Emotion
2010, Vol. 10, No. 6, 842–854

1528-3542/10/$12.00 DOI: 10.1037/a0019704

Exploring Emotional and Cognitive Conflict Using Speeded Voluntary Facial Expressions

Kimberly S. Chiew and Todd S. Braver
Washington University in St. Louis

Affective conflict and control may have important parallels to cognitive conflict and control, but these processes have been difficult to quantitatively study with emotionally naturalistic laboratory paradigms. The current study examines a modification of the *AX-Continuous Performance Task* (AX-CPT), a well-validated probe of cognitive conflict and control, for the study of emotional conflict. In the Emotional AX-CPT, speeded emotional facial expressions measured with electromyography (EMG) were used as the primary response modality, and index of emotional conflict. Bottom-up emotional conflict occurred on trials in which precued facial expressions were incongruent with the valence of an emotionally evocative picture probe (e.g., smiling to a negative picture). A second form of top-down conflict occurred in which the facial expression and picture probe were congruent, but the opposite expression was expected based on the precue. A matched version of the task was also performed (in a separate group of participants) with affectively neutral probe stimuli. Behavioral interference was observed, in terms of response latencies and errors, on all conflict trials. However, bottom-up conflict was stronger in the emotional version of the task compared to the neutral version; top-down conflict was similar across the two versions. The results suggest that voluntary facial expressions may be more sensitive to indexing emotional than nonemotional conflict, and importantly, may provide an ecologically valid method of examining how emotional conflict may manifest in behavior and brain activity.

Keywords: emotion, cognitive control, facial expressions, electromyography, conflict

The term "cognitive control" refers to a diffuse collection of mechanisms, including perceptual selection, response biasing, and online maintenance of contextual or goal information, by which the human cognitive system adaptively configures itself to optimally perform specific tasks. The ability to employ cognitive control is thought to be essential to the flexibility, sophistication and complexity of human cognitive processing across a wide domain of tasks and is central to goal-oriented behavior. Much research has been devoted to understanding the components of cognitive control. These include the detection of situations warranting the deployment of control processes, modulation of these processes once they are engaged, and the withdrawal of control as necessary. The presence of *conflict*, defined on its most mechanistic level as simultaneous concurrent processes competing with one another for common resources (Botvinick, Braver, Barch, Carter, & Cohen, 2001), is a canonical example of a situation in which control is warranted. Accordingly, much research has been devoted to the examination of conflict detection and resolution via deployment of cognitive control (Botvinick, Cohen, & Carter, 2004; Carter et al., 1998; Yeung et al., 2004). In the current paper, we discuss efforts to extend the conflict and control framework into the affective domain.

The Stroop task is a classic example of a task used to investigate conflict and conflict-related deployment of cognitive control (Stroop, 1935). In this task, participants are presented with words, and must name the color that they are printed in. In some trials, the text and ink color are congruent (e.g., the word GREEN printed in green ink); thus, no conflict is present, and the control demands of the trial are relatively low. In contrast, in other trials, the text and ink color are incongruent (e.g., the word GREEN printed in red ink). In these trials, automatic reading of the text of the word interferes with the color-naming task; cognitive control must be deployed to overcome this interference and complete the naming task successfully. Similarly, in the Simon task (Lu & Proctor, 1995) automatic processing of the spatial position of presented stimuli can conflict with responding (even when stimulus position is task-irrelevant), if responses also have spatial associations (e.g., making a response with the left hand to a stimulus appearing on the right side of a display).

In recent years, the characterization of conflict and control has been extended from cognitive processes to the domain of emotion. Emotion is both a major driver and subjective outcome of human behavior, and accordingly, investigations of the information-processing mechanisms that mediate emotional processing have become numerous in recent years (Pessoa, 2008). A handful of paradigms have been developed and used toward the goal of characterizing emotional conflict and conflict-eliciting control pro-

This article was published Online First November 8, 2010.

Kimberly S. Chiew and Todd S. Braver, Department of Psychology, Washington University in St. Louis.

We thank Timothy Heaven for assistance with data collection and Jordan Taylor for assistance with data analysis. This work was supported by Grant RO1 MH66078 from the National Institutes of Health to T.S.B. and a Natural Sciences and Engineering Research Council of Canada Postgraduate Scholarship to K.S.C.

Correspondence concerning this article should be addressed to Kimberly S. Chiew, Department of Psychology, Washington University in St. Louis, Campus Box 1125, St. Louis, MO 63130. E-mail: kschiew@artsci.wustl.edu

cesses. In such paradigms, the conflict situation is typically operationalized as arising when the participant must complete a controlled processing task, but automatic perception and processing of emotional information interferes with completion of that task. An example of such a task is the emotional Stroop task (Mathews & MacLeod, 1985; McKenna, 1986) an adaptation of the classic Stroop task described above. In the emotional Stroop task, as in the original Stroop task, participants are presented with words and must name the color that they are printed in. The key manipulation is that some of the word names are emotionally laden (e.g., "death") whereas others are emotionally neutral (e.g., "apple"). Thus, emotional Stroop interference is defined as the cost to reaction time in color naming for emotionally laden versus emotionally neutral words. Individuals with emotional disturbances are slower to perform the Stroop with emotional words than with neutral words, while healthy individuals demonstrate no such slowdown (Williams, Mathews, & McLeod, 1996). The validity of the emotional Stroop as a paradigm with which to investigate emotional conflict has been questioned by critics who assert that the interference effects may be because of lower-level lexical factors associated with the emotional words (Larsen, Mercer, & Balota, 2006) or to the attention capturing effects of emotional stimuli (Algom et al., 2004), rather than a direct conflict between competing automatic and controlled responses comparable to those present in the original Stroop. To address these issues, Etkin and colleagues (Egner et al., 2008; Etkin et al., 2006) developed a second Stroop-like task presenting participants with words pertaining to emotions (e.g., "HAPPY" or "SAD") superimposed over emotional or nonemotional faces. They observed performance slowing in trials when the word was emotionally incongruent with the emotional expression of the simultaneously presented face (e.g., "HAPPY" presented over a fearful face) relative to trials where the word and the face were emotionally congruent with one another. This task retains the conflict of automatic and controlled processes present in the emotional Stroop, but by making both relevant and irrelevant information semantically related and either congruent or incongruent, more closely approximates the conflict and required engagement of control in the original Stroop.

We aimed to build upon these previous investigations and develop a paradigm that more closely approximates emotional conflict as it may occur in real-life situations, yet permits the level of experimental control necessary to effectively characterize behavior in relation to conflict manipulations. We considered real-life emotional conflict situations where one's subjective emotional experience may interfere with a necessary overt response (e.g., keeping cool while being confronted with a difficult or frustrating situation; smiling and acting gracious in the wake of defeat). These real-life situations often involve suppression or alteration of facial expressions, which have been characterized as potent social cues and indices of emotional response (Dimberg & Thunberg, 1998; Ekman, 1984). Thus, we focused on conflict stemming from emotional stimulus-response (S-R) incompatibility, by developing a task that required participants to respond to emotionally evocative cue-probe combinations with emotionally congruent or incongruent facial expressions.

Emotional facial expressions may provide an ideal performance measure to use while examining emotional conflict because previous literature indicates that they are impacted both by automatic, emotional influences and conscious, cognitively controlled influences. Using electromyography (EMG), Dimberg and colleagues (Dimberg, Thunberg, & Grunedal, 2002) measured activity in the facial musculature as participants made voluntary expressions to affective stimuli. Specifically, activity was monitored in the *Zygomaticus major* (zygomatic; associated with smiling) and *Corrugator supercilii* (corrugator; associated with frowning) muscles, which have been stereotypically associated with positive and negative affect, respectively (Cacioppo et al., 1986). A key finding was that controlled zygomatic activity was facilitated when viewing positive stimuli and attenuated when viewing negative stimuli, and likewise for corrugator activity. Conversely, under conditions when the stimuli were incongruent with the required facial expressions, interference effects were observed in the EMG activity, reflected in slower rise-times and reduced amplitudes. Lee and colleagues (Lee et al., 2008) expanded on this research in a recent study that examined behavior and brain activity (measured via EMG and functional MRI; fMRI) when participants had to make facial expressions that were congruent or incongruent with visually presented face stimuli that varied parametrically in the intensity of expression. They observed a significant correlation between expression onset latency and stimulus intensity when the stimuli were incongruent with the required expressions. Together, these findings are consistent with the idea that emotion-related interference may vary parametrically, and can be observed behaviorally when using facial expressions as a dependent measure of performance. Capitalizing on these observations, we adapted a cognitive control task to examine emotion-related interference using facial expressions as a mode of response instead of the more typical button press.

