How long-lasting is the post-conflict slowing after incongruent trials?

Evidence from the Stroop, Simon, and Flanker tasks

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Abstract

The purpose of the present study was to determine how long-lasting the post-conflict slowing following incongruent stimuli is. In previous research, incongruent stimuli have been used to induce a conflict because they have relevant features for two different response alternatives. So far, the post-conflict slowing following incongruent stimuli has mainly been assessed up to one trial. In the first two experiments, we assessed the persistence of this post-conflict slowing across several trials. To this end, we presented a few incongruent stimuli among non-conflict stimuli. The results showed a consistent slowing for the first few trials immediately following the incongruent trials. In addition, a sporadic slowing was still found on later trials. In two subsequent experiments, we investigated to what extend the infrequence of incongruent trials – rather than their conflict – induced this slowing. To determine this, we used the same design as in the first two experiments, but we presented non-conflict stimuli as infrequent stimuli. The results showed a slowing on one trial, ruling out the possibility that the post-conflict slowing following incongruent trials was only caused by infrequence. Together, the findings of the present study indicate that the conflict induced by incongruent trials can have a longer-lasting impact on subsequent trials than previously thought.

Keywords: post-conflict slowing, bivalency effect, conflict adaptation, cognitive control, orienting response

How long-lasting is the post-conflict slowing after incongruent trials?

Evidence from the Stroop, Simon, and Flanker tasks

A current issue in cognitive psychology concerns the cognitive control processes following a conflict. When facing a conflict, cognitive control allows us to select goal-relevant features and inhibiting irrelevant features. Thus, responding to a conflict slows performance. Interestingly, performance is also slowed on subsequent (non-conflict) stimuli (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001; Duthoo, Abrahamse, Braem, Boehler, & Notebaert, 2014; Loft, Kearney, & Remington, 2008; Verguts, Notebaert, Kunde, & Wühr, 2011; Woodward, Meier, Tipper, & Graf, 2003). The purpose of the present study was to determine how long-lasting this "post-conflict slowing" is.

The different kinds of post-conflict slowing

So far, the post-conflict slowing has been investigated when the conflict occurs in the task-switching paradigm, the prospective memory paradigm as well as in the Stroop, Simon and Flanker tasks (see Table 1 for a description of these paradigms and their trials). In the task-switching paradigm, the post-conflict slowing has been called *bivalency effect* (Grundy et al., 2013; Meier, Rey-Mermet, & Rothen, 2015; Meier, Rey-Mermet, Woodward, Müri, & Gutbrod, 2013; Meier, Woodward, Rey-Mermet, & Graf, 2009; Rey-Mermet, Koenig, & Meier, 2013; Rey-Mermet & Meier, 2012a, 2012b, 2013, 2014, 2015; Woodward, Metzak, Meier, & Holroyd, 2008). In the paradigm typically used to investigate this effect, participants are asked to switch during three blocks between three tasks, such as a parity decision (odd vs. even), a color decision (red vs. blue), and a case decision (uppercase vs. lowercase). In the first and third blocks (the pure blocks), all stimuli are univalent (i.e., black numerals for the parity decision, colored symbols for the color decision, and black letters for the case decision). In the second block (the

mixed block), occasionally the letters for the case decisions are printed in red or blue color, which turns them into bivalent stimuli. The bivalency effect is the performance slowing that occurs on all univalent trials following bivalent stimuli, including those sharing no relevant features with bivalent stimuli (i.e., the parity-decision trials). Critically, the bivalency effect has been found to persist across many subsequent trials (Meier et al., 2015, 2013, 2009, Rey-Mermet & Meier, 2013, 2015). Moreover, increasing the interval from 1000 ms to 5000 ms after each task triplet does not affect its magnitude (Meier et al., 2009). Thus, the bivalency effect affects subsequent trials for more than 20 seconds after the occurrence of the conflict (see Meier & Rey-Mermet, 2012a, for a review).

In the prospective memory paradigm (see Table 1), the conflict is triggered by prospective memory targets (Loft et al., 2008; Meier & Rey-Mermet, in press, 2012b). Loft et al. (2008) first revealed the presence of a slowing induced by prospective memory targets. That is, after participants were instructed to perform a prospective memory task, performance was slower on ongoing trials when prospective memory targets were presented compared to when they were not presented. In our study (Meier & Rey-Mermet, 2012b), we specifically investigated the persistence of this slowing. Thus, we used the typical bivalency effect paradigm but we asked participants to press another key (i.e., the key “h” instead of “b” or “n”) when they encountered the targets (i.e., the red or blue letters). The results showed a performance slowing for the first three trials that immediately followed these targets. This slowing lasted up to 6 seconds. Interestingly, we found that ongoing task performance was also slowed on subsequent trials but only for those trials sharing relevant features with the prospective memory targets (Meier & Rey-Mermet, in press, 2012b).

In the Stroop, Simon and Flanker tasks (see Table 1), the conflict is triggered by incongruent trials (Eriksen & Eriksen, 1974; MacLeod, 1991; Simon & Small, 1969; Stroop, 1935). In all three tasks, responding to incongruent trials results in slower and more error-prone performance than responding to congruent trials (Eriksen & Eriksen, 1974; MacLeod, 1991; Simon & Small, 1969; Stroop, 1935). Interestingly, this *congruency effect* is reduced when incongruent trials are presented more frequently than congruent trials, which results in a *proportion congruency effect* (Gratton, Coles, & Donchin, 1992; Hommel, 1994; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982). Moreover, the congruency effect is also reduced after incongruent trials compared to after congruent trials (Duthoo, Abrahamse, Braem, Boehler, et al., 2014; Egner, 2007). This *congruency sequence effect* refers to the combination of two effects: a performance acceleration observed on incongruent trials following incongruent trials, and a performance slowing observed on congruent trials following incongruent trials. Thus, the congruency sequence effect demonstrates that the conflict induced by incongruent stimuli on trial T has an impact on the immediate subsequent performance (i.e., on T+1). Only a few studies have explored the impact on subsequent trials, specifically, on T+2 trials (Akçay & Hazeltine, 2008; Horga et al., 2011; Mayr, Awh, & Laurey, 2003; Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002; Wendt, Kluwe, & Peters, 2006). The main goal of these studies was to determine whether an incongruent trial could reduce the congruency effect on trial T+2. The results were mixed. Some studies found no impact on T+2 (see Stürmer et al., 2002, Experiment 3; Wendt et al., 2006, Experiments 1 and 2a), while others did (Akçay & Hazeltine, 2008, Experiment 2; Mayr et al., 2003, Experiment 2; Wendt et al., 2006, Experiment 3). However, these studies focused on the performance acceleration on incongruent trials following incongruent trials.

Only two studies have focused on the post-conflict slowing following incongruent trials (Rey-Mermet & Meier, 2016; Verguts et al., 2011) [1]. The first study focused on the immediate subsequent trial (Verguts et al., 2011), and showed a post-conflict slowing on this trial only if it had one common feature with the incongruent trials (i.e., in our terminology, if this trial was neutral). If this subsequent trial had several features in common with the incongruent trials (e.g., if it was congruent or incongruent), no post-conflict slowing was found. This was explained by assuming that a post-focusing process (i.e., an increased attention to the relevant response feature) masks the post-conflict slowing. In our study (Rey-Mermet & Meier, 2016), the post-conflict slowing was assessed across several trials. The goal of that study was to determine whether this slowing could generalize to trials sharing no relevant features with the conflict (i.e., univalent trials). To this end, we asked participants to switch between a task including occasionally the incongruent trials (e.g., the Stroop, Simon or Flanker task) and a task sharing no relevant features with the conflict (i.e., a digit classification with univalent trials). The results revealed an initial performance slowing that affected both tasks after incongruent trials. This slowing affected 12 trials. On further trials, however, the slowing mainly affected the task sharing features with the conflict stimuli.

The different explanations underlying the post-conflict slowing

To explain the different kinds of post-conflict slowing, different explanations have been put forward. For example, we accounted for the post-conflict slowing following bivalent and incongruent trials by proposing an episodic context binding explanation (Meier & Rey-Mermet, 2012a; Meier et al., 2013, 2009, Rey-Mermet & Meier, 2015, 2016). According to this account, responding to a particular trial results in a memory representation that is bound to the proximate context (e.g., the particular task sequence of parity, color and case decisions in the case of

bivalent stimuli). This context is retrieved and updated each time a task is performed. When a conflict stimulus occurs within a task sequence, the whole context becomes conflict-loaded and thus on subsequent trials, the retrieval of this representation causes interference. As the representation included the whole task sequence, performance is generally slowed for several subsequent trials, which results in a long-lasting and task-unspecific post-conflict slowing.

In contrast, the post-conflict slowing following the prospective memory targets have been explained with two further accounts. That is, the performance slowing occurring on the first three trials immediately following the targets was interpreted as an orienting response effect (Meier & Rey-Mermet, 2012b). According to this account (cf. Notebaert et al., 2009; Notebaert & Verguts, 2011; Núñez Castellar, Kühn, Fias, & Notebaert, 2010), infrequent stimuli capture attention and it takes some time to re-direct attention to the task to be performed, which slows performance on subsequent trials. As prospective memory targets are infrequent events, this means that they capture attention and re-direct it away from the ongoing task. Thus, when the ongoing task has to be performed again, it takes some time to re-direct attention to it, which results in a performance slowing for the first few trials following the prospective memory targets.

The later post-conflict slowing occurring only on those trials sharing shared features with the prospective memory targets was interpreted as the result of the prospective memory response (Meier & Rey-Mermet, 2012b). More precisely, as prospective memory targets require a different response than the ongoing tasks (e.g., the key “h”), responding to the prospective memory task strengthens the association between the (unusual) prospective memory response and the ongoing tasks with overlapping features with the targets. On subsequent ongoing task trials, the reactivation of the prospective memory response may interfere with the activation of the ongoing task response, which results in a performance slowing for the tasks with overlapping

features (see Metzker & Dreisbach, 2009). This later post-conflict slowing cannot, however, be accounted by an expectancy-based monitoring explanation. According to such an account (e.g., Meier, Zimmermann, & Perrig, 2006; Smith, 2003), monitoring for further prospective memory targets would steadily increase across trials and this monitoring process would result in an increase of the slowing across trials. However, the results showed a decline of the post-conflict slowing across trials (see also Meier & Rey-Mermet, in press).

Different or same kind(s) of post-conflict slowing?

