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Is "conflict adaptation" driven by conflict? Behavioral and EEG evidence for the underappreciated role of congruent trials

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Abstract

Theories of cognitive control argue that response conflict in speeded performance tasks leads to adaptive changes, such that irrelevant information is better ignored on subsequent trials. This study tested whether trial-by-trial changes are driven primarily by conflict on incongruent trials or instead by congruent trials, in which irrelevant and relevant stimulus dimensions match. In a Stroop task including congruent, incongruent, and neutral trials, interference was greater following congruent compared to incongruent and neutral trials, which did not differ. During the intertrial interval, EEG alpha power, an inverse measure of cerebral activation, was significantly lower following congruent than neutral trials, whereas incongruent and neutral trials did not differ. These results imply that trial-by-trial changes in performance may not be driven solely by conflict, but rather by changes in attention triggered by congruent information.

Descriptors: Cognitive control, Attention, EEG

Theories of cognitive control attempt to explain how the brain monitors ongoing performance and makes adaptive changes in order to sufficiently meet task goals. Understanding the mechanisms of cognitive control is important for understanding fundamental aspects of cognition, such as the motivation for performance change, and has potential application to clinical conditions in which adaptive control of performance is disrupted. A currently influential model of cognitive control proposes that the brain engages in adaptive control in response to situations of conflict (Botvinick, Braver, Barch, Carter, & Cohen, 2001). That is, when conflict is detected, for example, between a relevant and irrelevant stimulus dimension, the brain tightens its attentional filters so as to better screen out distracting information, thereby enhancing subsequent performance.

Evidence for such adaptive changes in ongoing cognitive performance has come largely through the study of speeded performance tasks, such as the Eriksen flankers task (Eriksen & Eriksen, 1974), the Simon spatial compatibility task (Simon, 1990), and the Stroop color-naming task (Stroop, 1935). In such tasks, participants must respond to a certain dimension of a stimulus (such as its color in the classic Stroop task) while ignoring another dimension (such as word meaning in the Stroop task). The well-known interference effect refers to slower performance on trials with a mismatch, or incongruency, between the information conveyed in the two dimensions. Researchers have recently described a phenomenon of trial-by-trial changes in the magnitude of the interference effect, a pattern that suggests adaptive control. Commonly referred to as the "Gratton effect" in deference to the first paper to describe it, the effect involves a decrease in interference on trials following incongruent trials, compared to following congruent trials (Gratton, Coles, & Donchin, 1992; see Egner, 2007, for review). This pattern is typically interpreted as evidence for a "conflict adaptation" mechanism, under the assumption that the experience of conflict between relevant and irrelevant stimulus dimensions leads to an adaptive change in attention.

The "conflict adaptation" interpretation of the Gratton effect has not gone unchallenged. Some researchers have proposed, for example, that repetition priming could partly account for the Gratton effect (Hommel, Proctor, & Vu, 2004; Mayr, Awh, & Laurey, 2003). Several studies failed to show significant Gratton effects when such repetition was controlled (Mayr et al., 2003; Nieuwenhuis et al., 2006; Wendt, Heldmann, Münte, & Kluwe, 2007), but others continued to find evidence for the effect even after taking measures to control repetitions on consecutive trials (Kerns et al., 2004; Ullsperger, Bylsma, & Botvinick, 2005; Verbruggen, Notebaert, Liefooghe, & Vandierendonck, 2006). Other lines of research have examined the extent to which the Gratton effect generalizes across tasks (e.g., Cho, Orr, Cohen, & Carter, 2009; Funes, Lupiáñez, & Humphreys, 2010a, 2010b; Notebaert & Verguts, 2008; Rünger, Schwager, & Frensch, 2010), the extent to which it is subject to attentional load manipulations (e.g., Fischer, Plessow, Kunde, & Kiesel, 2010), and the extent to which it varies across trial blocks (e.g., Mayr & Awh, 2009).