The present study used an emotional adaptation of the *AX-Continuous Performance Task* (AX-CPT), a paradigm that has been well-used to characterize cognitive conflict and control related to the processing of context information (Barch et al., 1997; Braver, Barch, & Cohen, 1999; Cohen, Braver, & O'Reilly, 1996). Before describing the adaptation, we first review the key elements of the paradigm in its classic form. The task involves presentation of a series of cue-probe pairs occurring sequentially. A target response is required to a specific probe stimulus (e.g., X), but only when it follows a particular cue (e.g., A). Target trials (AX trials; A-X cue-probe combination) occur with high frequency, facilitating target performance, but also establishing response biases that lead to interference in two additional, low-frequency trial types. In BX trials (nontarget cue and target probe), the bias to make a target response to the probe must be overcome via utilization of the contextual cue information. Thus, interference occurs as a result of probe-driven response conflict, and is thus thought to be relatively bottom-up in nature. Conversely, in AY trials (target cue and nontarget probe) the contextual cue produces an invalid target expectancy bias that must be overcome by processing of the probe. Thus, AY conflict is cue-driven and more top-down in nature. Nevertheless, the labels 'bottom-up' and 'top-down' are relative rather than absolute; we use them here for convenience while acknowledging that it is not possible to make an absolute statement about the nature of interference associated with BX versus AY trials. Interference effects on AY and BX trials can be measured by comparing performance against AX targets, but also BY trials. BY trials (nontarget cue and nontarget probe) are low-frequency (like AY and BX trials), but are free from interference because of the absence of target-biasing information in the cue or probe.

In the emotional AX-CPT used here, text instructions (e.g., "SMILE" "FROWN") served as cues and emotional pictures (from the International Affective Picture System [IAPS]; (Lang, Bradley, & Cuthbert, 1999) served as probes (see Figure 1 and Table 1 for summary of task conditions). Participants smiled or frowned (target or nontarget response) to the cue-probe combinations; because of the trial frequency structure (a majority of target trials vs. nontarget trials) they were biased to automatize responses to a high-frequency, emotionally congruent cue-probe combination as the target (e.g., 'SMILE' + pleasant-picture or 'FROWN' + unpleasant-picture—analogous to the AX target combination). As in the original AX-CPT, top-down and bottom-up interference were expected to be established as a result of the high-frequency AX bias. In BX trials (nontarget cue, followed by a target probe) the emotional valence of the probe is incongruent with the required response (e.g., smiling to an unpleasant picture, or frowning to a pleasant picture). Thus, these trials may result in a form of bottom-up interference, as the automatic emotional experience elicited by the probe conflicts with the overt facial expression of emotion that is required by the task. On AY trials, conflict also occurs, but may be qualitatively different in nature. On these trials, the required facial expression response is congruent with the valence of the probe, but is incongruent with the expectancy set up by the contextual cue. Thus, the interference observed on these trials may be of a more top-down form (compared to BX trials) resulting from the violation of an attentional expectancy. The unique component of the present research is how the Emotion AX-CPT elicits emotional conflict, relative to other paradigms that have been used for this purpose. In contrast to the emotional Stroop and related tasks, where effective performance hinges on the participant's ability to effectively ignore automatically processed emotional information, the Emotion AX-CPT requires explicit processing and integration of the cue-probe combination to implement the correct response; the cue and probe may independently help or hinder the response, leading to different forms of emotional conflict.

In the present study, one group of participants performed the Emotion AX-CPT. A second group of participants performed another AX-CPT (Neutral AX-CPT) that was matched in all respects to the Emotion AX-CPT except that the probes had no emotional content. Thus, in both groups, speeded facial expressions were the required mode of responding. Performance was measured via EMG measurement of zygomatic and corrugator muscle activity (indexing smiling and frowning). We aimed to demonstrate reliable interference in facial expression performance stemming from either relatively emotional or nonemotional conflict, confirming multiple contributions to facial expression behavior, as well as validating the use of controlled expressions as an ecologically valid measure of performance in emotion processing tasks. By comparing performance in the Emotion AX-CPT relative to the Neutral version, we were able to investigate whether the emotional nature of the probe stimuli impacted the degree of interference observed. We hypothesized that in both versions, interference would be observed because of generic S-R incompatibility effects (Kornblum, Hasbroucq, & Osman, 1990), but that in the Emotion version an additional component of this effect would be because of affective incompatibility between the stimulus and response. Specifically, in the Emotion AX-CPT, there is an automatic linkage between the affective valence of probe stimuli and associated facial expressions that occurs in addition to generic S-R incompatibility effects. This should make bottom-up or probe-driven interference (i.e., occurring in BX trials) more powerful in the Emotional version than in the Neutral version. Thus, we anticipated larger interference effects in the Emotion AX-CPT compared to the Neutral AX-CPT, but especially for BX trials.

Method

Participants

Sixty-eight healthy young adults participated (Emotion: $N = 34$; 13 men, 21 women; mean age 20.3 years $\pm$ *SE* 0.25; Neutral: $N = 34$; 15 men, 19 women; mean age 20.8 years $\pm$ *SE* 0.25). Participants were recruited from participant pools maintained by the Department of Psychology at Washington University in St. Louis. All participants provided written informed consent as outlined by

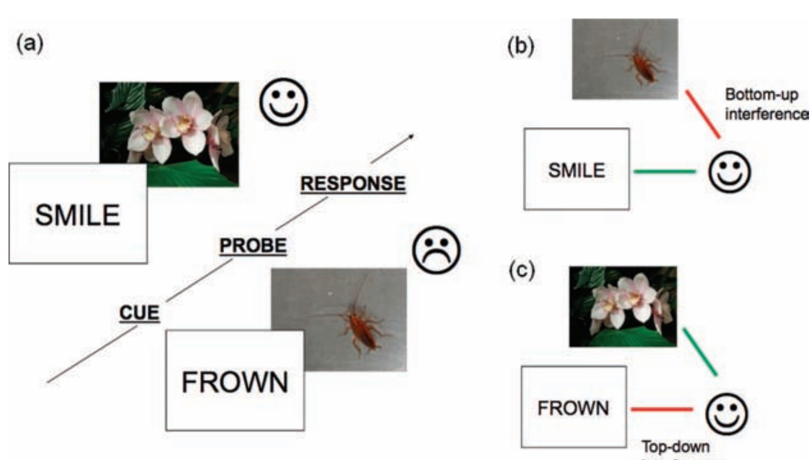

Figure 1. Task structure. (a) Examples of the target (AX) cue-probe-response combination for smile-target and frown-target conditions of the Emotion AX-CPT; (b) Example of BX (nontarget cue, target probe); and (c) AY (target cue, nontarget probe) conflict trials for frown condition of the task.

Table 1
Summary of Task Design for All Trials and Conditions of the Emotional and Neutral AX-CPTs

Trial (freq)	Conflict	Meaning	Target expression condition	Cue	Probe: Emotion	Probe: Neutral	Correct response
AX (high)	No	Baseline (target)	Smile	'SMILE'	Positive picture	Vowel	☺
			Frown	'FROWN'	Negative picture	Vowel	☹
AY(low)	Yes	Top-down interference	Smile	'SMILE'	Negative picture	Consonant	☹
			Frown	'FROWN'	Positive picture	Consonant	☺
BX(low)	Yes	Bottom-up interference	Smile	'FROWN'	Positive picture	Vowel	☹
			Frown	'SMILE'	Negative picture	Vowel	☺
BY(low)	No	Baseline (nontarget)	Smile	'FROWN'	Negative picture	Consonant	☹
			Frown	'SMILE'	Positive picture	Consonant	☺

Note. All task conditions conducted at short and long cue-probe delay.

the Washington University Human Studies Committee. Participants were paid $15/hr remuneration for their participation.

Behavioral Tasks

Behavioral task design is summarized in Table 1. In the Emotion version, participants performed an emotional adaptation of the AX-CPT, with the words "SMILE" and "FROWN" as cues, emotional pictures from the IAPS as probes, and emotional facial expressions (smiling/frowning) as responses to the cue-probe combination (see Introduction). Seventeen of 34 Emotion participants performed the task with "SMILE" + pleasant-picture as the AX (target) cue/probe combination (smile-target condition); 17 performed the task with "FROWN" + negative-picture as the target cue/probe combination (frown-target condition). In the Neutral version, participants performed the task with letters rather than pictures serving as probe stimuli (vowels served as target probes and consonants served as nontarget probes). As in the Emotion version, the words "SMILE" and "FROWN" served as cues and emotional facial expressions served as responses. Seventeen of the 34 Neutral participants performed the task with smile/target as the target cue/probe combination (smile-target condition) and 17 performed the task with frown/target as the target cue-probe combination (frown-target condition). All other details of the paradigm described below were the same for both task versions.