This overview reveals that the post-conflict slowing can persist across several trials, and its trajectory and the underlying processes differs only if the conflict is induced by prospective memory targets. At first sight, the post-conflict slowing following bivalent and incongruent trials did not seem to differ. However, this hypothesis might be questioned by at least two arguments. First, in the few studies in which the bivalency effect was compared after incongruent and congruent bivalent stimuli (as bivalent stimuli can be either incongruent or congruent, see Table 1), the results were inconclusive (see Grundy & Shedden, 2014a; Rey-Mermet & Meier, 2014, for behavioral studies; and see Grundy & Shedden, 2014b, for an EEG study). Grundy and colleagues found a larger post-conflict slowing after incongruent bivalent stimuli than after congruent bivalent stimuli, whereas we found no difference. This discrepancy might stem from the fact that Grundy and colleagues did not inform participants about the occurrence of bivalent stimuli (see Grundy & Shedden, 2014b, for an exception), while we did. Furthermore, Grundy and colleagues presented bivalent stimuli randomly, while we presented them regularly. Therefore, it is possible that the design used by Grundy and colleagues results in some uncertainty about which task to perform when incongruent bivalent trials were encountered (see Kray & Lindenberger, 2000; Metzak, Meier, Graf, & Woodward, 2013), and this uncertainty

would persist across several trials, thus resulting in a larger post-conflict slowing after incongruent bivalent trials. In contrast, in our study, such task uncertainly was highly improbable because bivalent stimuli occurred regularly and participants were instructed which task to perform on bivalent stimuli. In any case, it remains unclear whether the post-conflict slowing following bivalent (congruent) stimuli differs from the post-conflict slowing following (bivalent) incongruent trials.

A second reason to question the hypothesis of similar post-conflict slowing after bivalent and incongruent trials is that in all studies investigating the post-conflict slowing following incongruent trials (Grundy & Shedden, 2014a, 2014b; Rey-Mermet & Meier, 2016; Verguts et al., 2011), participants switched between at least two tasks. Although a task-switching paradigm is necessary to create bivalent stimuli, it is not the case for incongruent trials. Thus, using a task-switching design for both bivalent and incongruent trials might have promoted the similarities between both kinds of post-conflict slowing. Moreover, the results of Verguts et al. (2011) emphasize the importance of considering under which conditions the post-conflict slowing is investigated. The purpose of the present study was thus to investigate the trajectory of the post-conflict slowing following incongruent trials in a more “natural” paradigm for incongruent trials, that is, when no task switching is required. This is important because it might inform us about the unity or diversity of cognitive control processes. Thus, if no task-switching design is used but the post-conflict slowing following incongruent trials is as long-lasting as the post-conflict slowing following bivalent stimuli, this would suggest similar cognitive processes underlying both kinds of post-conflict slowing (e.g., the episodic context binding). In this case, this would challenge research in which different sources of conflict were found to induce different kinds of

cognitive control processes (see Braem, Abrahamse, Duthoo, & Notebaert, 2014; Egner, 2008, for reviews).

In the present study, we conducted four experiments (see Table 2, left part, for an overview of the manipulations). In Experiments 1 and 2, we investigated how long-lasting the post-conflict slowing following incongruent trials is. To this end, we occasionally presented incongruent trials among non-conflict stimuli (i.e., congruent trials in Experiment 1 and neutral trials in Experiment 2). In Experiments 3 and 4, we determined whether the slowing following incongruent trials results from their infrequence rather than their conflict. To this end, we examined to what extent infrequent (non-conflict) stimuli result in a slowing on subsequent trials. In Experiment 3, we thus reversed the ratio of incongruent and congruent trials used in Experiment 1 by occasionally presenting congruent trials among incongruent trials. In Experiment 4, we occasionally presented neutrals among congruent trials. In each experiment, we investigated the persistence of the slowing following conflict or infrequent stimuli by determining the trajectory of the performance slowing across the subsequent trials that immediately followed.

Experiment 1

The goal of Experiment 1 was to determine how long-lasting the post-conflict slowing following incongruent trials is. To this end, we asked our participants to perform either a Stroop, a Simon or a Flanker task during three blocks. In the first and third blocks, only congruent stimuli were presented; in the second block, incongruent stimuli appeared occasionally. In addition, we manipulated the interval between sequences of four trials so that the interval was 1000 ms for half of the participants and 2000 ms for the other half. Previous research has revealed that the post-conflict slowing following bivalent stimuli persists across time (see Meier

et al., 2009; Rey-Mermet & Meier, 2013). However, it might not be the case for the post-conflict slowing following incongruent trials as the congruency sequence effect diminished across time (Duthoo, Abrahamse, Braem, & Notebaert, 2014; Egner, Ely, & Grinband, 2010). Thus, increasing the interval from 1000 ms to 2000 ms after incongruent trials allowed us to examine whether the post-conflict slowing following incongruent trials persists across time in addition to across trials.

In the present experiment, we thus manipulated two variables within-subject (*block* and *trial*) and two variables (*task* and *interval*) between-subjects.[2] The variable *block* takes into account the three blocks (block 1, block 2, and block 3). The variable *trial* takes into account the number of trials following an incongruent stimulus (i.e., T+1, T+2, etc. with T referring to the trial containing an incongruent stimulus). The variable *task* takes into account the three different tasks (i.e., Stroop, Simon and Flanker). The variable *interval* takes into account the two different intervals between the sequences of four trials (i.e., 1000 ms or 2000 ms).

We hypothesized that if the task-switching paradigm is not relevant for the persistence of the post-conflict slowing following incongruent trials (Rey-Mermet & Meier, 2016), the post-conflict slowing would be in the present study as long-lasting as the bivalency effect (Meier et al., 2009; Rey-Mermet & Meier, 2013). In this case, performance after incongruent trials would be slowed across several trials. However, it is also possible that the post-conflict slowing would be masked because congruent trials were used as baseline (see Verguts et al., 2011). In this case, no slowing would be expected after incongruent trials.

Method

Participants. Participants were 156 volunteers (26 in each between-subjects condition) from the University of Bern. Overall, we replaced nine participants (five participants because of

an accuracy level on incongruent trials less than 50%, two because of a technical error, and two because they did not follow task instructions). Demographic characteristics of the sample are described in Table 2 (right part). The study was approved by the local ethics committee of the University of Bern, and all participants gave written consent.

Materials. In the following section, the stimuli for each task are presented. An overview of the manipulation is also presented in Table 2 (left part).

Stroop task. For the Stroop task, participants performed a color decision on color words. The congruent stimuli were the four German words blue, red, green, and yellow (i.e., “blau”, “rot”, “grün”, and “gelb”), displayed in blue, red, green, and yellow, respectively. Incongruent stimuli were stimuli in which the color words were printed in a non-corresponding color (e.g., the color word “red” printed in blue). For each participant, six incongruent stimuli were determined randomly and without replacement. All stimuli were presented on a grey background at the center of the computer screen in 60-point Times New Roman. Participants used four response keys (*v*, *b*, *n*, *m*) with their left and right index and middle fingers. These response keys were mapped to the colors blue, red, green, and yellow, respectively.

Simon task. For the Simon task, participants performed a color decision on symbols. The symbols were $, #, §, %, displayed either in blue, red, green, or yellow. All stimuli were presented on a grey background in 60-point Times New Roman in one of the four corners of a centered, non-displayed 4 cm x 4 cm square. Participants used four response keys (*g*, *b*, *n*, *j*) with their left and right index and middle fingers. These response keys were mapped to the colors blue, red, green, and yellow, respectively. Stimuli were congruent when the position of the symbol on the computer screen corresponds to the location of the response key required by the color decision. In contrast, they were incongruent when the position of the symbol on the

computer screen does not correspond to the location of the relevant response key. For each participant, six incongruent stimuli were determined randomly and without replacement.

Flanker task. For the Flanker task, participants performed letter identification on letter triplicates. The congruent stimuli were the four letters H, P, R, and S, displayed as triplicates with the same letters (e.g., HHH). Incongruent stimuli were the same four letters, but the central letter was different from the flanking letters (e.g., SHS). For each participant, six incongruent stimuli were determined randomly and without replacement. All stimuli were presented on a grey background in 60-point Times New Roman at the center of computer screen. Participants used four response keys (v, b, n, m) with their left and right index and middle fingers. These response keys were mapped to the letters H, P, R, and S, respectively.

Procedure. In each experiment, participants were tested individually. Participants were instructed to perform a color decision on color words for the Stroop task, a color decision on symbols for the Simon task, and a letter decision on letter triplicates for the Flanker task. Participants were instructed to press one of the four computer keys with their index and middle fingers of their left and right hands for each task. The mapping information, printed on paper, was presented below the computer screen throughout the experiment. For the Stroop task, participants were informed that occasionally, the color word would not correspond to the color in which it was printed (e.g., the word “red” printed in blue), and that they had to proceed as usual by responding to the color of the color word. For the Simon task, they were informed that occasionally, the position of the stimulus would not correspond to the location of the response key (e.g., a red symbol requiring a lower left key press, but presented on the upper right corner), and that they had to proceed as usual by responding to the color of the symbol. For the Flanker

task, they were informed that occasionally, the central letter would not correspond to the flanking letters (e.g., HSH), and that they had to proceed as usual by responding to the central letter.

After the instructions, a block of 120 congruent trials was presented for practice. The stimulus for each trial was determined pseudo-randomly so that neither the task-relevant stimulus feature nor the task-irrelevant stimulus feature repeated. The stimulus was displayed until the participant responded. Then, the screen blanked for 500 ms before the next stimulus appeared. After every four trials, an additional blank interval of 500 or 1500 ms was included so that the screen blanked for 1000 ms in half of participants, and for 2000 ms in the other half. A sequence of four trials for each task (Stroop, Simon, and Flanker) is illustrated in Figure 1. After the practice block and a brief break, each participant completed three experimental blocks without break between blocks. The first block included 128 trials, with the first eight trials serving as “warm-up” trials which were discarded from the analyses. The second and third blocks had 120 trials each.

In the first and third block, only congruent stimuli were presented. In the second block, stimuli were congruent except on six trials in which incongruent stimuli appeared. Incongruent stimuli were always displayed on the fourth position of a four-trial sequence and they were evenly interspersed among the 120 trials of the block. Thus, they occurred in every 20th trial, specifically in the 12th, 32nd, 52nd, 72nd, 92nd, and 112th trial. The entire experiment lasted about 15 minutes.