One underexamined aspect of the Gratton effect, and the focus of the present study, is the potential role that congruent trials may play in leading to attentional changes on a trial-by-trial basis. The most commonly favored theoretical interpretation of the Gratton effect is framed in reference to incongruent trials, despite the fact that the effect is actually a difference between postincongruent and postcongruent trials. Indeed, the very label "conflict adaptation"

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assumes that the source of the effect is an adaptation to conflict. However, it is equally plausible that congruent trials trigger a broader attentional focus that encompasses both the relevant and irrelevant stimulus dimensions. Such a change in focus could be adaptive on the present congruent trial, by taking advantage of the redundant information in the two dimensions, but it would not be adaptive on subsequent incongruent trials because it would lead to increased interference. Although early considerations of the Gratton effect alluded to the possible attentional broadening role of congruent trials (Botvinick et al., 2001; Gratton et al., 1992), little subsequent research has directly pursued this issue. Differentiating the roles of congruent and incongruent trials in contributing to trial-by-trial changes in interference has theoretical importance, because it addresses the primacy of conflict as a motivator of performance change.

The most straightforward means of differentiating the potential roles of congruent and incongruent trials in the Gratton effect is to include neutral trials, in which the irrelevant information is neither consistent with nor directly conflicting with the relevant information. If conflict triggers adaptive changes, then interference should be reduced following incongruent trials compared to both neutral and congruent trials. Alternatively, if congruent information triggers attentional changes, then interference should be increased following congruent trials compared to both neutral and incongruent trials. Until recently, virtually no published studies included neutral trials, and the rare exceptions did not approach the data with the present aims (Bugg, 2008; Davelaar & Stevens, 2009). However, a recent study (Lamers & Roelofs, 2011) included neutral, congruent, and incongruent trials in both a flanker task and a Stroop task, and found that sequential changes in performance in both tasks were driven primarily by congruent trials. That is, relative to a neutral-trial baseline, postcongruent interference was increased, but postincongruent interference was not reduced. These findings imply that conflict may not be the primary motivator of trial-by-trial performance changes.

The present study further examines trial-by-trial adjustments by assessing not only behavioral measures of interference but also electroencephalogram (EEG) measures of cortical activity during the intertrial interval (ITI). In previous work, we have found that EEG alpha power during the ITI is influenced by previous trial accuracy and previous trial type, implying that alpha power is sensitive to cues that signal the need for enhanced control (Carp & Compton, 2009; Compton, Arnstein, Freedman, Dainer-Best, & Liss, 2011). Generally speaking, because alpha power is inversely correlated with mental activation (e.g., Davidson, Jackson, & Larson, 2000; Klimesch, 1999), decreases in alpha power (sometimes referred to as alpha suppression or alpha desynchronization) are presumed to reflect increased mental engagement. Prior studies have found decreases in alpha power between a warning cue and an imperative stimulus, for example, implying mental activation in preparation for the stimulus (Klimesch et al., 1998). Prestimulus alpha power has been correlated with self-reports of attentional state on a trial-by-trial basis (Macdonald, Mathan, & Yeung, 2011). Spatial cuing paradigms demonstrated that a cue leads to alpha suppression over the hemisphere contralateral to the cue (Sauseng et al., 2005; Thut et al., 2006; see also Gould, Rushworth, & Nobre, 2011), again demonstrating that transient changes in alpha power reflect activation related to attentional processing. Further, disrupting cue-induced changes in alpha power through transcranial magnetic stimulation (TMS) appears to disrupt attentional performance (Capotosto, Babiloni, Romani, & Corbetta, 2009, 2011), suggesting a causal role for alpha suppression in attention.