Target (AX) trials occurred with a 7:1 frequency compared to all nontarget task trials. Participants performed two runs of 120 task trials each, broken down into 70 AX, 10 AY, 10 BX, 10 BY, and 20 no-go trials. These trial-types were intermixed in a pseudorandom sequence (i.e., 10 repetitions of 12 trial sequences at the frequencies described above, order randomized within each sequence). No-go trials were indicated via the probe stimulus (with an equal proportion of target and nontarget cues): a fixed neutral picture (rather than emotionally valenced) in the Emotion condition, and a digit (rather than letter) in the Neutral condition. Participants were required to withhold responding on these trials (i.e., make no facial expression). These no-go trials were included to prevent participants from preparing facial expressions prematurely (i.e., in advance of the probe stimulus) and were not included in analyses.

The two runs of the task varied in terms of whether the delay between the cue and probe stimulus was short or long. This delay manipulation varied the goal maintenance demands of the task, allowing us to investigate whether such demands impacted performance. In both the short and long delay conditions, cues were shown for 750 ms and probes were shown for 2,500 ms. In the short delay condition, the delay between cue offset and probe onset was 1,000 ms, while in the long delay condition the delay between cue offset and probe onset was 3,250 ms. Intertrial intervals in the short and long delay conditions were 3,250 ms and 1,000 ms, respectively, to ensure that total trial duration was equated between delay conditions. The trial structure and timing for each type of trial, within the two different expression conditions (smile-target and frown-target), are summarized in Figure 1. Order of run administration was also counterbalanced across participants. The experiment was programmed in Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993) and presented on a Macintosh computer.

EMG Data Acquisition

Before application of facial electrodes, the skin overlying *Zygomatic major* and *Corrugator supercilii* muscles was cleaned with alcohol to reduce interelectrode impedence to $<10\ k\Omega$. Electrode placement followed standard facial EMG guidelines (Fridlund & Cacioppo, 1986). Electrodes were applied to the left side of the face only, following observations that emotions appear to be expressed more intensely on the left side of the face (Sackeim et al., 1978). Beckman miniature Ag-AgCl electrodes were filled with Beckman electrode paste and applied to the zygomatic and corrugator facial muscles. The raw EMG signal was measured using an amplifier and subjected to a low-pass filter analysis (Biopac Systems Inc., Santa Barbara, CA) before being sent to a computer with EMG recording software (Acq*Knowledge*, Biopac Systems Inc.).

EMG Data Analysis

EMG data was analyzed using in-house scripts in MATLAB (The Mathworks, Inc., Natick, MA). The data were filtered using a second-order digital Butterworth high-pass filter with a normalized cutoff frequency of 0.01 Hz and converted to the root-mean-square of the signal, with smoothing set to 25 ms and frequency to 1,000 Hz.

EMG data were first characterized in terms of two dependent measures, response onsets and error rates. Response onsets were obtained by calculating the time after probe onset at which muscle activity, measured by EMG recording at the channel of the correct response (zygomatic or corrugator muscle), exceeded a threshold of 50 μV on each experimental trial For the purposes of data analysis, response onsets were treated as analogous to reaction times (RTs) in standard versions of the AX-CPT. However, it is important to note that response onset times were generally much faster than the time of peak EMG amplitude (e.g., see Figure 4), and thus may provide a more sensitive measure. Median correct response onsets were used as a dependent performance measure and were calculated for each individual subject, separately for each delay and trial condition. Task performance was also measured using error rates as a dependent measure. Performance errors were defined as trials in which a greater peak amplitude was detected in the incorrect expression channel than in the correct expression channel (e.g., if participants were supposed to smile on a trial, but peak corrugator activity exceeded peak zygomatic activity, that trial was classified as an error). Error rates were used as a dependent measure of performance and were calculated for each individual subject, separately for each delay and trial condition, as a percentage of total trials at that particular delay and trial condition combination.

A separate, complementary analysis examined the continuous timecourse of EMG activity within the first second following probe onset. This analysis was conducted in an analogous fashion to prior work examining rapid effects of emotional stimuli on voluntary facial expressions (Dimberg et al., 2002). Although the error rate and response onset analyses described above provide data comparable to typical studies of conflict and interference using discrete (e.g., manual) responses, an advantage of using EMG as a dependent measure is the ability to examine potential conflict effects as they evolve continuously over time. Moreover, because EMG was recorded in two distinct channels, it is possible to analyze evolving effects in the incorrect channel that may also reflect subthreshold conflict or interference.

The analysis was conducted by computing the continuous amplitude of muscle activity for correctly executed responses in both the correct and incorrect channel in the first second following probe onset, with activity examined at 50 ms intervals. The key goal of the analysis was to detect the presence of interference effects, by comparing activity on high interference trials (BX and AY) relative to the matched low-interference baseline that involved the same response channel (BY). Thus, analyses were conducted examining timecourse activity in two focused contrasts (1:BX vs. BY; 2:AY vs. BY) as a function of trial, time point, and task version (Emotion vs. Neutral). These contrasts enabled direct examination of the evolution of bottom-up (BX) or top-down (AY) conflict interference effects by referencing them against the nonconflict baseline condition (BY) involving the same muscle channel and response frequency. These analyses were conducted separately for each expression condition and muscle channel.

Results

Examining Interference via Error Rates and Response Onsets

We first tested the hypothesis that performance would be worse in conflict trials (AY and BX) relative to nonconflict trials using both response onsets and error rates as dependent measures. Repeated-measures analyses of variance (ANOVAs) were conducted on both the Emotion and Neutral task versions with trial-type (AX, AY, BX, BY), delay (long vs. short), and expression condition (smile-target vs. frown-target) as factors. These results are summarized in Table 2 and Figure 2.

In terms of error rates, the main effect of trial-type proved to be significant for both versions (see Figure 2a; Emotion: $F(3, 96) = 3.512$, $p = .018$; Neutral: $F(3, 96) = 3.817$, $p = .012$). This effect was because of a common pattern of elevated errors on BX trials relative to both AX (Emotion: $p = .005$; Neutral: $p = .017$) and BY (Emotion: $p < .001$; Neutral: $p = .017$) trials. However, error rates were not elevated on AY trials, and indeed were significantly reduced relative to BX trials, at least in the Neutral condition ($p = .022$). Additional effects were also observed in error rates, including a main effect of delay in the Neutral, but not Emotion task version (higher errors at long vs. short delay [Emotion: $F(1, 32) = .172$, $p = .681$; Neutral: $F(1, 32) = 5.297$, $p = .028$]). Finally, there was a trend level effect of expression in the Neutral version, but not Emotion, because of more errors in smile-target than frown-target (Emotion: $F(1, 32) = .109$, $p = .743$; Neutral: $F(1, 32) = 4.057$, $p = .052$]).

In terms of response onsets, the main effect of trial-type was also significant for both task versions (see Figure 2b; Emotion: $F(3, 96) = 10.472$, $p < .001$; Neutral: $F(3, 96) = 41.898$, $p < .001$]). Planned contrasts confirmed that these effects, like the error rates, were because of conflict-related interference effects. AY trials were slower than both AX and BY trials in both task versions ($p < .001$). Likewise, BX trials were slower than BY (Emotion: $p = .005$; Neutral: $p = .017$) and AX trials (Emotion: $p = .060$; Neutral: $p = .004$). Finally, paralleling the pattern observed in classic AX-CPT tasks (Braver, Barch, & Cohen, 2002), AY trials were slower than BX (Emotion: $p = .067$; Neutral: $p < .001$). No other significant effects were observed.

The error rate and response onset effects are consistent with the idea of increased conflict on BX and AY trials. A specific hypothesis of the study was that the bottom-up form of conflict (i.e., on BX trials) would be stronger in the Emotion version compared to Neutral. We tested this hypothesis by computing a direct relative interference measure in terms of a difference score, using the average of the two control trial-types (AX and BY) as a baseline (i.e., bottom-up interference = [BX – 0.5 * (AX + BY)]). For comparison purposes an analogous measure of top-down interference was computed involving AY trials (i.e., top-down interference = [AY – 0.5 * (AX + BY)]). These interference measures were calculated for response onsets only, as no significant differences in relative interference using error rate measures were found.

