0.84)$). There were no differences between the fear and angry condition participants in mean age, education, or any cognitive or psychological measures ($t_s < 1.85$, $p_s > 0.05$, Cohen’s $d_s < 0.44$). Target sample size was determined *a priori*¹. Of the 73 participants included in analyses, 45 completed the study protocol at Santa Clara University and 28 at Saint Louis University². The study was approved by the Institutional Review Boards of both institutions.

Procedures

Participants were recruited and anonymously screened through online participant management systems (Sona Systems (Tallinn, Estonia) and Qualtrics (Provo, Utah), respectively). If individuals did not endorse any exclusion criteria (as described in Participants section above), they were given a code to sign up to participate. Informed consent was obtained from all individual participants included in the study. The study visit took approximately 1 hour, and participants were given course credit for their participation. Participants were assigned to one of the two study conditions (fear or angry) in an alternating fashion as they enrolled. All participants completed the study protocol in a quiet lab space.

Measures

Following informed consent, participants answered a self-report of emotion regulation, the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003), and self-reports of anxiety and depression symptoms, including Mood and Anxiety Symptom Questionnaire (MASQ; Wardenaar et al., 2010), State Trait Anxiety Inventory (STAI; Spielberger & Gorsuch, 1983), Beck Anxiety Inventory (BAI; Steer & Beck, 1997), and Beck Depression Inventory (BDI; Beck et al., 1961)³. Participants then completed a computerized emotional go/no-go task (described below). Finally, although not part of the primary aims for this study, participants completed standardized measures of executive functioning, as they are thought to share common neural mechanisms with measures of response inhibition (Ridderinkhof, van den Wildenberg, Segalowitz, & Carter, 2004). Executive functioning measures included: the Trail Making Test, parts A and B (Reitan, 1958), and Color-Word Interference and Verbal Fluency from the Delis-Kaplan Executive Function System (Delis, Kaplan, & Kramer, 2001). See Table 1 for results from all self-report and standardized testing measures.

Emotional go/no-go task.

Task stimuli comprised happy, neutral, and threatening (fearful or angry) faces from the NimStim set of facial expressions (Tottenham et al., 2009; available at www.macbrain.org). The task was modelled after Hare and colleagues (2005, 2008). The fear condition used the same stimuli and task protocol as Hare and colleagues (2005). The angry condition protocol was identical to the fear condition, and the same stimulus set of happy and neutral faces was employed in both the angry and fear conditions, but open-mouth ‘angry’ facial expressions from the NimStim set were substituted for the fearful expressions (see supplementary materials for additional details about stimulus set). Participants were asked to press a key in response to a specified facial expression, i.e., the target, and inhibit their response (not press the key) to any other facial expressions, i.e., the distractor (see Figure 1). The six task blocks included the following target/distractor pairs: neutral/threatening, threatening/neutral, happy/threatening, threatening/happy, happy/neutral, and *neutral/happy*. Within each block, participants were presented with 35 targets and 13 distractors. All images of faces were normalized for size and luminance and were presented in grayscale on a black background in the center of the screen. Faces appeared for 500 ms with a variable inter-stimulus fixation cross lasting 1 to 2.5 seconds (see figure 1). The task was programmed in E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA) and completed on an HP ProBook laptop with 15.6 inch LED HD display.

Analysis Approach

All analyses were conducted using SPSS Version 23.0 (IBM SPSS Statistics, Armonk, NY). The Greenhouse-Geisser epsilon correction was applied to adjust the degrees of freedom of the F-ratios in all omnibus ANOVA analyses that violated sphericity (Mauchly’s $p < 0.05$). All post-hoc pairwise comparisons were conducted using the Bonferroni correction ($\alpha < 0.05$). The experimental task outcome measures were percentage of FAs to distractors, i.e., accuracy, and RTs to target stimuli, i.e., speed.