Data preparation and analysis. For each participant in each experiment, the accuracy rates and the median reaction times (RTs) were computed for each trial following an incongruent stimulus in block 2 and for each corresponding trial in the blocks 1 and 3. Specifically, an incongruent stimulus was presented on every 20th trial in block 2, and this trial was designated

with the label T, with succeeding trials labelled T+1, T+2, and so on until T+19. Trials from blocks 1 and 3 were labelled accordingly. To remove any confound with error and post-error slowing (e.g., Carter & Veen, 2007; Kleiter & Schwarzenbacher, 1989; Notebaert et al., 2009), median RTs were computed on correct responses whose immediate preceding trial and incongruent trial also involved a correct response.

To ensure that participants were slower and less correct on incongruent trials than on congruent trials, we first compared performance on Trials T from block 2 (i.e., the incongruent trials) with performance on Trials T from blocks 1 and 3 (i.e., the corresponding congruent trials). To this end, we conducted a three-way analysis of variance (ANOVA) with block (block 1, block 2, block 3) as a within-subject factor, and task (Stroop, Simon, Flanker) and interval (1000 ms, 2000 ms) as between-subjects factors.

The main objective of the present experiment was to determine the trajectory of the post-conflict slowing following incongruent trials. Thus, we assessed whether performance in block 2 following incongruent trials is slower than performance in blocks 1 and 3. To this end, we carried out a four-way ANOVA with block (block 1, block 2, block 3) and trial (T+1 until T+19) as within-subject factors, and task (Stroop, Simon, Flanker) and interval (1000 ms, 2000 ms) as between-subjects factors. We then disentangled the critical interaction by performing follow-up two-way repeated-measures ANOVAs for each task, with the factors block (block 1, block 2, block 3) and trial (T+1 until T+19). Finally, to assess the performance difference between the different blocks, we conducted follow-up one-way repeated-measures ANOVA with the factor block (block 1, block 2, block 3). In these one-way ANOVAs, we focused on the quadratic component of the block effect because this is informative about a difference in block 2 compared to blocks 1 and 3.[3]

Means and standard errors for each task and time interval are presented for RTs and accuracy in the Table A1 of the Supplementary Material. As our focus was mainly on RT data, and accuracy was close to ceiling (98%), accuracy data is referred to only when diverging from RT data. We used an alpha level of 0.05, which was Bonferroni adjusted for multiple comparisons. Greenhouse-Geisser corrections are reported where appropriate and effect sizes are expressed as partial η_p^2 values.

Results

Performance on Trial T. The three-way ANOVA across blocks, tasks, and intervals is shown in Table 3, separately for RT and accuracy. Performance on Trial T is presented in Table 4. Most importantly, the RT analysis revealed a significant main effect of block, with a significant quadratic component, $F(1, 155) = 405.81$, $p < .001$, $\eta_p^2 = .72$. Thus, as expected, performance was slower on incongruent trials from block 2 than on the corresponding congruent trials from blocks 1 and 3 (see Table 4). For accuracy, the three-way ANOVA revealed a significant interaction between block and task. The follow-up quadratic components revealed that responses were less accurate in incongruent trials from block 2 than in the corresponding congruent trials from blocks 1 and 3 for the Stroop and Simon tasks, $F(1, 51) = 14.02$, $p < .001$, $\eta_p^2 = .22$, and $F(1, 51) = 88.40$, $p < .001$, $\eta_p^2 = .63$, respectively, but not for the Flanker task, $F(1, 51) = 0$, $p = 1$, $\eta_p^2 = 0$. Thus, for accuracy, the difference between incongruent and congruent trials was significant for the Stroop and Simon tasks only (see Table 4).

Impact of incongruent trials on subsequent congruent trials. The most relevant results are the RTs from the congruent trials in block 2 compared to those in blocks 1 and 3. These results are depicted in Figure 2. The results of the four-way ANOVA are shown in Table 5. Critically, the RT analysis revealed a significant main effect of block and significant interactions

between block and trial as well as between block, trial, and task. Thus, performance was slowed after incongruent trials in block 2 compared to blocks 1 and 3, and this slowing changed across subsequent congruent trials (see Figure 2). Moreover, this change differed across tasks.

To investigate this change more thoroughly, we performed additional two-way ANOVAs for each task separately, with block and trial as within-subject factors. These revealed a significant interaction between block and trial for all tasks (i.e., the Stroop task: $F(8.46, 431.42) = 2.91$, $p = .003$, $\eta_p^2 = .05$; the Simon task: $F(16.08, 819.95) = 2.86$, $p < .001$, $\eta_p^2 = .05$; and the Flanker task: $F(15.70, 800.81) = 2.77$, $p < .001$, $\eta_p^2 = .05$). The follow-up relevant quadratic components are shown in Table 6 for each trial and each task. They revealed that first, performance was slowed on the first two and three trials immediately following incongruent trials and then, the performance slowing became more sporadic, affecting only some of the trials. This later and more sporadic slowing affected more subsequent trials in the Simon and Flanker tasks than in the Stroop task. However, the post-conflict slowing was longer-lasting for the Stroop task than for the Simon and Flanker tasks because it came back at T+16 in the Stroop task but not the Simon or flanker tasks (in these tasks, it only came back at T+12).

Table 5 also shows that the interaction between block and interval was significant. Follow-up one-way repeated-measures ANOVA with the factor block (block 1, block 2, block 3) revealed a significant main effect of block with a significant quadratic component for both intervals (1000 ms interval: main effect, $F(2, 154) = 35.55$, $p < .001$, $\eta_p^2 = .32$, and quadratic component, $F(1, 77) = 70.43$, $p < .001$, $\eta_p^2 = .48$; as well as 2000 ms interval: main effect, $F(1.69, 129.86) = 9.37$, $p < .001$, $\eta_p^2 = .11$, and quadratic component, $F(1, 77) = 20.34$, $p < .001$, $\eta_p^2 = .21$). Thus, the performance slowing was found in both intervals, but it was larger in the 1000 ms interval (block 1: $M = 616$ ms, $SE = 13$; block 2: $M = 661$ ms, $SE = 12$; block 3: $M =$

627 ms, *SE* = 11) than in the 2000 interval (block 1: *M* = 634 ms, *SE* = 16; block 2: *M* = 654 ms, *SE* = 13; block 3: *M* = 620 ms, *SE* = 12).

Discussion

The results of Experiment 1 showed a performance slowing for the first few trials immediately following incongruent trials. This slowing occurred in all three tasks. It lasted circa 5 seconds (i.e., required for making up to the 3rd trial, i.e., 3 decisions, each requiring approximately 650 ms, plus 2 blanks of 500 ms, plus 1 blank of 2000 ms). The results also showed a more sporadic performance slowing on later trials. This later and more sporadic slowing affected more trials in the Simon and Flanker tasks than in the Stroop task. However, it was longer-lasting for the Stroop task than for the Simon and Flanker tasks. Therefore, the present findings indicate that when participants are not required to switch between at least two tasks, the post-conflict slowing following incongruent trials persists across trials, but is not as long-lasting as the post-conflict slowing following bivalent stimuli (Meier et al., 2009; Rey-Mermet & Meier, 2013, 2016).

In Experiment 1, the post-conflict slowing was investigated on congruent trials. However, this might not be optimal to find a long-lasting post-conflict slowing following incongruent trials because congruent trials could invoke a post-focusing process, which might mask the post-conflict slowing (Verguts et al., 2011). To test this possibility, we conducted a second experiment (i.e., Experiment 2) in which the post-conflict slowing was examined on neutral trials, that is, on trials on which no post-focusing process could occur. Therefore, we used the same design as Experiment 1 but we occasionally presented incongruent trials among neutral trials. As increasing the interval from 1000 ms to 2000 ms after incongruent did not affect the trajectory of the post-conflict slowing in Experiment 1, we removed this manipulation from the

design of Experiment 2. Here, we expected to find a longer-lasting post-conflict slowing following incongruent trials if the post-conflict slowing observed in Experiment 1 was masked on some congruent trials (Verguts et al., 2011).

Experiment 2

Method

Participants. Participants were 78 volunteers (26 in each task) from the University of Bern. We replaced two participants because of an accuracy level on incongruent trials less than 50%. Demographic characteristics of the sample are described in Table 2 (right part).

Materials. The material was the same as in Experiment 1, except that instead of congruent stimuli, neutral stimuli were presented. That is, for the Stroop task, the neutral stimuli were the symbols $$$, ###, §§§, and %%%, displayed in blue, yellow, red, and green, respectively. For the Simon task, the neutral stimuli were the symbols $, #, §, and % displayed centrally. For the Flanker task, the neutral stimuli were the four triplicates <H>, §P§, %R%, and +S+.

Procedure. The procedure was the same as in Experiment 1, except that there was only one interval (1000 ms).

Data preparation and analysis. The data preparation and data analysis were the same as in Experiment 1, except for the following modifications. First, performance on Trial T was investigated with a two-way ANOVA with block (block 1, block 2, block 3) as a within-subject factor, and task (Stroop, Simon, Flanker) as a between-subjects factor. Second, the trajectory of the post-conflict slowing was assessed with a three-way ANOVA with block (block 1, block 2, block 3) and trial (T+1 until T+19) as within-subject factors, and task (Stroop, Simon, Flanker) as a between-subjects factor.

Results

Performance on Trial T. The two-way ANOVA across blocks and tasks is shown in Table 3. Performance on Trial T is presented in Table 4. Most importantly, the RT analysis revealed a significant interaction between block and task. The follow-up quadratic components revealed that responses were slower in incongruent trials from block 2 than in the corresponding neutral trials from blocks 1 and 3 in all three tasks (Stroop task: $F(1, 25) = 91.50$, $p < .001$, $\eta_p^2 = .78$; Simon task: $F(1, 25) = 65.03$, $p < .001$, $\eta_p^2 = .72$; Flanker task, $F(1, 25) = 68.81$, $p < .001$, $\eta_p^2 = .73$. Thus, for RTs, the difference between incongruent and neutral trials was larger for the Stroop and Flanker tasks than for the Simon task (see Table 4). For accuracy, the three-way ANOVA revealed a significant main effect of block, with a significant quadratic component, $F(1, 77) = 8.95$, $p = .004$, $\eta_p^2 = .10$. Thus, as expected, performance was less correct on incongruent trials from block 2 than on the corresponding neutral trials from blocks 1 and 3 (see Table 4).