Repeated-measures ANOVAs conducted using expression (smile-target vs. frown-target) and version (Emotion vs. Neutral) as factors,[1] revealed a significant interaction between expression and version for the bottom-up interference score ($F(1, 64) =$

[1] Delay was not included as a factor in these analyses. Because no significant delay effect was revealed in bottom-up interference, bottom-up analyses were redone using a univariate ANOVA collapsed across delay, with expression and version as between-subjects factors. For top-down interference, the delay effect reached statistical significance ($p = .03$), because of higher top-down interference at short delay than at long. However, this effect did not interact with expression condition, and so is not described further.

Table 2
Summary of Conflict Effects Using Error Rates, Response Onsets, as Well as Continuous Timecourse Data (Timecourse Data Taken From the First Second Following Probe Onset) as the Performance Measure

	Presence of conflict (trial effect) by performance measure					
	Error rates		Response onsets		Interference measures: difference scores (conflict—averaged baselines)	
Task	Top-down	Bottom-up	Top-down	Bottom-up	Top-down	Bottom-up
Emotion	N	Y	Y	Y	Y	Y (frown)
Neutral	N	Y	Y	Y	Y	N

	Presence of emotion and conflict effects by EMG timecourse measure							
	Bottom-up interference (BX vs. BY)				Top-down interference (AY vs. BY)			
	Correct channel		Incorrect channel		Correct channel		Incorrect channel	
	Smile-target	Frown-target	Smile-target	Frown-target	Smile-target	Frown-target	Smile-target	Frown-target
Conflict effect (main effect of trial)	Y	Y	N	N	Y	Y	N	N
Emotion > neutral (main effect of version)	Y	N	N	Y	Y	N	Y (reversed; Neutral > Emotion)	Y
Emotion > neutral conflict (trial × version interaction)	N	Y	N	Y	Y	N	N	Y

5.378, $p = .024$; Figure 3). This effect was because of the fact that the smile-target condition interference effect was similar in the Emotion and Neutral task versions, but in the frown-target condition bottom-up interference tended to be larger in Emotion versus Neutral. Although bottom-up interference was overall lower in Neutral than in Emotion, main effects of expression and version did not reach significance. In contrast, the ANOVA examining top-down interference in Emotion versus Neutral task versions, revealed no significant effects (see Figure 3). These results are summarized in Table 2.

EMG Timecourses: Error Versus Correct Trials

For the purposes of data analysis, we defined errors as trials for which greater peak amplitude was detected in the incorrect expression channel than in the correct expression channel. It is important to acknowledge that this definition is somewhat of a liberal one (e.g., some trials that may have involved activity in the correct channel would be classified as an error, but might more accurately be termed a "corrected error"). Nevertheless, we believe that this definition of error remains more sensitive than the typical definition of error used with button-press responses (where there is no possibility of examining corrected errors at all). Moreover, inspection of the EMG timecourses on defined in this way demonstrated that such a definition did not lead to a high proportion of corrected error trials. Figure 4 presents a graph comparing the average EMG timecourse on correct versus error trials for a representative condition (smile-target AX trials, Emotion condition, long delay). As the graph illustrates, although overall muscle amplitude is lower on error trials, average activity in the incorrect channel is clearly higher than in the corrected channel, and does not suggest that error trials were typically "corrected." This pattern was typical of individual error trials across all other trial types and conditions as well. Finally, it is important to note responses had to reach a minimum amplitude of 50 μV to be included in any analyses. Thus, trials in which the peak channel amplitude was low were treated as nonresponses. Generally, on correct response trials, the peak amplitude in the intended response channel was highly above this threshold, while the amplitude of the incorrect channel was well below (see Figure 4a). Thus, we feel justified in using peak amplitudes of activity to functionally define errors in the present study.

Examining Interference via Timecourse Analysis

Direct analyses of EMG timecourse activity were conducted to test the following hypotheses: (a) increased interference should be present in conflict trials relative to nonconflict trials; (b) this interference should be manifest as a reduction in EMG amplitude in the correct response channel on conflict trials (relative to nonconflict trials); (c) interference may also be exhibited in terms of increased EMG amplitude in the incorrect response channel on conflict relative to nonconflict trials; and (d) interference effects should emerge relatively rapidly ($<$1 second after probe onset).

Continuous EMG activity was analyzed separately in the smile-target and frown-target conditions with zygomatic and corrugator muscle amplitude as a dependent measure. We conducted repeated-measures ANOVAs with trial (BX vs. BY and AY vs. BY) and time point (20 time points; every 50 ms up to the first 1,000 ms after probe onset) as within-subject factors and task version (Emotion vs. Neutral) as a between-subjects factor. Separate ANOVAs were conducted for smile-target and frown-target conditions, and for the zygomatic and corrugator channel amplitudes. Interference effects are summarized in Table 2.

Because repeated-measures *F* tests can lead to positively biased tests, correction approaches are often used, such as Greenhouse

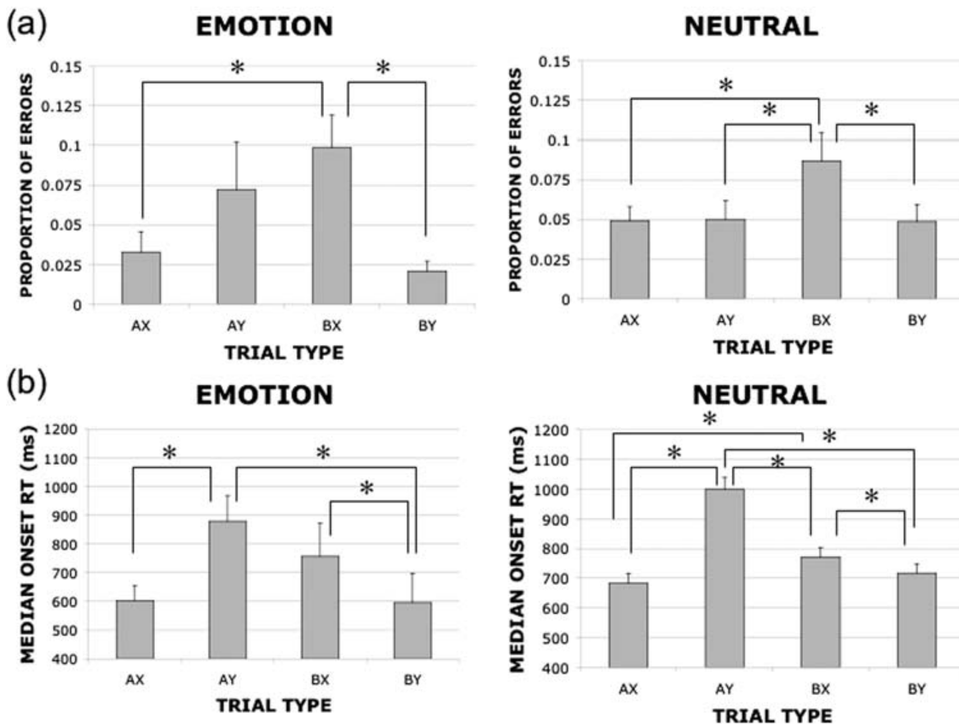

Figure 2. Performance in Emotion and Neutral experiment versions with (a) response onsets and (b) error rates as the dependent measure. Significant trial contrasts ($p < .05$) are indicated with asterisks.

and Geisser, to reduce such bias. For the current analysis, this issue could be especially problematic given the nature of serial correlation in adjacent EMG time points. We implemented the most conservative form of the Greenhouse and Geisser correction approach (Kirk, 1968), in which the degrees of freedom for treatments and error terms were $(g - 1)$ and $(n - g)$ where g is the number of between-subjects groups and n is the number of subjects, respectively (i.e., for the current analysis, 1 and 32 degrees of freedom were used). It should be noted that this approach may be overly conservative, and thus significance may be underestimated, but we felt this approach was preferable to less conservative ones, to increase confidence in the significance of the results.