The primary aim of the present study was to assess differences in accuracy and speed as a function of the threatening face condition and task block. To address the primary aims, accuracy and speed were each submitted to mixed ANOVAs with between-subject factor of condition (fearful versus angry facial expressions; i.e., hypotheses 1a and 1b), and within-subject factor of *target/distractor* block (i.e., hypotheses 2a and 2b). Planned comparisons on factor block assessed emotional contrast in blocks of threatening faces with happy faces (higher contrast) compared to threatening faces with neutral faces (lower contrast). To make these specific comparisons, post-hoc tests drew direct comparisons between happy and neutral distractors in the context of threatening targets (i.e., *threatening/happy* versus *threatening/neutral*) and between happy and neutral targets in the presence of threatening distractors (i.e., *happy/threatening* versus *neutral/threatening*). Lastly, Pearson’s correlations assessed the relationship between self-reported psychological functioning and task performance (i.e., hypotheses 3a and 3c), and to assess the relationship between speed and accuracy within the blocks. (Pearson’s correlations between cognitive measures and task performance, and between speed and accuracy within blocks are reported in supplemental materials.)

Results

Accuracy

Test of effects of condition and load on response accuracy (i.e., hypotheses 1a and 2a), with a mixed ANOVA of FAs to distractors with factors of condition (angry, fear) and block (*threatening/neutral*, *threatening/happy*, *neutral/threatening*, *happy/threatening*), revealed a significant main effect of block on FA to distractors ($F(2.60, 184.33) = 8.33$, $p < 0.001$, $\eta_p^2 = 0.11$; see figure 2). Post-hoc analysis revealed participants made significantly more FAs to threatening face distractors in the context of happy ($M = 25.40\%$, $SD = 17.61\%$) compared to neutral face targets ($M = 18.86\%$, $SD = 13.33\%$, $t(72) = 3.92$, $p < 0.01$, Cohen's $d = 0.48$). In the context of threatening targets, numerically there were more FAs to happy than neutral face distractors, although the comparison did not reach statistical significance (*threatening/happy* $M = 21.08\%$, $SD = 15.23\%$; *threatening/neutral* $M = 17.07\%$, $SD = 14.91\%$; $t(72) = 2.24$, $p = 0.17$, Cohen's $d = 0.26$). There were no significant interactions or main effects of condition, ($F_s < 1.03$, $p_s > 0.30$, all $\eta_p^2 < 0.02$).

Speed

Test of effects of condition and load on response speed (i.e., hypotheses 1b and 2b), with a mixed ANOVA of RT with factors of condition (angry, fear) and block (*threatening/neutral*, *threatening/happy*, *neutral/threatening*, *happy/threatening*), revealed a significant main effect of RT to targets ($F(2.51, 177.88) = 18.87$, $p < 0.001$, $\eta_p^2 = 0.21$; see figure 3). Post-hoc analysis revealed RTs to threatening targets were significantly slower in the presence of happy ($M = 473.06$ ms, $SD = 69.54$ ms) compared to neutral face distractors ($M = 441.30$ ms, $SD = 50.34$ ms; $t(72) = 6.60$, $p < 0.001$, Cohen's $d = 0.86$). Post-hoc analysis also revealed that in the presence of threatening distractors, participants responded significantly more slowly to happy face targets ($M = 456.46$ ms, $SD = 47.97$ ms) compared to neutral face targets ($M = 440.87$ ms, $SD = 49.40$ ms; $t(72) = 3.49$, $p < 0.01$, Cohen's $d = 0.41$). There were no significant interactions or main effects of condition ($F_s < 2.10$, $p_s > 0.15$, all $\eta_p^2 < 0.03$).

Self-report measures of psychological function

Test of relationships between task measures and self-reported emotion regulation and symptoms of anxiety and depression (i.e., hypotheses 3a and 3b) were assessed with Pearson's correlations. Psychological measures were assessed for normality. The data were positively skewed for MASQ general distress and anxious arousal subscales, STAI state, BAI, and BDI, as expected for a sample of healthy young adults and consistent with eligibility criteria that participants do not have current psychiatric diagnoses or treatment. Higher self-reported suppression of emotions (ERQ subscale) correlated with slower RTs to threatening face targets in the presence of happy distractors (*threatening/happy* RTs, $r(72) = 0.25$, $p = 0.04$). Higher self-reported anxious arousal (MASQ subscale) correlated with greater FAs to threatening distractors in the context of neutral faces (*neutral/threatening* FAs, $r(72) = 0.25$, $p = 0.03$). Higher self-reported anhedonic depression (MASQ subscale) correlated with slower RTs to neutral faces in the presence of threatening distractors