Impact of incongruent trials on subsequent neutral trials. The most relevant results are the RTs from the neutral trials in block 2 compared to those in blocks 1 and 3. These results are depicted in Figure 3. For accuracy, the descriptive results are presented in the Table A2 of the Supplementary Material. The results of the three-way ANOVA are shown in Table 7. Critically, the RT analysis revealed a significant main effect of block and a significant interaction between block and trial. Thus, performance was slowed after incongruent trials in block 2 compared to blocks 1 and 3, and this slowing changed across subsequent neutral trials (see Figure 3).

To investigate this change more thoroughly, we focused as in Experiment 1 on the follow-up relevant quadratic components. These are shown in Table 8 for each trial. They

revealed that first, performance was slowed on the first three trials immediately following incongruent trials and then, the performance slowing became more sporadic, affecting only some of the trials.

Discussion

The results of Experiment 2 replicate the findings of the first experiment by showing a performance slowing for the first few trials immediately following incongruent trials. It lasted circa 4 seconds (i.e., required for making up to the 3rd trial, i.e., 3 decisions, each requiring approximately 660 ms, plus 2 blanks of 500 ms, plus 1 blank of 1000 ms). The results also showed a performance slowing on later trials. In contrast to Experiment 1, however, the trajectory of the post-conflict slowing did not differ across the three tasks. Together, the results of Experiment 2 indicate that no post-focusing process masks the post-conflict slowing in Experiment 1 (cf. Verguts et al., 2011). More generally, these findings emphasize that even if the post-conflict slowing following incongruent trials was not as long-lasting as the post-conflict slowing following bivalent stimuli (e.g., Meier et al., 2009; Rey-Mermet & Meier, 2013), this post-conflict slowing clearly affected more than one trial.

However, occasionally presenting incongruent trials among congruent trials (Experiment 1) or neutral trials (Experiment 2) has the disadvantage that incongruent trials are not only conflict stimuli but also infrequent events. Therefore, it is possible that the slowing following incongruent trials in Experiments 1 and 2 was not caused by the conflict induced by incongruent trials, but rather by their infrequence (Notebaert et al., 2009; Notebaert & Verguts, 2011; Núñez Castellar et al., 2010; Rey-Mermet & Meier, 2013). To test this possibility, we conducted Experiment 3 in which we reversed the ratio of incongruent and congruent trials of Experiment 1. That is, we used the same design as Experiment 1 but we occasionally presented congruent

trials among incongruent trials. We hypothesized that if the post-conflict slowing following incongruent trials was only caused by the infrequence of incongruent trials (Notebaert & Verguts, 2011; Rey-Mermet & Meier, 2013), infrequent congruent trials would result in a similar performance slowing as the one observed in Experiments 1 and 2.

Experiment 3

Method

Participants. Participants were 78 volunteers (26 in each task) from the University of Bern. Demographic characteristics of the sample are described in Table 2 (right part).

Materials. The material was the same as in Experiment 1.

Procedure. The procedure was the same as in Experiment 1 except for the following two modifications. First, only incongruent stimuli were presented in the first and third blocks. In the second block, stimuli were incongruent except on six trials in which congruent stimuli appeared. Second, there was only one interval (1000 ms).

Data preparation and analysis. The data preparation and data analysis were the same as in Experiment 2.

Results

Performance on Trial T. The two-way ANOVA across blocks and tasks is shown in Table 3. Performance on Trial T is presented in Table 4. Most importantly, the RT analysis revealed a significant interaction between block and task. The follow-up quadratic components revealed that responses were significantly slower in incongruent trials from blocks 1 and 3 than in the corresponding congruent trials from block 2 in the Simon task only (see Table 4), $F(1, 25) = 26.88$, $p < .001$, $\eta_p^2 = .52$. The difference between incongruent and congruent trials were not significant for the Stroop and Flanker tasks (Stroop task: $F(1, 25) = 6.29$, $p = .019$, $\eta_p^2 = .20$; and

Flanker task, $F(1, 25) = 4.71$, $p = .040$, $\eta_p^2 = .16$, with the alpha level of 0.05 being Bonferroni adjusted to 0.017). For accuracy, the three-way ANOVA revealed a significant main effect of block, with a significant quadratic component, $F(1, 77) = 6.80$, $p = .011$, $\eta_p^2 = .08$. Thus, in all three tasks, performance was less correct on incongruent trials from blocks 1 and 3 than on the corresponding congruent trials from block 2 (see Table 4).

Impact of congruent trials on subsequent incongruent trials. The most relevant results are the RTs from the incongruent trials in block 2 compared to those in blocks 1 and 3. These results are depicted in Figure 4. For accuracy, the descriptive results are presented in the Table A3 of the Supplementary Material. The results of the three-way ANOVA are shown in Table 9. Critically, the RT analysis revealed a significant main effect of block and a significant interaction between block and trial. The follow-up quadratic components of the block effect are shown in Table 10. These revealed that performance was slowed only on the 12th trial following congruent trials.

Discussion

The results of Experiment 3 showed a performance slowing only on the 12th trial following congruent trials, probably induced by some kind of expectancy-based monitoring process. These findings are not compatible with a conservative version of an expectancy-based monitoring account (e.g., Meier et al., 2006; Smith, 2003) because according to such an account, participants would monitor for infrequent events so that the monitoring process would steadily increase across trials and thus result in an increase of the slowing across trials. Nevertheless, it seems plausible that participants anticipated the infrequent events on the 12th trial, thus directing their attention away from the trial processing and slowing down their performance. But why did they anticipate specifically on the 12th trial? As trials were presented in sequence of four and

infrequent events were presented on the fourth position of this sequence, this could have emphasized this position. Moreover, participants should have realized that the infrequent events did not occur every four trials, but with a larger extent so that they expected infrequent events on the 12th trial. Thus, according to this explanation, participants did not steadily monitor for the occurrence of incongruent trials, but rather anticipated them specifically due to the design of the experiment.

More generally, the findings of Experiment 3 showed that the slowing following infrequent congruent trials is different from the post-conflict we observed in Experiments 1 and 2. This suggests that the conflict, but not the infrequence of incongruent trials, is responsible for the post-conflict slowing. However, in Experiment 3, it is possible that because incongruent trials were presented more frequently than congruent trials, more control processes were overall engaged. This could have reduced the slowing observed in this experiment, similar to a proportion congruency effect (Gratton et al., 1992; Hommel, 1994; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982). Thus, the design of Experiment 2 might be suboptimal to find the impact of infrequent events on subsequent trials. To ensure that the post-conflict slowing results from the conflict induced by incongruent trials, we conducted a fourth experiment. In this experiment, most trials were congruent, and infrequent (non-conflict) events were neutral trials. As for Experiment 3, we expected that if the post-conflict slowing following incongruent trials was only caused by the infrequence of incongruent trials (Notebaert & Verguts, 2011; Rey-Mermet & Meier, 2013), infrequent neutral trials would result in a similar performance slowing as the slowing observed in the first two experiments.

Experiment 4

Method

Participants. Participants were 78 volunteers (26 in each task) from the University of Bern. We replaced one participant because of an accuracy level on neutral trials less than 50%. Demographic characteristics of the sample are described in Table 2 (right part).

Materials. The material was the same as in Experiment 2.

Procedure. The procedure was the same as in Experiment 1 except for the following two modifications. First, only congruent stimuli were presented in the first and third blocks. In the second block, stimuli were congruent except on six trials in which neutral stimuli appeared. Second, there was only one interval (1000 ms).

Data preparation and analysis. The data preparation and data analysis were the same as in Experiment 2.

Results

Performance on Trial T. The two-way ANOVA across blocks and tasks is shown in Table 3. Performance on Trial T is presented in Table 4. Most importantly, the RT analysis revealed a significant interaction between block and task. The follow-up quadratic components showed that responses were slower in neutral trials from block 2 than in the corresponding congruent trials from blocks 1 and 3 in all three tasks (Stroop task: $F(1, 25) = 97.59$, $p < .001$, $\eta_p^2 = .80$; Simon task: $F(1, 25) = 118.92$, $p < .001$, $\eta_p^2 = .83$; and Flanker task, $F(1, 25) = 71.27$, $p < .001$, $\eta_p^2 = .74$). This difference was, however, larger for the Simon task than for the Stroop and Flanker tasks (see Table 4).

For accuracy, the three-way ANOVA also revealed a significant interaction between block and task. The follow-up quadratic components revealed that responses were significantly less correct in neutral trials from block 2 than in the corresponding congruent trials from blocks 1 and 3 in the Simon task (see Table 4), $F(1, 25) = 14.14$, $p = .001$, $\eta_p^2 = .36$. The difference

between neutral and congruent trials, was, however, not significant for the Stroop and Flanker tasks (Stroop task: $F(1, 25) = 2.00$, $p = .170$, $\eta_p^2 = .07$; and Flanker task, $F(1, 25) = 0$, $p = 1$, $\eta_p^2 < .001$).

Impact of neutral trials on subsequent congruent trials. The most relevant results are the RTs from the congruent trials in block 2 compared to those in blocks 1 and 3. These results are depicted in Figure 5. For accuracy, the descriptive results are presented in the Table A4 of the Supplementary Material. The results of the three-way ANOVA are shown in Table 11. Critically, the RT analysis revealed a significant main effect of block and significant interactions between block and trial as well as between block, trial and task. Thus, performance was slowed after infrequent neutral trials in block 2 compared to blocks 1 and 3, and this slowing changed across subsequent congruent trials (see Figure 5). Moreover, this change differed across tasks.

To investigate this change more thoroughly, we performed additional two-way ANOVAs for each task separately, with block and trial as within-subject factors. These ANOVAs revealed a significant interaction between block and trial for the Stroop task, $F(36, 900) = 1.63$, $p = .012$, $\eta_p^2 = .06$, and the Flanker task, $F(36, 900) = 2.01$, $p < .001$, $\eta_p^2 = .07$. For the Simon task, however, the interaction did not approach the level of significance, $F(36, 900) = 1.41$, $p = .059$, $\eta_p^2 = .06$. For all three tasks, the follow-up relevant quadratic components of the block effect are shown in Table 12. These revealed a significant performance slowing on the first trial following infrequent neutral trials for the Flanker task, but no significant performance slowing for the Stroop task (see Figure 5). For the sake of comparison, we also computed the quadratic components of the block effect for each trial of the Simon task (see Table 12). These revealed a significant performance slowing on the first trial following infrequent neutral trials (see Figure 5).