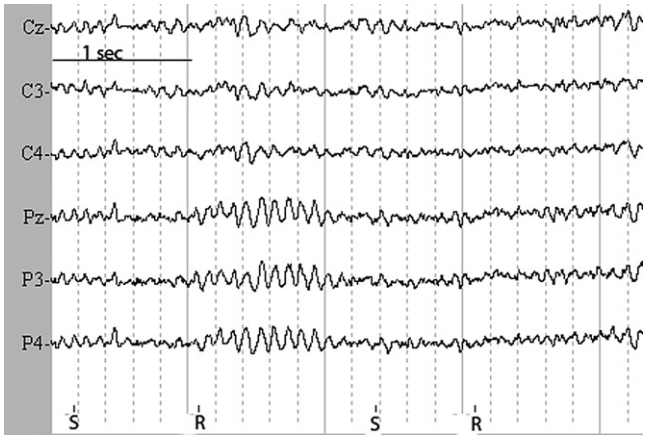

Figure 1. Example of raw EEG data from two trials, illustrating alpha power changes following manual (button press) responses. S = stimulus onset; R = response onset. Increased alpha is evident following the response to the first trial, but is less evident following the response to the second trial.

In prior research, we examined alpha power following button presses in speeded performance tasks, and found that during the ITI following the button press, alpha power increased and then decreased in a quadratic pattern (e.g., Carp & Compton, 2009; see Figure 1). This pattern suggests a phasic mental disengagement during the brief period following the response and while awaiting the next trial, and a re-engagement as the next trial approaches. This quadratic pattern was significantly reduced following errors compared to correct responses (Carp & Compton, 2009), implying that error detection serves as a warning cue that triggers greater mental engagement. We also found that the quadratic pattern of alpha power in the ITI was reduced following correct incongruent trials compared to correct neutral trials (Compton et al., 2011). This latter finding may be consistent with conflict-based models of cognitive control, which predict greater mental engagement in the form of attentional adjustments in the ITI following incongruent versus neutral trials. However, because the prior study did not include congruent trials, we were unable to fully test the influence of incongruent versus congruent trials on neural activity in the ITI.

The goals of the present study were therefore twofold. First, we aimed to provide an independent replication of Lamers and Roelofs' (2011) finding that behavioral measures of trial-by-trial adjustment are driven by congruent trials, not by incongruent trials. While the data from the Lamers and Roelofs study are persuasive, coming as they do from two separate studies employing different performance tasks, additional replications are useful, particularly when a theory as influential as the conflict-adaptation theory is being challenged. Second, we aimed to address whether post-trial alpha power changes could differentiate among neutral, incongruent, and congruent trials. Conflict-driven models of cognitive control predict that both behavior change and EEG indices of mental engagement should be greater following incongruent than neutral trials, which in turn should not differ from congruent trials (as neither involve conflict). Alternatively, a model of congruency-driven cognitive control, such as that articulated by Lamers and Roelofs (2011), predicts that both behavior change and EEG activity should be increased following congruent trials compared to neutral trials, which may not differ from incongruent trials.

Method

Participants

Twenty undergraduates (15 females) participated. One participant was excluded from EEG analysis due to excessive EEG artifact,and another was excluded because ceiling levels of performance precluded the examination of error trials.

Stroop Task

The task was a 6-choice Stroop color identification task, composed of 990 trials divided into 11 blocks, following a 24-trial practice set. Each block consisted of 30 congruent, 30 incongruent, and 30 neutral trials, presented in randomized order. Color words (and font colors) were *red*, *orange*, *yellow*, *green*, *blue*, *purple*, and neutral words were *dog*, *cat*, *mouse*, *bird*, *cow*, *horse*. For incongruent and neutral stimulus sets, each font color was paired with only one word, to parallel the unique color-word pairing on congruent trials (because in congruent trials, there can be no crossing between the word and all possible colors) and to avoid confounds in which unique congruent stimuli would be either repeated more often or presented less frequently than the other trial types. The total stimulus set therefore involved 18 unique stimuli (6 congruent, 6 incongruent, 6 neutral), each presented 5 times within the 90-trial block. Response options were mapped onto the first three fingers of each hand positioned on a computer keyboard. The stimulus word was presented against a black background for 150 ms, followed by a black screen until the participant's response or for a maximum of 2 s, and then a 1,280-ms black-screen interval between the response and the next stimulus. Color and word repetitions on consecutive trials were allowed to occur as a natural consequence of the randomization of trial order, but trials with either color or word repetitions were removed from both performance and EEG data prior to analysis, in order to avoid contamination of the Gratton effect by repetition priming (Hommel et al., 2004; Mayr et al., 2003).