BX Versus BY

The first analysis examined bottom-up interference by comparing the EMG timecourse on BX trials relative to the baseline BY. In smile-target, participants were to frown to BX and BY trials, and in frown-target, they were to smile; thus corrugator indexed correct-channel activity for smile-target and zygomatic indexed correct-channel activity for frown-target (see Figure 5a). Although

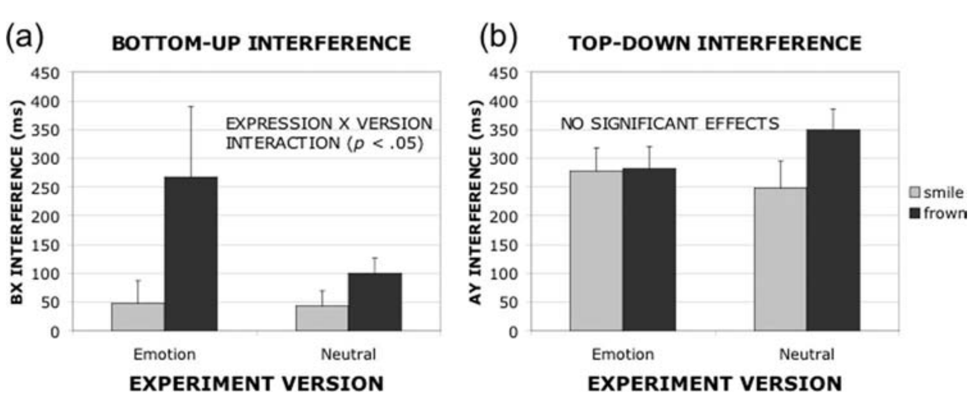

Figure 3. Relative (a) BX interference and (b) AY interference in RT as a function of expression and experiment version.

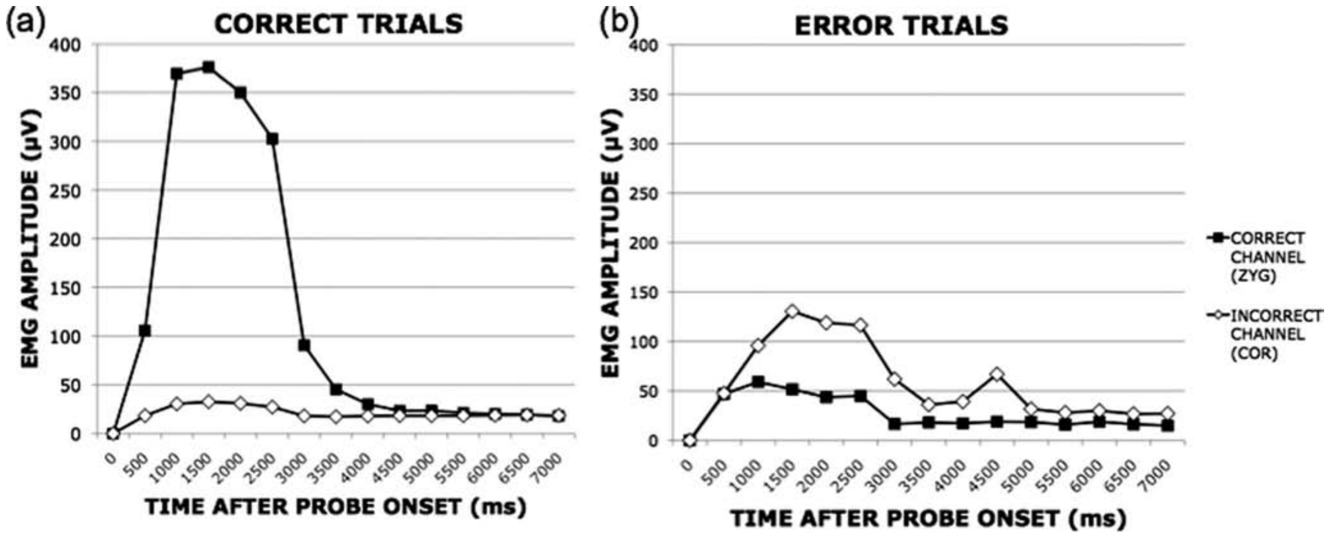

Figure 4. Representative graphs of muscle activity in (a) correct and (b) error trials for smile-target AX trials at long delay.

activity in correct channels reliably increased as a function of time point (all $p < .001$), there was also a significant effect of trial-type in both expression conditions (smile-target: $F(1, 32) = 4.728$, $p = .037$; frown-target: $F(1, 32) = 15.620$, $p < .001$]). This reflected lower overall activity on BX trials compared to BY, consistent with an interference effect. Moreover, the trial-type effect also interacted with time point for frown-target ($F(1, 32) = 8.836$, $p = .006$), which indicated that the interference effects began to emerge after around 500 ms, consistent with previous results by Dimberg (Dimberg et al., 2002).

We also observed stronger correct-channel EMG responses in the Emotion task version compared to Neutral, as evidenced by a main effect of version for smile-target ($F(1, 32) = 7.851$, $p = .009$), plus version × time point interactions in the smile-target condition only ($F(1, 32) = 4.132$, $p = .050$). The latter effect reflected a steeper rise of EMG activity in the Emotion condition than in Neutral, which tended to emerge after about 200 ms. Finally, and most critically in frown-target, a significant trial-type × version interaction was observed ($F(1, 32) = 4.684$, $p = .038$). This finding provided strong evidence that the bottom-up interference effect (BX-BY difference) was greater in Emotion than Neutral.

Interestingly, similar interference effects were observed (but in reverse) for incorrect-channel activity, particularly in the frown-target condition (corrugator channel) (see Figure 5b). Activity in incorrect channels also increased as a function of time (all $p < .001$). A significant main effect of version indicated stronger incorrect channel activity in Emotion compared to Neutral ($F(1, 32) = 5.417$, $p = .026$), plus a trial × version interaction ($F(1, 32) = 7.369$, $p = .011$) suggested that this effect was most prominent on BX trials rather than BY, consistent with bottom-up interference. Finally, a significant trial × version × time point interaction ($F(1, 32) = 4.436$, $p = .043$) indicated that BX and BY pulled apart not only to a greater extent, but also earlier in Emotion than in Neutral. In smile-target, incorrect-channel BX activity was higher than incorrect-channel BY activity and, surprisingly, Neutral activity was higher than Emotion activity, but none of these effects reached statistical significance.

AY Versus BY

The second analysis examined top-down interference by comparing the EMG timecourse on AY trials relative to the baseline BY. In smile-target, participants were to frown to AY and BY trials, and in frown-target, they were to smile; thus corrugator indexed correct-channel activity for smile-AX and zygomatic indexed correct-channel activity for frown-AX (see Figure 6a). Activity in these channels reliably increased as a function of time point (all $p < .001$) but there was also a significant effect of trial-type in both smile-target and frown-target conditions (smile-target: $F(1, 32) = 36.729$, $p < .001$; frown-target: $F(1, 32) = 44.560$, $p < .001$), with the lower AY activity indicating an interference effect. The trial-type effect interacted with time point (smile-target: $F(1, 32) = 9.665$, $p = .004$; frown-target: $F(1, 32) = 11.590$, $p = .002$) indicating that the interference effect emerged and increased over time. For AY (top-down) interference this period was earlier (200–300 ms) than observed for BX (bottom-up) interference (~500 ms).

Again, stronger correct-channel EMG effects were observed in the Emotion condition compared to Neutral, as indicated by a significant effect of version in smile-target ($F(1, 32) = 6.545$, $p = .015$), plus a version x time point interaction in both conditions (smile-target: $F(1, 32) = 4.155$, $p = .050$; frown-target: $F(1, 32) = 3.564$, $p < .068$). Moreover, the critical trial × version interaction was also statistically significant in the smile-target condition ($F(1, 32) = 6.524$, $p = .016$), indicating that not only was overall EMG activity greater in the Emotion AX-CPT, but also that the top-down interference effect was larger as well.