Discussion

The results of Experiment 4 showed at best a performance slowing on the first trial following infrequent neutral trials, probably indicating some orienting response (Notebaert et al., 2009; Notebaert & Verguts, 2011; Núñez Castellar et al., 2010; Rey-Mermet & Meier, 2013). However, no slowing was observed on the later trials. These results contrast to those of Experiment 3 in which a slowing was only observed on a later trial. Together, the results of Experiments 3 and 4 reveal that when incongruent trials were presented frequently and thus induced more cognitive control processes, there was no slowing caused by an orienting response, but a slowing induced by some anticipation process. In contrast, when no incongruent trials were presented and thus cognitive control processes were less necessary, only a slowing due to an orienting response (if any) occurred. More generally, the results of both Experiments 3 and 4 indicate that the slowing following infrequent events is different from the slowing following incongruent trials. This suggests that the conflict, but not the infrequence of incongruent trials, is responsible for the post-conflict slowing.

Analyses across Experiments

To strengthen the finding that the post-conflict slowing is different from the slowing following an infrequent event, we conducted a follow-up analysis in which experiment was added as a between-subjects variable. That is, we carried a four-way ANOVA with block (block 1, block 2, block 3) and trial (T+1 until T+19) as within-subject factors, and task (Stroop, Simon, Flanker) and experiment (experiment 1, experiment 2, experiment 3, experiment 4) as between-subjects factors. As shown in Table 13 (right part), the results revealed a significant four-way interaction, ensuring that the slowing we observed in each experiment differed across experiments.

Moreover, combining the data from Experiment 1 (only the 1000 ms interval condition) and Experiment 3 allowed us to analyse a fully counterbalanced design with one condition in which incongruent trials were presented infrequently across congruent trials (i.e., Experiment 1) and another condition in which congruent trials were presented infrequently across incongruent trials (i.e., Experiment 3). With these data, we conducted a four-way ANOVA with block (block 1, block 2, block 3) and trial (T+1 until T+19) as within-subject factors, and task (Stroop, Simon, Flanker) and experiment (experiment 1 with 1000 ms as interval, experiment 3) as between-subjects factors. As shown in Table 3 (left part), the results also revealed a significant four-way interaction, ensuring statistically that the post-conflict slowing observed after incongruent trials in Experiment 1 was different from the slowing observed after infrequent congruent trials in Experiment 3.

General Discussion

The purpose of the present study was to determine how long-lasting the post-conflict slowing following incongruent trials is. To this end, we performed two experiments in which we occasionally presented incongruent trials among non-conflict stimuli (i.e., congruent trials in Experiment 1 and neutral trials in Experiment 2), and we assessed the persistence of the slowing following incongruent trials by determining the trajectory of the performance slowing across the subsequent trials that immediately followed. In both experiments, the results showed a performance slowing for the first few trials immediately following incongruent trials. On some later trials, performance was still slowed. To ensure that this performance slowing was not caused by the infrequence of incongruent trials among non-conflict stimuli, we conducted two further experiments. In Experiment 3, congruent trials were occasionally presented among incongruent trials; in Experiment 4, neutral trials were occasionally presented among congruent

trials. In both experiments, the results revealed that performance was only affected at best on one trial after infrequent events were presented. This rules out the explanation that the post-conflict slowing we observed in Experiments 1 and 2 was only caused by the infrequence of incongruent trials. This rather demonstrates that the conflict induced by incongruent trials is responsible for the post-conflict slowing.

The question is now: How can we explain the post-conflict slowing following incongruent trials? As the post-conflict slowing following incongruent trials was not in the present study as long-lasting as the post-conflict slowing following bivalent stimuli (Meier et al., 2009; Rey-Mermet & Meier, 2013), this calls into question the episodic context binding explanation, at least when no task-switching is required (but see Rey-Mermet & Meier, 2016). Moreover, as stated above, because the post-conflict slowing was not caused by the infrequence of incongruent trials, an orienting response account is not sufficient to explain the slowing on the first few trials following incongruent trials (Notebaert et al., 2009; Notebaert & Verguts, 2011; Núñez Castellar et al., 2010; Rey-Mermet & Meier, 2013). Finally, according to a conservative version of the expectancy-based monitoring account (e.g., Meier et al., 2006; Smith, 2003), the performance slowing would steadily increase across the later trials. However, although the present findings show a post-conflict slowing following incongruent trials on some later trials, the magnitude of this slowing did not follow a pattern, such as a linear increase (see Figures 2 and 3).

Most probably, the post-conflict slowing we observed in the present study results from a focusing process (Ullsperger, Bylsma, & Botvinick, 2005; cf. Verguts et al., 2011). That is, encountering the conflict induced by incongruent trials widens attention or more precisely direct attention to irrelevant features. Then, a focusing process is necessary to re-direct attention to the

relevant response feature. As the post-conflict slowing occurred on congruent and neutral trials (see Experiments 1 and 2), attention seems not only directed to irrelevant response features (as it would be the case in congruent trials) but also to other irrelevant features (as it must be the case for neutral trials as they have no irrelevant response feature). Thus, this additional focusing process slows performance, resulting in the post-conflict slowing. Critically, to explain the irregularity of the post-conflict slowing across later trials, this focusing process cannot be an all-or-none process that is triggered as soon as a stimulus is presented after an incongruent stimulus. The present results rather suggest that this process is variable. Accordingly, when attention is sufficiently widened (e.g., because the current trial is the fourth of the sequence of four trials and participants anticipated incongruent trials on this trial as they realized that incongruent trials were sometimes presented on this position), a focusing process is necessary, and thus a post-conflict slowing occurs on later trials. In contrast, when attention is not widened, no focusing process is required, and therefore no slowing occurs. These variations might be explained by the specific designs of the experiments (see Verguts et al., 2011) as well as by fluctuations in current attentional demands and/or in current motivation states (see De Jong, 2000).

One may wonder why in the present study and in particular in Experiment 1, the post-conflict slowing was found on congruent trials and even might be caused by a focusing process, whereas Verguts et al. (2011) argue that the post-conflict slowing was masked by a focusing process on congruent trials. The reason for this difference might be in the conditions under which the post-conflict slowing was investigated. In Verguts et al. (2011), the post-conflict slowing was computed on congruent or neutral trials whose immediate preceding trial was either neutral, congruent or incongruent. Thus, as all trial types were intermixed, it is possible that control processes carry over the trials. This would slow the trials used as baseline, which might mask

some post-conflict slowing. In the present study, the post-conflict slowing emerged from the comparison between a pure block of congruent or neutral trials and a mixed block including some incongruent trials. Thus, the carry-over of cognitive processes was avoided because baseline trials (i.e., congruent and neutral trials) were presented in pure blocks. Moreover, as the focusing process is an additional process in the block with incongruent trials compared to the pure block, this results in a performance slowing.

Together with our previous findings (Rey-Mermet & Meier, 2016) in which the post-conflict slowing was observed on tasks sharing features with the incongruent trials and on tasks sharing no relevant features with the incongruent trials (i.e., tasks including univalent stimuli), the present results suggest that with our design, the trials used as baseline (i.e., congruent, neutral or univalent) do not seem to be critical for the post-conflict slowing following incongruent trials. Rather, the conditions under which the post-conflict slowing was investigated (e.g., whether participants were asked to switch between tasks or whether all trial types were intermixed) seem central. At a global level, this is in line with Verguts et al. (2011) who emphasize the importance of considering under which conditions the post-conflict slowing is investigated. Furthermore, this underscores the necessity of further experiments to determine why using a task-switching design results in a long-lasting post-conflict slowing or to investigate the real impact of this post-conflict slowing in studies investigating the congruency sequence effect or proportion congruency effect, for example.

More generally, the results of the present study reveal that the post-conflict slowing following incongruent trials can be different from the post-conflict slowing following bivalent stimuli or prospective memory targets (see, e.g., Meier & Rey-Mermet, 2012a, 2012b). Therefore, the source of conflict (bivalent stimulus, prospective memory target, or incongruent

trial) is important in determining the kind of adjustment of cognitive control underlying the post-conflict slowing (see Braem et al., 2014; Egner, 2008). However, these sources of conflict are interconnected (e.g., Meier & Rey-Mermet, 2012b; Steinhauser & Hübner, 2009). That is, bivalent stimuli and prospective memory targets are incongruent because they may involve competing responses (see Table 1). Conversely, incongruent stimuli might be considered as bivalent. For example, in a task-switching paradigm, participants can encounter Stroop stimuli and thus can be asked to switch between naming the colour of the word and reading the word. Therefore, at a conceptual level, the different sources of conflict share critical features. Further research is thus necessary to understand what is critical in these sources of conflict to induce different kinds of post-conflict slowing.

To summarize, the results of the present study show that the conflict induced by incongruent trials results in a consistent slowing for the first few subsequent trials. In addition, a slowing was also found on later trials. Moreover, this post-conflict slowing was not caused by an orienting response due to the infrequence of incongruent trials. Together, the present findings demonstrate that the post-conflict slowing induced by incongruent stimuli is longer-lasting than previously thought. Interestingly, this post-conflict slowing differs from the post-conflict slowing induced by bivalent stimuli or prospective memory targets.

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Footnotes

[1] There are also some studies focusing on the impact of several successive incongruent trials. These revealed a performance slowing on the immediate subsequent congruent trial even when the two or three previous trials were incongruent (Duthoo, Abrahamse, Braem, & Notebaert, 2014; Jiménez & Méndez, 2013, 2014).

[2] In order to be as concise as possible and to assess statistically the differences between the post-conflict slowing induced by the Stroop, Simon and Flanker tasks, we added *task* as a between-subjects variable. However, the different tasks were thought as separate experiments. Therefore, although recruitment and testing conditions were similar across all tasks, the data collection for the three tasks was not started simultaneously. However, as soon as half of participants were tested, all three tasks were tested concurrently.

[3] To account for baseline RT differences between Stroop, Simon and Flanker tasks, we computed proportional scores for each participant in each experiment. That is, for each trial (i.e., T+1 until T+19), mean RT for block 2 was subtracted from the mean RT averaged across blocks 1 and 3; then, this difference was divided by the mean RT averaged across all blocks. In each experiment, the analyses on the proportional scores revealed the same findings as those with the RT, ruling out the possibility that our findings are caused by baseline RT difference between the tasks.

Table 1

Overview of the different paradigms and trials used to investigate the post-conflict slowing.