EEG Recording and Analysis

Electrodes were applied using an elastic cap (Quik-Caps) fitted with sintered Ag/AgCl electrodes. Data were recorded continuously from 4 midline scalp sites (Fz, FCz, Cz, Pz) and three pairs of lateral sites (F3/4, C3/4, and P3/4). Signals were amplified by a NuAmps amplifier controlled by Neuroscan software, with a sampling rate of 1,000 Hz and a bandpass of 0.1–40 Hz (-3 dB). Data were referenced online to the left mastoid and digitally rereferenced offline to the average of left and right mastoids. Eye movements were monitored by electrodes placed above and below the left eye and at the outer canthus of each eye. Recordings from these four sites were used to compute bipolar horizontal and vertical electrooculogram (EOG) channels offline.

Artifacts were addressed offline in three steps. First, upon visual inspection, portions of the EEG record with large nonblink artifacts were manually excluded. Second, the effect of blinks was reduced using the Neuroscan software's regression-based algorithm for ocular artifact reduction. Finally, remaining artifacts in the EEG were identified using a $\pm 150\ \mu v$ threshold, and corresponding epochs were excluded.

Power spectra were computed for 256-ms epochs beginning at the button press response and continuing during the ITI. EEG time series were divided into nonoverlapping windows beginning at 0, 256, 512, 768, and 1,024 ms postresponse. Power spectra were obtained for each window using the fast Fourier transform and a cosine windowing method. This procedure yielded time-frequency representations of the ITI with a resolution of 256 ms in the time domain and 4 Hz in the frequency domain. Spectra for each window were then averaged separately for the six trial types (i.e., correct and error trials for congruent, incongruent, neutral types). Statistical analyses were conducted using log-transformed mean power values in the 10–14 Hz frequency band.

Table 1. *Mean (SEM) Reaction Times in ms as a Function of Current and Previous Trial Type*

	Current trial type		
Previous Trial type	Congruent	Incongruent	Neutral
Congruent	514 (18)	670 (32)	523 (26)
Incongruent	531 (26)	636 (29)	538 (31)
Neutral	522 (21)	639 (28)	518 (25)

Results

Performance Data

Reaction times (RTs) were submitted to a 3×3 repeated measures analysis of variance (ANOVA) with the factors current trial type (congruent, incongruent, neutral) and previous trial type (congruent, incongruent, neutral). Trials were included only if both the current trial and the previous trial were correct, to avoid confounds related to post-error slowing. The main effect of current trial type confirmed the well-established Stroop interference effect, $F(2,38) = 87.2$, $p < .0001$. Responses were significantly slower (Bonferroni post hoc, ps $< .001$) on incongruent trials ($M = 648$ ms, $SEM = 29$ ms) compared to congruent ($M = 523$ ms, $SEM = 21$ ms) and neutral trials ($M = 526$ ms, $SEM = 27$ ms), which did not differ.

The interaction of current and previous trial type, $F(4,76) = 4.5$, $p < .005$, indicates that Stroop interference was influenced by the preceding trial type, consistent with a Gratton effect. Means are presented in Table 1. To identify the source of the interaction, we conducted an analysis with Stroop interference (incongruent RT minus congruent RT) as the dependent variable and previous trial type as the repeated measures factor. The effect of previous trial type, $F(2,38) = 5.6$, $p < .01$, was due to greater interference (Bonferroni post hoc, ps $< .05$) following congruent compared to incongruent and neutral trials, which did not differ ($p > .90$). Figure 2 displays the interference effect as a function of previous trial type.