(*neutral/threatening* RTs, $r(72) = 0.24$, $p = 0.04$). Self-reported symptoms of depression (BDI) correlated with greater FAs to blocks combining threatening and neutral faces (*threatening/neutral* FAs, $r(72) = 0.27$, $p = 0.02$, and *neutral/threatening* FAs, $r(72) = 0.29$, $p = 0.02$). STAI and BAI did not significantly correlate with any task variables ($ps > 0.05$).

Discussion

The present study assessed the impact of trial-to-trial emotional contrast (i.e., an instantiation of cognitive load) and psychological function on response inhibition to threatening faces in a nonclinical sample. The angry and fearful conditions produced similar response patterns. However, participants made more FAs and responded more slowly in blocks with high contrast (threatening paired with happy faces) than with low contrast (threatening paired with neutral faces). Lastly, suppression of emotions and symptoms of anxiety and depression corresponded with greater FAs and slower RTs.

Response inhibition to angry and fearful faces

Although it was predicted that the angry face condition would result in more FAs and slower responses than the fearful condition (i.e., hypotheses 1a and 1b), results indicated these two types of threatening faces did not differentially impact task performance. Results are partially consistent with those of Tottenham and colleagues (2011) who employed an emotional go/no-go task involving happy and negative (fearful, angry, and sad) emotions. While our RT results are consistent with theirs, our FA results differed from their finding of greater FAs to angry than fearful faces. Together with their findings, this may indicate RTs are generally less sensitive to detecting differences in response inhibition between fearful and angry faces. However, it is worth noting that Tottenham and colleagues (2011) had a much younger sample (e.g., including children, adolescents, and young adults), so it is possible that discrepant results are attributable to developmental effects detected among their sample. It is notable that several previous behavioral studies have reported differences between fearful and angry face conditions, so it is possible that responses to negative emotions are sensitive to methodological and developmental effects.

One behavioral measure that has differentiated between fearful and angry faces is inhibition of return (IOR), a long-lasting behavioral indicator of novelty-seeking response bias. Juncai and colleagues (2017) found that angry, but not fearful, faces can override the IOR effect, suggesting greater dwelling on the social/relational threat of angry faces, while fearful faces take advantage of IOR for searching for novel, dangerous stimuli in the environment. Additional evidence demonstrates that differences between fearful and angry face processing are observable with behavioral methods of head tracking or push-versus-pull lever procedures (Kaltwasser, Moore, Weinreich, & Sommer, 2017). In the context of the present emotional go/no-go task, participants responded to static faces, rather than attending to dynamic angry and fearful faces or full body emotional stimuli, which have been found to effectively detect neural differences. For example, Pichon and colleagues (2009) observed differences in neural activation to dynamic videos of angry versus fearful actions, suggestive of wider spread neural activation for stimuli depicting anger. Dynamic whole body expressions of anger and fear also evoke differential patterns of neural activation (Grèzes,

Pichon, & de Gelder, 2007; Pichon, de Gelder, & Grèzes, 2008). In sum, more elaborative or dynamic processing on a longer time scale (e.g., IOR) may be needed to observe behavioral differences between the angry and fearful face conditions in adults.