When examining incorrect-channel activity (zygomatic for smile-target and corrugator for frown-target; see Figure 6b), we

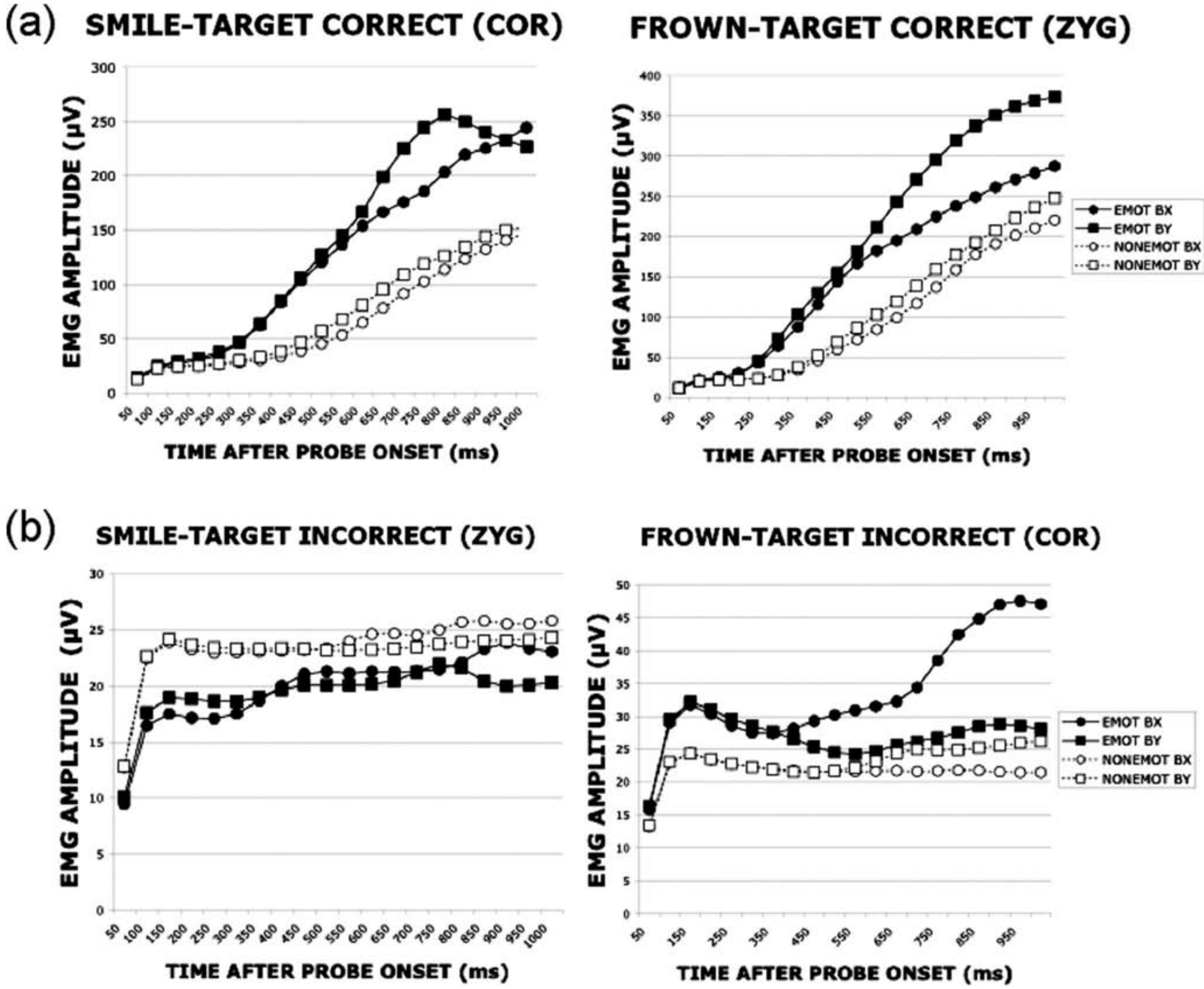

Figure 5. The first second of correct and incorrect channel timecourse activity in both expression conditions for BX and BY trials in Emotion and Neutral experiment versions: (a) Correct channel activity, (b) Incorrect-channel activity.

observed a main effect of version in both conditions (smile-target: $F(1, 32) = 4.255$, $p = .047$; frown-target: $F(1, 32) = 3.987$, $p = .054$) but for different reasons: in frown-target, Emotion activity was higher than Neutral, and the reverse was true for smile-target. Other than this main effect of version and a main effect of time point (all $p < .001$), no significant effects were observed in the incorrect-channel activity for either expression condition.

Discussion

The present study introduces a new experimental paradigm for the study of emotional conflict: the emotional AX-CPT. In the cognitive literature, conflict processes have typically been studied through the introduction of S-R incompatibility effects. A key feature of the current paradigm is that conflict is introduced through S-R incompatibility, but with both the stimulus (emotionally evocative pictures) and response (facial expressions) containing an affective valence component. Moreover, the paradigm permitted examination of two forms of conflict, one driven by bottom-up factors (automatic response tendencies associated with the probe stimulus) and the second driven by top-down factors (attentional expectancies generated by a preparatory cue stimulus). Thus, although cognitive and emotional conflict have been compared in prior studies (Compton et al., 2003; Etkin et al., 2006; Lee et al., 2008), as has the use of affectively valenced responses (Dimberg et al., 2002), this is the first study to examine these components together, in terms of multiple forms of conflict.

A key goal in the development of this new paradigm was to establish that it could elicit reliable behavioral indices of emotional conflict. The results clearly affirm this. In terms of multiple behavioral measures, there were clear interference effects observed in the task conditions associated with both bottom-up (BX) and top-down (AY)

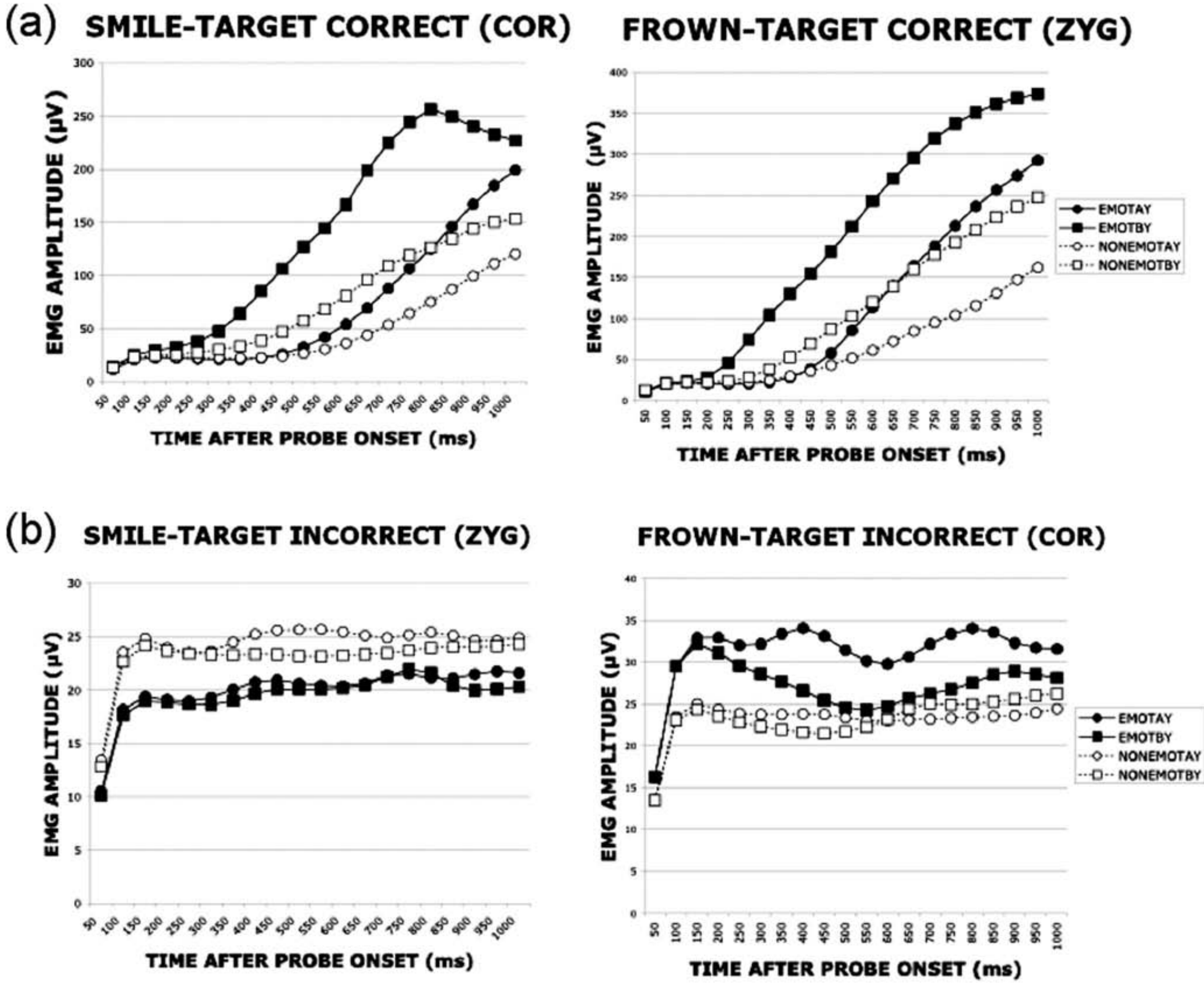

Figure 6. The first second of correct and incorrect channel timecourse activity in both expression conditions for AY and BY trials in Emotion and Neutral experiment versions: (a) Correct channel activity, (b) Incorrect-channel activity.