Analysis of accuracy data (proportion correct) found a significant effect of current trial type, $F(2,38) = 15.6$, $p < .001$, consistent with the standard Stroop effect. Accuracy was lower (Bonferroni post hoc, ps $< .02$) on incongruent ($M = 0.87$, $SEM = 0.02$) compared to congruent ($M = 0.92$, $SEM = 0.01$) and neutral trials ($M = 0.93$, $SEM = 0.01$), which did not differ. Previous trial type did not affect accuracy.

EEG Data

Mean alpha power values in the ITI were submitted to a repeated measures ANOVA with accuracy (correct, error), trial type (congruent, incongruent, neutral), epoch (beginning 0, 256, 512, 768, 1,024 ms after response), and site (Fz, FCz, Cz, Pz, F3, F4, C3, C4,

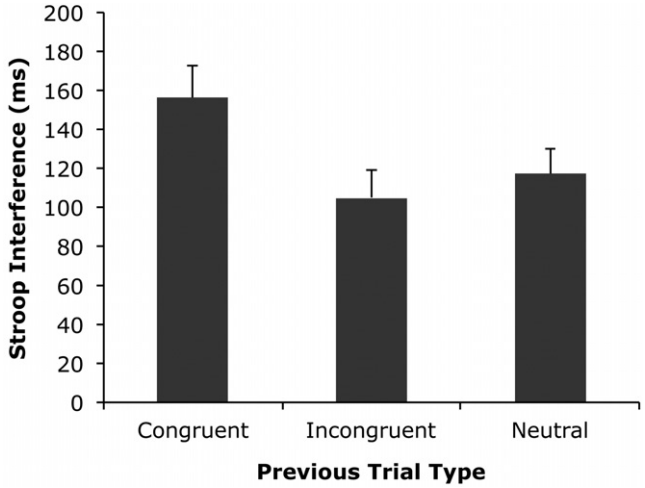

Figure 2. Stroop interference (incongruent trial RT—congruent trial RT) as a function of previous trial type. Error bars represent standard errors of the mean.

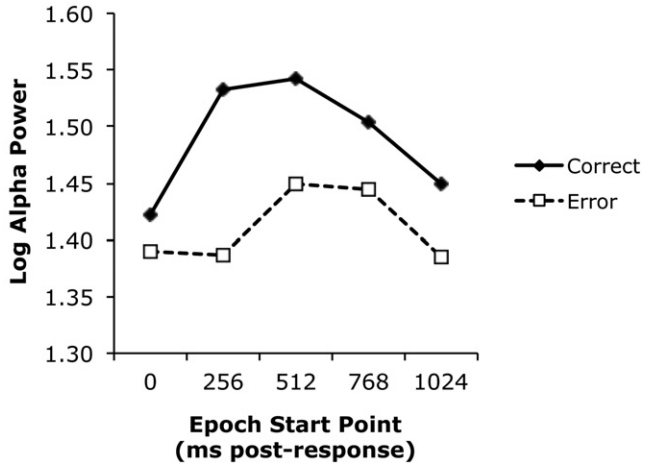

Figure 3. Log alpha power (in μV^2) during the intertrial interval following correct and error responses. Epochs in the intertrial interval are 256 ms long, and time 0 is the time of the response.

P3, P4) as factors. For effects involving site, *p* values were adjusted by the Greenhouse-Geisser method to correct for violations of sphericity.

Results replicated prior findings indicating a curvilinear increase and decrease in alpha power during the ITI that is modulated by response accuracy (Carp & Compton, 2009; Compton et al., 2011). The main effect of epoch, $F(4,68) = 4.8$, $p < .02$; quadratic trend across epoch, $F(1,17) = 16.7$, $p < .001$; main effect of accuracy, $F(1,17) = 14.0$, $p < .002$; and accuracy × epoch interaction, $F(4,68) = 3.7$, $p < .02$, are depicted in Figure 3.