Emotional contrast effects

The effects of emotional contrast were assessed as within-group measures of target/distractor block (*neutral/threatening* versus *happy/threatening*, and *threatening/neutral* versus *threatening/happy*, i.e., hypotheses 2a and 2b). Adults typically interpret angry and fearful faces to have similar levels of negative valence, which significantly contrast from positive valence ratings of happy faces (Almeida et al., 2016; Smith, Weinberg, Moran, & Hajcak, 2013). Moreover, adults often interpret neutral or ambiguous faces as slightly negative (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Neta, Kelley, & Whalen, 2013). On a spectrum of positive to negative valence, this interpretation situates neutral faces closer to the negative than positive end of the valence spectrum, and produces greater contrast between positive (i.e., happy) and negative (i.e., threatening) faces than between neutral and negative faces. Accordingly, participants made more FAs and responded more slowly in high versus low contrast blocks, suggesting that greater emotional valence contrast adversely impacts both response inhibition accuracy and speed. Our findings converge with studies of emotional conflict—employing emotional face-word Stroop tasks—which reported that greater conflict leads to poorer task performance and slower RTs (Etkin et al., 2006; Shen et al., 2013; Xue et al., 2015). In other words, conflicting or contrasting valence of emotions increases cognitive load and thereby adversely impacts task performance. Although manipulations of emotional stimulus presentations vary across studies (within-stimulus (Stroop task) versus trial-to-trial (go/no-go task)), taken together results suggest that cognitive load from emotional contrast adversely impacts adults' accuracy and speed of responses to emotional information.

Notably, while stimulus arousal could also impact response inhibition, the evidence provides greater support for inferences that task results are driven by effects of valence contrast. Specifically, the alternative possibilities that (1) greater trial-to-trial contrast in arousal or (2) greater average arousal across blocks containing happy faces could adversely impact response inhibition (Almeida et al., 2016; Balconi & Pozzoli, 2003; Smith et al., 2013) are not supported by the data. If results were attributable to (1) greater trial-to-trial contrast in arousal, we would expect poorer performance in blocks containing neutral and threatening faces (versus blocks of happy and threatening faces), due to trial-to-trial shifting between high arousal threatening face trials and low arousal neutral face trials. However, results did not support this possibility and showed results show the opposite pattern; performance was worse in blocks of happy and threatening faces, which have less trial-to-trial contrast in arousal level than the blocks of neutral and threatening faces. Furthermore, the possibility that (2) greater average arousal across the blocks containing happy faces could adversely impact response inhibition is also not supported by the data. Supplemental results showed inconsistent effects of emotional contrast between blocks with similar average arousal (i.e., blocks containing neutral and threatening faces versus blocks containing neutral and happy faces; see supplemental Table S4). Taken together, observed results are more likely

attributable to cognitive load due to valence contrast than trial-to-trial arousal contrast or average arousal.

Broadly, from an evolutionary perspective, findings suggest processing threatening faces in the context of sequentially experienced contrasting emotional information may increase cognitive load and adversely impact reactions to the threat. Moreover, results of the present study may contribute to understanding mechanisms of trauma- and stressor-related disorders. For example, individuals who experience significant threat immediately followed by a contrasting, positive emotional experience, may experience more resulting cognitive load, impairing adaptive cognitive and emotional processing of the stressful experience. This would be consistent with theories on the development of emotion dysregulation in psychopathology (e.g., posttraumatic stress disorder and social anxiety disorder; Etkin & Wager, 2007).

Finally, in the context of approach-avoidance motivation, the present findings partially support the tendency approach to happy faces, given greater FAs in blocks containing happy (versus neutral) targets or distractors (Hare et al., 2008; Hare, Tottenham, Davidson, Glover, & Casey, 2005; Tottenham, Hare, & Casey, 2011). However, patterns of RTs were in the opposite direction; blocks with happy faces resulted in slower, rather than faster responses. Given the inconsistent support for approach motivation as an explanation for the effects of target/distractor blocks, results are better explained by emotional valence contrast increasing cognitive load, as described above.

Relationships between response inhibition and psychological function

Self-reported maladaptive emotion regulation and symptoms of anxiety and depression corresponded with worse task performance, supporting *a priori* predictions (i.e., hypotheses 3a and 3b). Individuals reporting higher use of emotional suppression as an emotion regulation strategy demonstrated slower responses to threatening faces with happy distractors. This may suggest that individuals who are less willing to engage with emotions also show less engagement with threatening faces under conditions of higher cognitive load, e.g., in which they had to simultaneously approach threatening face targets and withhold responses to happy face distractors. Similarly, greater symptoms of anxiety and depression corresponded with poorer accuracy, converging well with previous studies that reported impaired inhibition to threatening faces in anxious individuals (Ladouceur et al., 2009; Pacheco-Unguetti et al., 2012). Of note, findings for anxiety and depression symptoms were specifically observed in blocks with neutral, but not happy faces. This may be related to negativity biases and attentional vigilance in individuals with symptoms of anxiety and depression, leading them to interpret neutral faces as more negative, and to engage further with both neutral and threatening stimuli, thereby increasing FAs (Joormann & Gotlib, 2010; Lawson & MacLeod, 1999; Mogg & Bradley, 2005).