Paradigm	Decision(s) to be performed	Trial	Type	Trial definition	Example
task-switching	Participants are asked to switch between at least two tasks, such as a color decision (red vs. blue) and a case decision (upper vs. lower case).	bivalent	conflict	trial with relevant features for two different tasks currently performed	the lowercase letter “a” printed in red because both the color and case decisions can be performed
		univalent	baseline	trial with only one relevant feature for one task	the lowercase letter “a” printed in black because only the case decision can be performed
prospective memory [a]	Participants are instructed to execute an ongoing task (e.g., a lexical decision), unless a target event occurs (e.g., an animal word). In this case, they have to perform the prospective memory task (e.g., to press the key “h”).	target	conflict	trial with relevant features for the prospective memory task and the ongoing task	the word “dog” because both the prospective memory task and the ongoing task can be performed
		ongoing	baseline	trial with relevant features only for the ongoing task	the letter string “dgo” because only the ongoing task can be performed
Stroop	Participants are asked to indicate the color of a color word while ignoring the meaning of the word.	incongruent	conflict	trial with features for two different responses	the word “blue” printed in red because the color “red” is different from the word meaning “blue”
		congruent	baseline	trial with two features leading to the same response	the word “red” printed in red because both the color and the word meaning result in the same response
		neutral	baseline	trial with only one relevant response feature	the letter string “xxx” printed in red for which only the color is relevant

Paradigm	Decision(s) to be performed	Trial	Type	Trial definition	Example
Simon	Participants are asked to classify stimuli while ignoring the position of these stimuli on the screen. For example, participants might encounter a colored symbol on the left or right side of the screen and they are asked to decide whether this symbol is printed in red or blue by pressing a left key for “red” and a right key for “blue”.	incongruent	conflict	trial with features for two different responses	the red symbol % presented to the right side of the screen because the response side (i.e., left) is different from the position on the screen (i.e., right)
		congruent	baseline	trial with two features leading to the same response	the red symbol % presented to the left side of the screen because both the position on the screen and the response side result in the same response (i.e., left)
		neutral	baseline	trial with only one relevant response feature	the red symbol % presented in the middle of the screen for which only the color “red” is relevant for a response
Flanker	Participants encounter a row of characters and they are asked to classify the central character while ignoring the flanking characters.	incongruent	conflict	trial with features for two different responses	the letter string SHS because the central letter requires a different response than the flanking letters
		congruent	baseline	trial with two features leading to the same response	the letter string HHH because both the central and flanking letters result in the same response
		neutral	baseline	trial with only one relevant response feature	the character string %H% for which only the central letter is relevant

Note. In the task-switching paradigm, bivalent stimuli can be incongruent or congruent. They are incongruent when both tasks require different responses (e.g., when the correct response would be a left-key press in the color decision but a right-key press for the case

decision). However, they are congruent when both tasks require the same response (e.g., when the correct response would be a left-key press for both color and case decisions).

[a] Prospective memory refers to the ability to remember to perform a particular task at some designated point in the future (McDaniel & Einstein, 2000).

Table 2

Characteristics of the sample and overview of the experiments.

Experiment	Manipulation	Task	Interval	N	Men/Women	Mean age
1	Impact of *incongruent* trials on the following *congruent* trials	Stroop Simon Flanker	1000 ms 2000 ms	156	56/100	25.3 (4.8)
2	Impact of *incongruent* trials on the following *neutral* trials	Stroop Simon Flanker	1000 ms	78	29/49	22.2 (2.7)
3	Impact of *congruent* trials on the following *incongruent* trials	Stroop Simon Flanker	1000 ms	78	32/45[a]	21.3 (1.8)
4	Impact of *congruent* trials on the following *neutral* trials	Stroop Simon Flanker	1000 ms	78	36/42	23.5 (3.4)

Note. Standard deviations are presented in parentheses.

[a] One participant did not indicate his/her gender.

Table 3

Performance on Trial T for each experiment: Three-way analysis of variance (ANOVA) with block (block 1, block 2, block 3) as a within-subject factor and task (Stroop, Simon, Flanker) and interval (1000 ms, 2000 ms) as between-subjects factors for Experiment 1, and two-way ANOVA with block (block 1, block 2, block 3) as within-subject factor and task (Stroop, Simon, Flanker) as between-subjects factor for Experiments 2, 3 and 4.

Experiment & Effect	Reaction Times				Accuracy			
	df	F	p	η_p^2	df	F	p	η_p^2
Experiment 1								
block	1.29, 193.40	349.17	< .001	.70	1.31, 196.91	74.98	< .001	.33
task	2, 150	14.76	< .001	.16	2, 150	18.13	< .001	.19
interval	1, 150	0.05	.825	< .001	1, 150	4.00	.047	.03
block x task	2.58, 193.40	0.43	.705	< .01	2.63, 196.91	31.91	< .001	.30
block x interval	1.29, 193.40	0.75	.420	< .01	1.31, 196.91	3.38	.056	.02
task x interval	2, 150	0.34	.714	< .01	2, 150	3.88	.023	.05
block x task x interval	2.58, 193.40	1.28	.282	.02	2.63, 196.91	2.22	.095	.03
Experiment 2								

Experiment & Effect	Reaction Times				Accuracy			
	df	F	p	η_p^2	df	F	p	η_p^2
block	1.14, 85.75	188.97	< .001	.72	1.56, 117.16	6.73	.004	.08
task	2, 75	12.22	< .001	.25	2, 75	0.49	.613	.01
block x task	2.29, 85.75	12.50	< .001	.25	3.12, 117.16	0.26	.865	< .01
Experiment 3								
block	1.76, 132.08	1.63	.202	.02	1.60, 119.74	7.02	.003	.09
task	2, 75	19.38	< .001	.34	2, 75	1.88	.159	.05
block x task	3.52, 132.08	7.09	< .001	.16	3.19, 119.74	0.23	.886	< .01
Experiment 4								
block	1.53, 114.61	219.03	< .001	.74	1.84, 138.13	4.89	.011	.06
task	2, 75	22.63	< .001	.38	2, 75	4.52	.014	.11
block x task	3.06, 114.61	3.16	.027	.08	3.68, 138.13	7.18	< .001	.16

Table 4

Performance on Trial T for each experiment: Mean reaction times and mean accuracy rates.

Experiment	Reaction Times			Accuracy		
	Block 1	Block 2	Block 3	Block 1	Block 2	Block 3
Experiment 1						
Stroop – 1000 ms	641 (42)	1006 (74)	604 (39)	0.99 (0.02)	0.90 (0.03)	0.99 (0.02)
Stroop – 2000 ms	604 (52)	1028 (97)	574 (49)	0.99 (0.02)	0.94 (0.03)	0.99 (0.02)
Simon – 1000 ms	533 (31)	1008 (47)	555 (21)	0.99 (0.02)	0.72 (0.04)	0.99 (0.02)
Simon – 2000 ms	584 (27)	964 (41)	548 (29)	1.00 (0.02)	0.83 (0.03)	1.00 (0.02)
Flanker – 1000 ms	678 (40)	1085 (44)	714 (33)	0.99 (0.01)	0.99 (0.01)	0.97 (0.01)
Flanker – 2000 ms	694 (39)	1180 (49)	690 (32)	0.97 (0.02)	0.97 (0.02)	0.98 (0.02)
Experiment 2						
Stroop	618 (37)	1142 (64)	638 (34)	0.99 (0.02)	0.93 (0.04)	0.98 (0.02)
Simon	597 (21)	829 (32)	625 (22)	0.97 (0.02)	0.92 (0.02)	0.97 (0.02)
Flanker	640 (46)	1259 (84)	701 (43)	0.97 (0.02)	0.95 (0.03)	0.98 (0.02)
Experiment 3						
Stroop	624 (12)	592 (17)	633 (15)	0.99 (0.01)	0.99 (0.02)	0.96 (0.02)
Simon	646 (12)	599 (14)	676 (14)	0.99 (0.01)	1.00 (0.01)	0.96 (0.02)
Flanker	728 (26)	805 (37)	746 (33)	0.97 (0.02)	0.98 (0.02)	0.94 (0.03)
Experiment 4						
Stroop	564 (27)	806 (28)	580 (18)	0.98 (0.02)	0.99 (0.01)	0.96 (0.02)
Simon	440 (22)	777 (37)	436 (20)	0.97 (0.02)	0.86 (0.04)	0.97 (0.03)
Flanker	680 (22)	937 (35)	693 (28)	0.97 (0.02)	0.97 (0.02)	0.96 (0.02)

Note. Reaction times are given in milliseconds. Within-subject confidence intervals are presented parentheses (see Cousineau, 2005; Morey, 2008).

Table 5

Experiment 1: Impact of incongruent trials on subsequent congruent trials. Four-way analysis of variance with block (block 1, block 2, block 3) and trial (T+1 until T+19) as within-subject factors and task (Stroop, Simon, Flanker) and interval (1000 ms, 2000 ms) as between-subjects factors.

Effect	Reaction Times				Accuracy			
	df	F	p	η_p^2	df	F	p	η_p^2
block	1.84, 276.00	33.76	< .001	.18	1.94, 290.31	0.89	.408	< .01
trial	12.71, 1907.25	14.19	< .001	.09	13.50, 2024.93	1.77	.040	.01
task	2, 150	24.75	< .001	.25	2, 150	28.36	< .001	.27
interval	1, 150	0.03	.858	< .001	1, 150	0.78	.378	< .01
block x trial	21.11, 3166.25	4.83	< .001	.03	23.43, 3514.66	1.31	.143	< .01
block x task	3.68, 276.00	1.00	.403	.01	3.87, 290.31	0.68	.603	< .01
block x interval	1.84, 276.00	5.49	.006	.04	1.94, 290.31	0.45	.633	< .01
trial x task	25.43, 1907.25	1.37	.101	.02	27.00, 2024.93	1.50	.048	.02
trial x interval	12.71, 1907.25	8.90	< .001	.06	13.50, 2024.93	1.37	.162	< .01
task x interval	2, 150	1.36	.260	.02	2, 150	1.51	.223	.02

Effect	Reaction Times				Accuracy			
	df	F	p	η_p^2	df	F	p	η_p^2
block x trial x task	42.22, 3166.25	1.81	.001	.02	46.86, 3514.66	1.07	.348	.01
block x trial x interval	21.11, 3166.25	1.01	.453	< .01	23.43, 3514.66	0.86	.650	< .01
block x task x interval	3.68, 276.00	1.00	.406	.01	3.87, 290.31	0.27	.892	< .01
trial x task x interval	25.43, 1907.25	1.21	.217	.02	27.00, 2024.93	0.95	.535	.01
block x trial x task x interval	42.22, 3166.25	0.76	.873	< .01	46.86, 3514.66	0.95	.569	.01

Table 6

Experiment 1: Impact of incongruent trials on subsequent congruent trials. Statistical values for the quadratic components of the block effect for each trial and task (Stroop, Simon, and Flanker). Please note that to account for the multiple comparisons, the alpha level of 0.05 was Bonferroni adjusted to 0.003, and cells indicating a significant performance slowing in block 2 compared to blocks 1 and 3 are displayed in grey.