Although the main effect of trial type was not significant ($p > .24$), the trial type × epoch interaction indicated a difference in alpha power across the ITI as a function of trial type, $F(8,136) = 2.1$, $p = .05$. This effect did not further interact with trial accuracy or electrode site. Figure 4 displays the means for the two-way interaction. In the middle segments of the ITI, alpha power peaked at highest levels for neutral trials, followed by incongruent and then congruent trials. Analysis of only the 512-ms and 768-ms epochs, where alpha values peaked, yielded a significant main effect of trial type, $F(2,34) = 4.5$, $p < .03$, that did not interact with epoch ($F < 1$). Least significant difference post hoc tests demonstrated lower alpha power on congruent trials ($M = 1.46\ \mu V^2$) compared to neutral trials ($M = 1.51\ \mu V^2$, $p < .01$), and lower power on congruent trials compared to incongruent trials ($M = 1.49\ \mu V^2$, $p = .059$), whereas incongruent and neutral trials did not differ ($p > .40$).

Two additional effects reflected the regional distribution of alpha power (main effect of site, $F(9,153) = 7.9$, $p < .001$; accuracy × epoch × site, $F(36,612) = 3.3$, $p < .01$) and are described only briefly here because they are not relevant to the main aims of the study. Means presented in Table 2 indicate that alpha values were higher at parietal sites compared to more anterior sites and at midline sites relative to lateral sites. A separate analysis that excluded the FCz site and grouped the remaining nine sites in a 3 × 3 design (anterior/posterior location: frontal, central, parietal; lateral location: left, midline, right) confirmed this pattern statistically. The main effect of anterior/posterior location, $F(2,34) = 9.11$, $p < .005$, was due to significantly higher alpha power at parietal compared to frontal and central sites (*p*s < .05), which did not differ, and the main effect of lateral location, $F(2,34) = 14.78$, $p < .001$, was due to higher alpha power at midline compared to left or right sites (*p*s < .001), which did not differ.

Finally, we conducted parallel analyses on log power values from two neighboring frequency bands that were yielded by the Fourier transform analysis, namely the 6–10 and 14–18 Hz bands. In neither of these analyses were there any significant effects related to trial type, suggesting that the effects were specific to power in the 10–14 Hz band.

Discussion

The purpose of this study was to examine the relative influence of congruent and incongruent trials on trial-by-trial cognitive control adjustments. Performance data confirm the significant Gratton effect that has been widely reported in the literature, namely, greater Stroop interference following congruent compared to incongruent trials (Egner, 2007; Gratton et al., 1992). In addition,

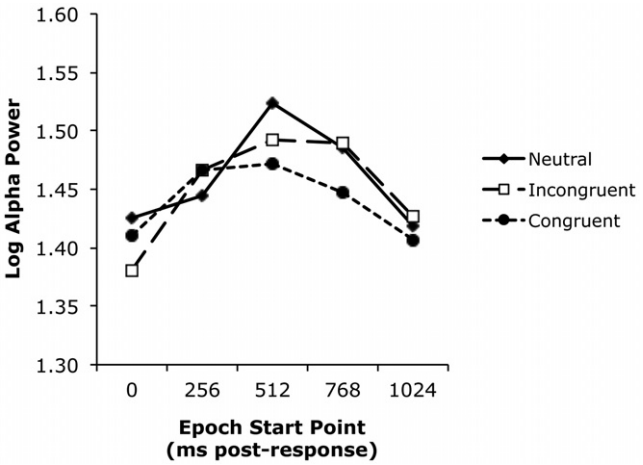

Figure 4. Log alpha power (in μV^2) during the intertrial interval following responses to neutral, incongruent, and congruent trials. Epochs in the intertrial interval are 256 ms long, and time 0 is the time of the response.