Relatedly, a negativity bias may increase ambiguity between neutral and negative faces, which would contribute to the observed increase in both FAs and RTs in these blocks. That is, in the presence of ambiguity, individuals with higher anxiety or depression may experience more difficulty distinguishing neutral from negative faces, thus eliciting more FAs and requiring more time (slower RTs) to distinguish between the faces. These findings

converge with other studies of responses to ambiguous emotional information such as surprise faces, which indicate greater ambiguity leads to slower RTs in anxious individuals (Forster, Nunez-Elizalde, Castle, & Bishop, 2014). The results of the present study are especially noteworthy given that participants were screened for past or present mental health conditions, indicating a relationship between response inhibition and symptoms of anxiety and depression, even in individuals with subclinical symptoms. In sum, our findings are consistent with patterns of adverse impacts of anxiety and depression on response inhibition to threatening faces, even at subclinical levels of symptomatology.

Limitations and Future Directions

The present study should be interpreted in the context of possible limitations. A purely within-subjects design directly comparing effects of the fearful and angry conditions would have increased statistical power. However, combining fearful and angry face stimuli in the same task may adversely impact task accuracy and make interpretation of results less clear because both expressions have similar levels of valence and arousal (Almeida et al., 2016; Balconi & Pozzoli, 2003; Smith et al., 2013). As discussed above, higher versus lower contrast comparisons also differed in arousal level, as blocks with threatening and happy faces have higher average arousal than blocks with threatening and neutral faces. Although the present design was not able to fully differentiate the contributions of valence and arousal, results indicate that trial-to-trial emotional contrast in valence is the most likely explanation for the pattern of results. However, future studies may consider including surprise faces, which have high arousal but are ambiguous with regard to valence, thus allowing further evaluation of the impact of emotional contrast in valence (Neta et al., 2013). Studies employing psychophysiological or ERP analyses may also help clarify the unique impact of arousal, compared to valence, on emotional inhibition.

Regarding our findings of relationships between psychological symptoms and measures of response inhibition, it should be noted that although we observed medium effect sizes that aligned with direction of *a priori* hypotheses, findings should be interpreted with some caution as they would not surpass correction for multiple comparison. We therefore consider these to be preliminary findings which require further investigation and replication. Furthermore, generalizability of the present study was limited by a sample of largely Caucasian individuals who viewed faces of varying racial groups including African-American, Asian, and Caucasian faces. As there is substantial literature indicating social categories such as race and ethnicity may impact processing of emotional faces (Hugenberg, 2005; Kawakami, Amodio, & Hugenberg, 2017), it should be noted this possibility cannot be entirely ruled out.

Results of the present study have raised new questions for future research investigations. While results suggest adults respond similarly to angry and fearful faces in the context of an emotional go/no-go task, we cannot rule out additional factors that may impact control over responses to threatening faces. For example, future studies may wish to evaluate the impact of face stimulus eye gaze direction, or of dynamic full-color emotional faces or body expressions (versus static greyscale faces) on response inhibition (Adams & Kleck, 2005; Fox, Mathews, Calder, & Yiend, 2007; Grèzes et al., 2007; Juncai et al., 2017; Pichon et al.,

2009). Moreover, the present study examined degrees of symptoms of anxiety and depression in healthy adults reporting no previous diagnosis or treatment for mental health conditions. However, expanding the enrollment to include individuals with mood or anxiety disorders may reveal a more robust effect of emotional contrast, given that clinical levels of symptomatology adversely impact emotional recognition and inhibition (Dalili et al., 2015; Degabriele & Lagopoulos, 2012; Gollan, McCloskey, Hoxha, & Coccaro, 2010). For example, emotion regulation difficulties in individuals with clinically elevated levels of anxiety may result in stronger, exaggerated responses to threatening faces, further increasing cognitive load. Whether the development of trauma- and stressor-related disorders are impacted by experiences of emotional contrast during stressful (e.g., threatening) events is another important question for future investigation.