forms of conflict: participants made more errors, demonstrated slower response onsets, and produced lower EMG amplitudes in the correct response channel and increased amplitudes in the incorrect channel (as measured via continuous muscle activity) in conflict trials versus nonconflict trials (refer to Table 2). More importantly, a second goal of the study was to investigate whether affective components of conflict could be behaviorally distinguished from nonaffective components of conflict. We tested this by comparing conditions in which conflict was because of both affective and nonaffective dimensions of S-R incompatibility (Emotion condition) versus other conditions in which only nonaffective S-R incompatibility was present (Neutral condition). The results supported our hypothesis, in that behavioral interference effects were significantly amplified in the Emotion condition relative to Neutral. Again, these interference effects were observed in multiple behavioral measures—both response onsets and the continuous timecourse of EMG activity. Notably, bottom-up interference was selectively highest for Emotion subjects. These effects occurred most prominently in the frown-target condition (i.e., in which a smile is required to a negative stimuli). We interpret this finding as consistent with the affective nature of the task, since negative emotional responses tend to be more difficult to suppress than positive ones (Baumeister et al., 2001). Moreover, this expression effect occurred in spite of the fact that volitional corrugator activity (indexing frowning) tended to be more generally weaker in amplitude than volitional zygomatic activity (indexing smiling) as demonstrated by performance on correct trials (e.g., Figure 5a). This further suggests that expression-related differences in bottom-up interference are because of emotion-related effects rather than innate differences in motor engagement across facial muscle groups.

The current study is not without limitations. Our most critical hypothesis was that interference effects would be largest in the Emotion conflict condition relative to Neutral, primarily for the bottom-up (BX) form of conflict. Although this hypothesis was supported, the effect appeared specifically in the frown-target condition, which required participants to smile to negative stimuli (as described above) instead of being observed across both expression conditions. Moreover, although these effects were found for BX trials, a similar pattern was also observed on AY trials, which engaged a more top-down form of conflict. Thus, we did not clearly establish the dissociability of bottom-up versus top-down emotional conflict, nor that the presence of affective sources of conflict amplified interference effects in a valence-independent manner. One reason this pattern may have been observed was a lack of statistical power. Within each of the two experimental manipulations (i.e., Emotion and Neutral), 34 participants took part, and within each manipulation, half of those participants were assigned to smile-target and half to frown-target (thus, only 17 participants in each). Although we had anticipated that this sample size would be sufficient, EMG activity may be more susceptible to individual variability than standard behavioral measures of performance; this may have made it more difficult for differences in BX interference across the experimental manipulations to reach statistical significance.

A key take-home message of this study is that facial expressions can be used effectively as a response modality in the study of emotional conflict. First, because there is an automatic association between facial expression and emotional valence (e.g., frowning and negative affect, smiling and positive affect), this association can easily be capitalized upon in experimental paradigms to produce S-R incompatibility with other cognitive and affective factors. This is analogous to the use of other automatic associations with response modalities that have been used to study conflict in cognitive paradigms, such as the spatial location of response buttons in the Simon task and color naming in the Stroop task. Indeed, utilizing preexperimental forms of S-R incompatibility may provide more robust emotional conflict than has been observed in previous paradigms (e.g., standard forms of the emotional Stroop). Specifically, in most work on emotional conflict, the conflict arises because of incompatibility between a relevant and irrelevant dimension of a stimulus (i.e., S-S incompatibility) rather than between the relevant dimension of the stimulus and the required response. Previous theorists have suggested that these two forms of incompatibility (S-S vs. S-R) might be qualitatively distinct, and that S-R incompatibility is the more powerful of the two (Kornblum et al., 1990; Zhang et al., 1999).

A second advantage in the use of facial expressions as a response modality is that it provides the flexibility to analyze responses in a discrete or continuous fashion. Specifically, when expressions are monitored with EMG, the expression can be scored not only via a discrete cutoff in amplitude (as we did with the response onsets) but also by examining the change in amplitude across time, not only in the correct response channel but also in the incorrect one. This flexibility enables a richer examination of conflict effects, which can become important. For example, in the current study, we found that not only was correct channel activity lower on conflict trials, but also in some conditions incorrect channel activity was also higher. The advantages of continuous measures of response processing have long been appreciated in the literature on cognitive conflict, where EMG measurement during manual responding has been utilized (Burle et al., 2002; Masaki et al., 2007). Our work demonstrates that this same approach, but with facial EMG, is viable and appropriate in studies of emotional conflict as well.

A final point is that our study demonstrates the feasibility of importing facial expressions as a measure of responding into standard experimental paradigms of cognitive conflict and control. The pioneering work of Dimberg and colleagues (Dimberg & Thunberg, 1998; Dimberg et al., 2002) provided the first indication that automatic emotional responses to affectively valenced stimuli can interfere with the generation of voluntary facial expressions. However, the paradigms used in the Dimberg study were not designed to systematically investigate the nature of conflict effects to the extent that these effects have been examined in the cognitive realm. For example, the AX-CPT paradigm used in our study, like similar paradigms such as the Stroop and Simon tasks, permits trial-by-trial conflict manipulations as well as the manipulation of the strength of conflict effects through manipulations such as stimulus frequency and timing. Thus, the flexibility afforded in these types of paradigms permits a more rigorous investigation into the nature of conflict. By adding a facial expression component to such paradigms it may be possible to characterize emotional conflict at a level of detail that has been achieved in the study of cognitive conflict. As such, an important direction for future work will be to develop new emotional conflict variants of the Stroop, Simon, and other tasks, which incorporate both affectively valenced stimuli and facial expressions to capitalize on the types of S-R incompatibility we have begun to examine here. In this way, emotional conflict can be investigated using experimental manipulations that parallel those which have been found to be effective for elucidating distinct conflict effects in the cognitive domain.

Another direction for future research would be to utilize additional experimental methodologies to characterize emotional conflict effects. Psychophysiological measures of autonomic function (e.g., skin conductance response, heart rate response, or pupillary reflex) provide a natural starting point, in that they have been frequently used as markers of subjective responses to affective stimuli. Such measures could help to corroborate and validate potential distinctions between emotional and nonemotional forms of conflict. Additionally, by linking trial-by-trial differences in psychophysiological measures to differences in task performance, the influence of emotion on task performance can be more systematically quantified. Neuroimaging methods provide an additional means of linking behavioral emotional conflict effects to physiologic indices such as particular patterns of regional brain activity. For example, an important question in the cognitive neuroscience literature is the extent to which the neural systems mediating emotional and cognitive conflict are dissociable. In particular, there have been suggestions that rostral and dorsal subregions within the anterior cingulate may be differentially related to emotional and cognitive conflict, respectively; other brain regions are thought to be commonly involved in both forms of conflict (Compton et al., 2003; Egner et al., 2008; Etkin et al., 2006; Ochsner et al., 2008). The use of S-R incompatibility designs, in conjunction with facial expression based responding might provide additional leverage on this and related issues (Lee et al., 2008).

In our view, a key outstanding issue that requires further investigation is the relationship between emotional conflict and control. Specifically, in the cognitive literature, it has been suggested that control processes may be mobilized not only in a reactive manner, to resolve conflict after it is detected, but also in a proactive or preparatory manner, based upon the anticipation of future conflict (Braver et al., 2009). This issue has typically been addressed through cueing designs, in which the timing and content of advance cues is experimentally manipulated. The AX-CPT represents one form of such a design, and our results provide initial support for the idea that this type of design can be used successfully to elicit emotional conflict. Although cue timing was examined as a potential factor in our study (i.e., the cue-probe delay manipulation), it was not found to have an effect on performance. However, this null effect may have been a function of the long delays utilized (1,000 vs. 3,250 ms). Typically, cueing paradigms have tended to focus on delay effects at much shorter intervals (e.g., 100–1,500 ms; (Posner, 1980); thus, conflict related to contextual cueing may have reached asymptote at even the short delay. A potentially more powerful design is to manipulate whether advance cues provide foreknowledge regarding upcoming conflict or not. Although the AX-CPT is not well-suited to such manipulations, they have been employed successfully with simpler tasks, such as the Stroop (Aarts et al., 2008). In such studies, it has been found that foreknowledge can modulate the magnitude of cognitive conflict effects. These effects have been interpreted as being because of the anticipatory deployment of control processes that may facilitate successful conflict resolution. Whether similar effects can be observed in the domain of emotional conflict remains to be determined.