Table 2. *Mean Alpha Power (μV^2) as a Function of Accuracy, Epoch, and Electrode Site*

	Epoch (ms postresponse)				
Site	0	256	512	768	1,024
			Correct		
Fz	1.43	1.54	1.55	1.50	1.45
FCz	1.43	1.54	1.56	1.52	1.47
Cz	1.42	1.54	1.55	1.52	1.47
Pz	1.58	1.69	1.66	1.62	1.55
F3	1.35	1.47	1.47	1.43	1.38
F4	1.38	1.48	1.49	1.45	1.39
C3	1.33	1.44	1.47	1.45	1.40
C4	1.33	1.44	1.46	1.44	1.39
P3	1.45	1.57	1.58	1.54	1.48
P4	1.53	1.62	1.62	1.57	1.51
			Error		
Fz	1.43	1.40	1.45	1.43	1.40
FCz	1.47	1.41	1.46	1.44	1.41
Cz	1.43	1.40	1.46	1.46	1.41
Pz	1.46	1.50	1.57	1.60	1.47
F3	1.33	1.34	1.38	1.38	1.33
F4	1.36	1.34	1.39	1.36	1.33
C3	1.34	1.31	1.39	1.38	1.34
C4	1.30	1.28	1.36	1.35	1.31
P3	1.37	1.44	1.48	1.50	1.41
P4	1.41	1.44	1.54	1.55	1.45

replicating Lamers and Roelofs (2011), we found that interference was significantly greater following congruent than neutral trials, whereas interference did not differ following incongruent versus neutral trials. In other words, it was postcongruent behavior, not postincongruent behavior, that differed from a neutral baseline. Likewise, the EEG data indicated that alpha power in the ITI differentiated congruent from neutral trials, but did not differentiate incongruent from neutral trials.

The behavioral results, like those of Lamers and Roelofs (2011), are difficult to reconcile with a conflict-driven model of cognitive control (e.g., Botvinick et al., 2001), because if control adjustments are driven by conflict, greater adjustments should follow incongruent than neutral trials, which contained no response conflict. Although neutral trials in the present study contained semantic information that did not match the color (e.g., the word *dog* in blue font), they clearly do not incorporate response conflict in the way that incongruent trials do. Indeed, responses were faster on neutral than incongruent trials by about 120 ms, as expected given the lack of direct interference by the neutral information. Despite differing robustly in the degree of conflict, incongruent and neutral trials did not differ in their influence on next-trial performance. At the same time, congruent trials produced greater next-trial interference than neutral trials, despite the fact that neither congruent nor neutral trials contain response conflict.

The different levels of Stroop interference between postcongruent and postneutral trials, combined with the similar levels of interference between postincongruent and postneutral trials, raises the intriguing possibility that "conflict adaptation" effects may not be driven primarily by conflict on incongruent trials, but rather by changes that occur following congruent trials. When a participant encounters congruent information (i.e., matching information in the relevant and irrelevant dimensions), attention may be broadened in response to that congruency, and thus irrelevant information is more poorly filtered during the next trial (Gratton et al., 1992; Lamers & Roelofs, 2011).

The interpretation that congruent trials are followed by active processing is supported by the EEG alpha power data. Alpha power displayed a quadratic pattern across the ITI following each of the three trial types, presumably due to phasic mental disengagement between trials. This pattern was significantly reduced for congruent trials, compared to neutral trials, whereas incongruent trials were not statistically distinguishable from neutral trials (and produced marginally greater alpha power, i.e., lesser activation, than congruent trials). This pattern is also difficult to reconcile with conflict-driven models of cognitive control. If the experience of response conflict leads to adaptive changes in attentional filters, then alpha power should be lowest for incongruent trials, indicating the highest level of mental engagement during the ITI, and alpha power should be similar for congruent and neutral trials, which do not involve conflict. The fact that congruent trials elicited the lowest alpha power (greatest activation) implies active mental processing following congruent trials even more so than following incongruent trials.