Conclusions

The results of this study suggest that behavioral patterns of response inhibition are similar for angry and fearful faces. Higher trial-to-trial emotional contrast in valence adversely impacted speed and accuracy of responses and is likely attributable to effects of greater cognitive load in the higher-contrast blocks, similar to patterns observed in emotional Stroop tasks. Preliminary findings revealed maladaptive emotional regulation and symptoms of anxiety and depression also corresponded with slower and less accurate responding. While previous literature has revealed a relationship between anxiety and response inhibition to threatening faces, the present study provides new insight regarding symptoms of depression. Notably, these relationships are evident in individuals below threshold for clinical anxiety or depression. Given evidence for behavioral correlates with anxiety and depression at the subclinical level, this study highlights the importance of recognizing the dimensionality of psychological symptomatology.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Schematic of emotional go/no-go task, example happy/angry block.

Figure 2. Distractor FA Rate.

FA rates for distractors stratified by condition and target. Tests of *a priori* comparisons showed greater FAs to threatening distractors in the context of happy than neutral targets. There was no difference between FAs to happy versus neutral distractors in the context of threatening targets. There were no main effects of condition or interaction between condition and block. $**p < 0.001$, *Cohen's d* = 0.48

Figure 3. Target RTs.

RTs to targets stratified by condition and distractor. Tests of *a priori* comparisons showed faster RTs to threatening targets in the presence of neutral than happy distractors, and faster RTs for neutral than happy targets in the presence of threatening distractors. There were no main effects of condition or interaction between condition and block. * $p < 0.01$, Cohen's $d = 0.41$; ** $p < 0.001$, Cohen's $d = 0.86$

Table 1.
Descriptive statistics for cognitive and psychological measures (N=73).

	Fear (n = 39)	Angry (n = 34)
Cognitive Measures	Mean (S.D.)	Mean (S.D.)
D-KEFS Color Word Interference		
Color Naming	26.19 (3.87)	26.02 (4.18)
Word Reading	19.78 (3.35)	19.76 (3.53)
Inhibition	43.83 (8.37)	43.09 (7.22)
D-KEFS Verbal Fluency		
Letter Fluency: FAS	41.05 (10.24)	39.97 (11.96)
Category Fluency: Animals	22.92 (5.13)	22.08 (5.27)
Category Fluency: Boys Names	19.97 (4.69)	19.71 (4.54)
Category Switching: Fruits & Furniture	14.51 (2.84)	14.56 (2.26)
Trail Making Test		
Part A	22.73 (6.34)	24.54 (11.10)
Part B	54.57 (17.25)	55.47 (17.02)
Psychological Measures	Mean (S.D.)	Mean (S.D.)
Emotion Regulation Questionnaire		
Reappraisal subscale	3.92 (0.48)	4.13(0.46)
Suppression subscale	2.91(1.03)	2.78 (0.95)
Mood and Anxiety Symptoms Questionnaire		
General Distress subscale	21.36 (6.72)	20.97 (6.86)
Anhedonic Depression subscale	30.18 (7.86)	27.74 (8.70)
Anxious Arousal subscale	14.69 (4.47)	13.74 (4.51)
State Trait Anxiety Inventory		
State Anxiety	37.41 (9.87)	35.71(12.00)
Trait Anxiety	41.13 (8.45)	40.03 (7.99)
Beck Anxiety Inventory	10.45 (9.25)	7.15 (6.03)
Beck Depression Inventory	7.54 (5.93)	6.12 (5.68)

Notes. D-KEFS= Delis-Kaplan Executive Function System. Citations for measures provided in text. Participants in fear and angry conditions did not significantly differ on any cognitive or psychological measures ($t_s < 1.85$, $p_s > 0.05$, Cohen's $d_s < 0.44$).