References

Aarts, E., Roelofs, A., & van Turennout, M. (2008). Anticipatory activity in anterior cingulate cortex can be independent of conflict and error likelihood. *Journal of Neuroscience, 28,* 4671–4678.

Algom, D., Chajut, E., & Lev, S. (2004). A rational look at the emotional stroop phenomenon: A generic slowdown, not a stroop effect. *Journal of Experimental Psychology: General, 133,* 323–338.

Barch, D. M., Braver, T. S., Nystrom, L. E., Forman, S. D., Noll, D. C., & Cohen, J. D. (1997). Dissociating working memory from task difficulty in human prefrontal cortex. *Neuropsychologia, 35,* 1373–1380.

Baumeister, R. F., Bravslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of General Psychology, 5,* 323–370.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review, 108,* 624–652.

Botvinick, M. M., Cohen, J. D., & Carter, C. S. (2004). Conflict monitoring and anterior cingulate cortex: An update. *Trends in Cognitive Science, 8,* 539–546.

Braver, T. S., Barch, D. M., & Cohen, J. D. (1999). Cognition and control in schizophrenia: A computational model of dopamine and prefrontal function. *Biological Psychiatry, 46,* 312–328.

Braver, T. S., Barch, D. M., & Cohen, J. D. (2002). The role of the prefrontal cortex in normal and disordered cognitive control: A cognitive neuroscience perspective. In D. T. Stuss & R. T. Knight (Eds.), *Principles of frontal lobe function* (pp. 428–447). Oxford: Oxford University Press.

Braver, T. S., Paxton, J. L., Locke, H. S., & Barch, D. M. (2009). Flexible neural mechanisms of cognitive control within human prefrontal cortex. *Proceedings of the National Academy of Sciences of the United States of America, 106,* 7351–7356.

Burle, B., Possamai, C. A., Vidal, F., Bonnet, M., & Hasbroucq, T. (2002). Executive control in the simon effect: An electromyographic and distributional analysis. *Psychological Research, 66,* 324–336.

Cacioppo, J. T., Petty, R. E., Losch, M. E., & Kim, H. S. (1986). Electromyographic activity over facial muscle regions can differentiate the valence and intensity of affective reactions. *Journal of Personality and Social Psychology, 50,* 260–268.

Carter, C. S., Braver, T. S., Barch, D. M., Botvinick, M. M., Noll, D., & Cohen, J. D. (1998). Anterior cingulate cortex, error detection, and the online monitoring of performance. *Science, 280,* 747–749.

Cohen, J. D., Braver, T. S., & O'Reilly, R. C. (1996). A computational approach to prefrontal cortex, cognitive control and schizophrenia: Recent developments and current challenges. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 351,* 1515–1527.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). Psyscope: A new graphic interactive environment for designing psychology experiments. *Behavior Research Methods, Instruments and Computers, 25,* 257–271.

Compton, R. J., Banich, M. T., Mohanty, A., Milham, M. P., Herrington, J., Miller, G. A., . . . Heller, W. (2003). Paying attention to emotion: An fMRI investigation of cognitive and emotional stroop tasks. *Cognitive Affect & Behavioral Neuroscience, 3,* 81–96.

Dimberg, U., & Thunberg, M. (1998). Rapid facial reactions to emotional facial expressions. *Scandinavian Journal of Psychology, 39,* 39–45.

Dimberg, U., Thunberg, M., & Grunedal, S. (2002). Facial reactions to emotional stimuli: Automatically controlled emotional responses. *Cognition and Emotion, 16,* 449–471.

Egner, T., Etkin, A., Gale, S., & Hirsch, J. (2008). Dissociable neural systems resolve conflict from emotional versus nonemotional distracters. *Cerebral Cortex, 18,* 1475–1484.

Ekman, P. (1984). Expression and the nature of emotion. In K. Scherer & P. Ekman (Ed.), *Approaches to emotion* (pp. 319–343). Hillsdale, NJ: Erlbaum.

Etkin, A., Egner, T., Peraza, D. M., Kandel, E. R., & Hirsch, J. (2006). Resolving emotional conflict: A role for the rostral anterior cingulate cortex in modulating activity in the amygdala. *Neuron, 51,* 871–882.

Fridlund, A. J., & Cacioppo, J. T. (1986). Guidelines for human electromyographic research. *Psychophysiology, 23,* 567–589.

Kirk, R. E. (1968). *Experimental design: Procedures for the behavioral sciences.* Belmont, CA: Wadsworth.

Kornblum, S., Hasbroucq, T., & Osman, A. (1990). Dimensional overlap: Cognitive basis for stimulus-response compatibility: A model and taxonomy. *Psychological Review, 97,* 253–270.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). *International affective picture system (IAPS): Technical manual and affective ratings.* Gainesville: University of Florida, Center for Research in Psychophysiology.

Larsen, R. J., Mercer, K. A., & Balota, D. A. (2006). Lexical characteristics of words used in emotional stroop experiments. *Emotion, 6,* 62–72.

Lee, T. W., Dolan, R. J., & Critchley, H. D. (2008). Controlling emotional expression: Behavioral and neural correlates of nonimitative emotional responses. *Cerebral Cortex, 18,* 104–113.

Lu, C.-H., & Proctor, R. W. (1995). The influence of irrelevant location information on performance: A review of the simon and spatial stroop effects. *Psychonomic Bulletin & Review, 2,* 174–207.

Masaki, H., Falkenstein, M., Sturmer, B., Pinkpank, T., & Sommer, W. (2007). Does the error negativity reflect response conflict strength? Evidence from a simon task. *Psychophysiology, 44,* 579–585.

Mathews, A., & MacLeod, C. (1985). Selective processing of threat cues in anxiety states. *Behaviour Research and Therapy, 23,* 563–569.

McKenna, F. P. (1986). Effects of unattended emotional stimuli on color-naming performance. *Current Psychology, 5,* 3–9.

Ochsner, K. N., Hughes, B., Robertson, E. R., Cooper, J. C., & Gabrieli, J. D. (2008). Neural systems supporting the control of affective and cognitive conflicts. *Journal of Cognitive Neuroscience, 21,* 1842–1855.

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature Reviews. Neuroscience, 9,* 148–158.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32,* 3–25.

Sackeim, H. A., Gur, R. C., & Saucy, M. C. (1978). Emotions are expressed more intensely on the left side of the face. *Science, 202,* 434–436.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology: General, 18,* 643–662.

Williams, J. M., Mathews, A., & MacLeod, C. (1996). The emotional stroop task and psychopathology. *Psychological Bulletin, 120,* 3–24.

Yeung, N., Botvinick, M. M., & Cohen, J. D. (2004). The neural basis of error detection: Conflict monitoring and the error-related negativity. *Psychological Review, 111,* 931–959.

Zhang, H. H., Zhang, J., & Kornblum, S. (1999). A parallel distributed processing model of stimulus-stimulus and stimulus-response compatibility. *Cognitive Psychology, 38,* 386–432.

Received August 11, 2009
Revision received March 26, 2010
Accepted March 26, 2010 ■

New Editors Appointed for *Journal of Neuroscience, Psychology, and Economics,* 2011–2016

The American Psychological Association is pleased to announce the appointment of new co-editors for ***Journal of Neuroscience, Psychology, and Economics*** for a 6-year term beginning in 2011. As of January 1, 2011, all new manuscripts should be directed to:

Daniel Houser, PhD
George Mason University
Truland Building, Suite 400
3330 Washington Blvd.
Arlington, VA 22201

Bernd Weber, MD
Department of Epileptology, University Hospital Bonn
Head, NeuroCognition/Imaging, Life & Brain Center
Sigmund-Freud-Str. 25
53127 Bonn
Germany

Electronic manuscript submission: As of January 1, 2011, manuscripts should be submitted electronically to the new editors via the journal's Manuscript Submission Portal: http://www.apa.org/pubs/journals/npe, under the Instructions to Authors.

Manuscript submission patterns make the precise date of completion of the 2010 volumes uncertain. The current co-editors, Martin Reimann, PhD, and Oliver Schilke, PhD, will receive and consider new manuscripts through December 31, 2010. Should 2010 volumes be completed before that date, manuscripts will be redirected to the new editors for consideration in the 2011 volume.