The alpha power findings for incongruent versus neutral trials stand somewhat in contrast to a prior study (Compton et al., 2011), in which we reported that incongruent trials evoked less postresponse alpha in the ITI than did neutral trials. In the present study, alpha power was lower following incongruent than neutral trials, but the difference was not statistically reliable ($p < .40$). Two differences between the studies may explain this discrepancy. First, the prior study involved a larger sample size, 70 participants compared with 20 in the present study, so the differences may simply result from greater statistical power to detect small differences in the prior study. In addition, the prior study involved a design in which participants viewed neutral, incongruent, and emotional words, whereas in the present design, participants viewed neutral, incongruent, and congruent words. Because attentional adjustments may depend on the composition of the stimulus set, and particularly the ratio of congruent to incongruent trials (e.g., Tzelgov, Henik, & Berger, 1992), it is difficult to directly compare the two studies. Nevertheless, the main conclusion of the present study, that congruent trials were better differentiated from neutral trials than were incongruent trials, is not undermined by the comparison with the prior study, which did not include congruent trials.

The present study was not designed to determine the exact nature of cognitive alterations that follow detection of congruent information. The effect of prior congruency on behavior cannot be explained as an expectation that the next trial will be the same type as the prior one (e.g., Gratton et al., 1992), because in that case one would expect a benefit for incongruent-type repetitions as well as for congruent-type repetitions, which is not evident in the data (see Table 1). Instead, the behavioral data imply that the change involves a broadening of attentional focus following congruent trials, because the consequence of congruency was greater interference from distracting information on the next trial, not slower responses overall. Because trial-by-trial variations in alpha power have been associated with attentional state (e.g., Macdonald, Mathan, & Yeung, 2011), it is reasonable to infer that the alpha power differences between neutral and congruent trials reflect differential attentional engagement. Reduced alpha power could reflect a number of specific processes taking place in the ITI, such as priming of the irrelevant dimension, inhibition of the relevant dimension, or generalized arousal in response to detection of matches between relevant and irrelevant dimensions. Future research using fMRI methods could address the nature of postresponse neural changes with greater regional specificity by examining whether activity in regions representing the irrelevant

or relevant stimulus dimensions is either enhanced or dampened following congruent compared to neutral and incongruent trials (e.g., Egner & Hirsch, 2005; King, Korb, von Cramon, & Ullsperger, 2010).

Although not a major focus of the present study, the EEG data replicated the effect of errors on alpha power in the ITI (cf. Carp & Compton, 2009; Compton et al., 2011). This finding is indirectly relevant to the present aims because it demonstrates that alpha power is responsive to events that signal a need for adaptive control. The effect of trial accuracy on alpha power appeared to be independent of the effect of congruency on alpha power, because the interaction between these factors was not significant. However, because of the small number of errors on congruent and neutral trials, there may not have been enough statistical power to detect any differential effect of errors as a function of trial type. Future research may further investigate the relative independence of post-error alpha power and postcongruent alpha power as part of a broader attempt to understand whether errors and conflict trigger common or independent cognitive changes (e.g., Notebaert & Verguts, 2011).

In sum, both behavioral and EEG data support the conclusion that active processing following congruent trials may play a role in trial-by-trial performance changes in speeded performance tasks. These findings have theoretical significance in implying that conflict may not be the only mechanism triggering trial-by-trial changes in attention. It is sensible for researchers to search for a "conflict detector" in the brain (e.g., Kerns et al., 2004) if detecting conflict is an important step in cognitive control adjustments. If trial-by-trial adjustments are driven instead (or in addition) by congruency, then it may be fruitful to better understand how matches between relevant and irrelevant stimulus dimensions are detected and lead to changes in attention and performance.

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