		Stroop			Simon			Flanker		
Trial	df	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
T+1	1, 51	45.34	< .001	.47	43.16	< .001	.46	14.96	< .001	.23
T+2	1, 51	17.05	< .001	.25	23.53	< .001	.32	9.55	.003	.16
T+3	1, 51	4.00	.051	.07	10.97	.002	.18	15.47	< .001	.23
T+4	1, 51	4.57	.037	.08	2.12	.152	.04	1.85	.180	.03
T+5	1, 51	1.34	.253	.03	10.44	.002	.17	10.72	.002	.17
T+6	1, 51	4.61	.037	.08	3.24	.078	.06	5.50	.023	.10
T+7	1, 51	6.21	.016	.11	3.20	.080	.06	0.14	.709	< .01
T+8	1, 51	1.80	.185	.03	10.81	.002	.17	3.81	.056	.07
T+9	1, 51	0.08	.785	< .01	1.10	.298	.02	2.78	.101	.05

		Stroop			Simon			Flanker		
Trial	df	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
T+10	1, 51	0.31	.581	< .01	4.75	.034	.09	6.02	.018	.11
T+11	1, 51	0.03	.871	< .001	3.02	.088	.06	0.95	.336	.02
T+12	1, 51	12.84	< .001	.20	15.93	< .001	.24	26.88	< .001	.35
T+13	1, 51	3.78	.057	.07	8.47	.005	.14	0.003	.955	< .01
T+14	1, 51	6.61	.013	.11	1.74	.193	.03	0.64	.429	.01
T+15	1, 51	6.04	.017	.11	1.12	.294	.02	0.15	.695	< .01
T+16	1, 51	15.00	< .001	.23	6.57	.013	.11	2.05	.158	.04
T+17	1, 51	4.19	.046	.08	2.81	.100	.05	0.40	.532	< .01
T+18	1, 51	3.00	.089	.06	0.56	.457	.01	0.10	.751	< .01
T+19	1, 51	0.72	.400	.01	4.95	.030	.09	7.40	.009	.13

Note. Trial T refers to the incongruent trial. Subsequent trials, represented here, are labelled T+1, T+2, etc.

Table 7

Experiment 2: Impact of incongruent trials on subsequent neutral trials. Three-way analysis of variance with block (block 1, block 2, block 3) and trial (T+1 until T+19) as within-subject factors and task (Stroop, Simon, Flanker) as a between-subjects factor.

Effect	Reaction Times				Accuracy			
	df	F	p	η_p^2	df	F	p	η_p^2
block	1.94, 145.19	26.33	< .001	.26	1.89, 141.86	0.39	.664	< .01
trial	12.76, 956.84	5.28	< .001	.07	13.85, 1038.99	1.71	.049	.02
task	2, 75	3.28	.043	.08	2, 75	1.37	.259	.04
block x trial	17.93, 1345.11	5.35	< .001	.07	20.51, 1538.13	1.36	.132	.02
block x task	3.87, 145.19	1.72	.151	.04	3.78, 141.86	1.07	.372	.03
trial x task	25.52, 956.84	1.05	.394	.03	27.71, 1038.99	0.74	.835	.02
block x trial x task	35.87, 1345.11	1.04	.402	.03	41.02, 1538.13	1.02	.445	.03

Table 8

Experiment 2: Impact of incongruent trials on subsequent neutral trials. Statistical values for the quadratic components of the block effect for each trial. Please note that to account for the multiple comparisons, the alpha level of 0.05 was Bonferroni adjusted to 0.003, and cells indicating a significant performance slowing in block 2 compared to blocks 1 and 3 are displayed in grey.

Trial	df	F	p	η_p^2
T+1	1, 77	38.86	< .001	.34
T+2	1, 77	20.87	< .001	.21
T+3	1, 77	15.76	< .001	.17
T+4	1, 77	6.50	.013	.08
T+5	1, 77	24.00	< .001	.24
T+6	1, 77	0.53	.470	< .01
T+7	1, 77	0.00	.979	< .01
T+8	1, 77	0.20	.659	< .01
T+9	1, 77	1.22	.273	.02
T+10	1, 77	2.05	.156	.03
T+11	1, 77	0.66	.418	< .01
T+12	1, 77	30.30	< .001	.28
T+13	1, 77	0.02	.890	< .01
T+14	1, 77	0.15	.702	< .01
T+15	1, 77	5.52	.021	.07
T+16	1, 77	0.52	.472	< .01

Trial	df	F	p	η_p^2
T+17	1, 77	0.00	.985	< .01
T+18	1, 77	0.33	.565	< .01
T+19	1, 77	0.00	.960	< .01

Note. Trial T refers to the incongruent trial. Subsequent trials, represented here, are labelled T+1, T+2, etc.

Table 9

Experiment 3: Impact of congruent trials on subsequent incongruent trials. Three-way analysis of variance with block (block 1, block 2, block 3) and trial (T+1 until T+19) as within-subject factors and task (Stroop, Simon, Flanker) as a between-subjects factor.

Effect	Reaction Times				Accuracy			
	df	F	p	η_p^2	df	F	p	η_p^2
block	1.88, 140.74	7.57	< .001	.09	1.90, 142.61	0.97	.377	.01
trial	12.27, 919.96	4.30	< .001	.05	12.89, 967.05	1.41	.148	.02
task	2, 75	14.53	< .001	.28	2, 75	1.98	.146	.05
block x trial	17.95, 1346.28	1.89	.013	.02	20.63, 1547.19	0.88	.611	.01
block x task	3.75, 140.74	2.31	.064	.06	3.80, 142.61	1.37	.248	.04
trial x task	24.53, 919.96	1.25	.185	.03	25.79, 967.05	0.64	.915	.02
block x trial x task	35.90, 1346.28	1.10	.321	.03	41.26, 1547.19	0.97	.531	.03

Table 10

Experiment 3: Impact of congruent trials on subsequent incongruent trials. Statistical values for the quadratic components of the block effect for each trial. Please note that to account for the multiple comparisons, the alpha level of 0.05 was Bonferroni adjusted to 0.003, and cells indicating a significant performance slowing in block 2 compared to blocks 1 and 3 are displayed in grey.

Trial	df	F	p	η_p^2
T+1	1, 77	5.45	.022	.07
T+2	1, 77	6.03	.016	.07
T+3	1, 77	1.38	.243	.02
T+4	1, 77	0.71	.403	< .01
T+5	1, 77	3.22	.077	.04
T+6	1, 77	2.32	.131	.03
T+7	1, 77	0.001	.971	< .01
T+8	1, 77	0.001	.973	< .01
T+9	1, 77	3.14	.080	.04
T+10	1, 77	2.31	.133	.03
T+11	1, 77	0.69	.407	< .01
T+12	1, 77	16.54	< .001	.18
T+13	1, 77	2.38	.127	.03
T+14	1, 77	0.61	.438	< .01
T+15	1, 77	0.97	.327	.01
T+16	1, 77	1.35	.249	.02

Trial	df	F	p	η_p^2
T+17	1, 77	0.01	.908	< .01
T+18	1, 77	0.46	.500	< .01
T+19	1, 77	5.70	.019	.07

Note. Trial T refers to the incongruent trial. Subsequent trials, represented here, are labelled T+1, T+2, etc.

Table 11

Experiment 4: Impact of neutral trials on subsequent congruent trials. Three-way analysis of variance with block (block 1, block 2, block 3) and trial (T+1 until T+19) as within-subject factors and task (Stroop, Simon, Flanker) as a between-subjects factor.

Effect	Reaction Times				Accuracy			
	df	F	p	η_p^2	df	F	p	η_p^2
block	1.99, 148.92	10.52	< .001	.12	1.93, 145.04	3.38	.038 [a]	.04
trial	12.11, 908.05	3.99	< .001	.05	12.74, 955.16	1.84	.035	.02
task	2, 75	51.77	< .001	.58	2, 75	3.80	.027	.09
block x trial	15.99, 1199.57	2.16	.005	.03	20.04, 1503.10	1.34	.145	.02
block x task	3.97, 148.92	1.26	.288	.03	3.87, 145.04	1.84	.126	.05
trial x task	24.21, 908.05	1.39	.099	.04	25.47, 955.16	1.04	.407	.03
block x trial x task	31.99, 1199.57	1.66	.012	.04	40.08, 1503.10	1.09	.319	.03

[a] The linear component was significant, $F(1, 25) = 5.17$, $p = .026$, $\eta_p^2 = .06$, but the quadratic component was not, $F(1, 25) = 1.40$, $p = .241$, $\eta_p^2 = .02$. Thus, accuracy slightly decreased across blocks (block 1: $M = 0.97$, $SE = .003$; block 3: $M = 0.97$, $SE = .003$; block 2: $M = 0.96$, $SE = .003$), but no speed–accuracy trade-off compromised the critical RTs effects.

Table 12

Experiment 4: Impact of neutral trials on subsequent congruent trials. Statistical values for the quadratic components of the block effect for each trial and task (Stroop, Simon, and Flanker). Please note that to account for the multiple comparisons, the alpha level of 0.05 was Bonferroni adjusted to 0.003, and cells indicating a significant performance slowing in block 2 compared to blocks 1 and 3 are displayed in grey.

		Stroop			Simon			Flanker		
Trial	df	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
T+1	1, 25	0.01	.943	< .01	22.53	< .001	.47	14.82	< .001	.37
T+2	1, 25	4.81	.038	.16	0.25	.621	< .01	6.56	.017	.21
T+3	1, 25	0.24	.626	< .01	2.86	.103	.10	1.69	.206	.06
T+4	1, 25	0.48	.494	.02	0.59	.450	.02	0.11	.744	< .01
T+5	1, 25	0.26	.613	.01	5.53	.027	.18	11.08	.003	.31
T+6	1, 25	0.34	.562	.01	0.75	.394	.03	0.61	.440	.02
T+7	1, 25	0.26	.614	.01	0.48	.497	.02	0.02	.883	< .01
T+8	1, 25	1.95	.175	.07	0.07	.790	< .01	0.04	.849	< .01
T+9	1, 25	0.91	.350	.03	1.68	.207	.06	1.59	.219	.06

		Stroop			Simon			Flanker		
Trial	df	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
T+10	1, 25	0.36	.556	.01	0.19	.669	< .01	7.85	.010	.24
T+11	1, 25	4.50	.044	.15	3.56	.071	.12	3.67	.067	.13
T+12	1, 25	7.27	.012	.23	3.14	.088	.11	2.27	.144	.08
T+13	1, 25	0.18	.675	< .01	2.38	.135	.09	1.04	.317	.04
T+14	1, 25	0.45	.508	.02	1.86	.185	.07	0.54	.471	.02
T+15	1, 25	0.79	.382	.03	0.22	.641	< .01	0.31	.582	.01
T+16	1, 25	0.78	.385	.03	4.02	.056	.14	0.001	.975	< .01
T+17	1, 25	3.62	.069	.13	2.67	.115	.10	3.17	.087	.11
T+18	1, 25	0.27	.606	.01	0.001	.974	< .01	0.19	.665	< .01
T+19	1, 25	0.06	.811	< .01	3.20	.086	.11	2.89	.102	.10

Note. Trial T refers to the incongruent trial. Subsequent trials, represented here, are labelled T+1, T+2, etc.

Table 13

Analyses across experiments. Four-way analysis of variance with block (block 1, block 2, block 3) and trial (T+1 until T+19) as within-subject factors and task (Stroop, Simon, Flanker) and experiment as between-subjects factors. In the left part, the variable "experiment" takes into account the four different experiments (i.e., experiment 1, experiment 2, experiment 3, and experiment 4). In the right part, the variable "experiment" takes into account Experiment 1 (1000 ms interval condition) and Experiment 3 (i.e., experiment 1 –1000 ms interval condition, and experiment 3).

Effect	*Comparison across the four experiments*				*Experiment 1 (1000 ms interval condition) vs. Experiment 3*			
	df	F	p	η_p^2	df	F	p	η_p^2
block	1.95, 738.65	113.75	< .001	.23	1.99, 298.01	59.80	< .001	.29
trial	15.11, 5710.39	60.50	< .001	.14	14.90, 2235.70	17.18	< .001	.10
task	2.00, 378.00	61.92	< .001	.25	2.00, 150.00	22.07	< .001	.23
experiment	3.00, 378.00	17.52	< .001	.12	1.00, 150.00	9.13	.003	.06
block x trial	25.07, 9474.65	61.58	< .001	.14	23.62, 3542.75	13.81	< .001	.08
block x task	3.91, 738.65	3.15	.015	.02	3.97, 298.01	1.95	.103	.03
block x experiment	5.86, 738.65	9.52	< .001	.07	1.99, 298.01	20.91	< .001	.12

Effect	*Comparison across the four experiments*				*Experiment 1 (1000 ms interval condition) vs. Experiment 3*			
	df	F	p	η_p^2	df	F	p	η_p^2
trial x task	30.21, 5710.39	2.21	< .001	.01	29.81, 2235.70	1.47	.050	.02
trial x experiment	45.32, 5710.39	10.31	< .001	.08	14.90, 2235.70	15.95	< .001	.10
task x experiment	6.00, 378.00	5.74	< .001	.08	2.00, 150.00	4.43	.013	.06
block x trial x experiment	50.13, 9474.65	2.63	< .001	.01	47.24, 3542.75	1.03	.412	.01
block x trial x experiment	75.20, 9474.65	8.75	< .001	.06	23.62, 3542.75	14.30	< .001	.09
block x task x experiment	11.72, 738.65	1.30	.212	.02	3.97, 298.01	2.13	.078	.03
trial x task x experiment	90.64, 5710.39	1.69	< .001	.03	29.81, 2235.70	1.44	.058	.02
block x trial x task x experiment	150.39, 9474.65	1.61	< .001	.02	47.24, 3542.75	1.38	.044	.02

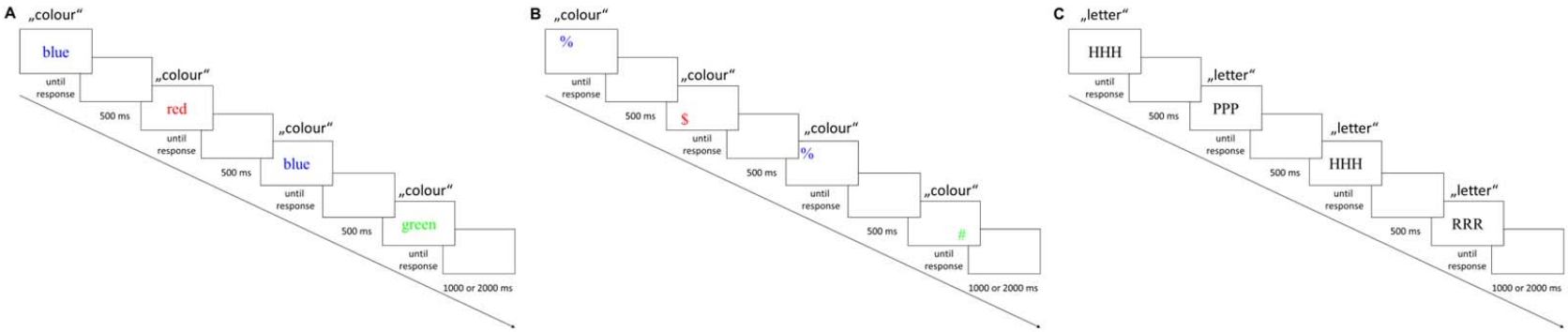

Figure 1. Example of one sequence of four congruent trials in Experiment 1. (A) Stroop task. On each trial, participants carried out a color decision on color words. On an incongruent trial (not pictured here), color words did not correspond to the color in which they were printed. (B) Simon task. On each trial, participants carried out a color decision on colored symbols. On an incongruent trial (not pictured here), the position of the symbol on the computer screen did not correspond to the location of the response key. (C) Flanker task. On each trial, participants carried out a letter decision on triplicates of letters. On an incongruent trial (not pictured here), the central letter was different from the flanking letters.

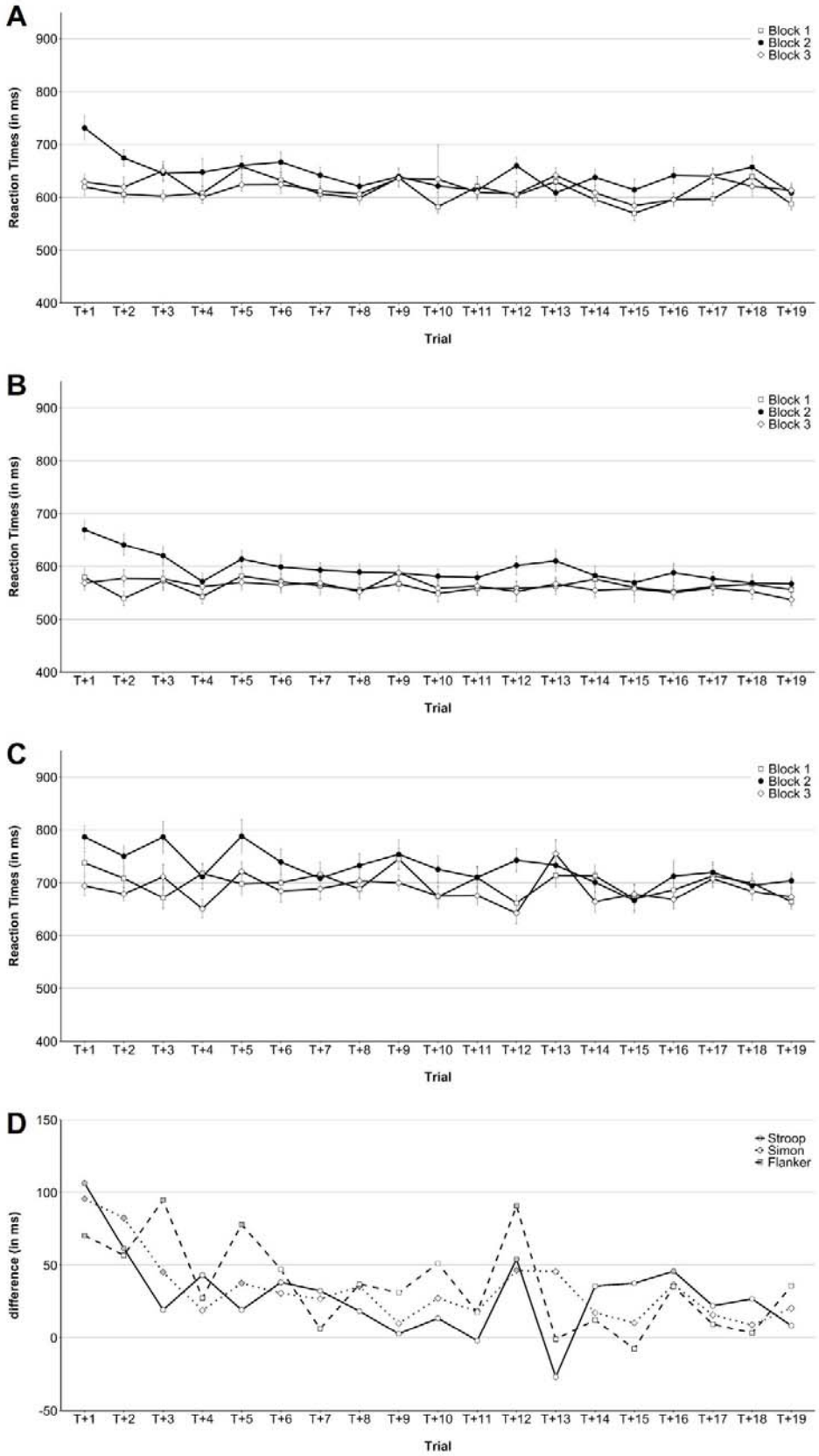
A
Block 1
Block 2
Block 3
Reaction Times (in ms)
900
800
700
600
500
400
T+1 T+2 T+3 T+4 T+5 T+6 T+7 T+8 T+9 T+10 T+11 T+12 T+13 T+14 T+15 T+16 T+17 T+18 T+19
Trial
B
Block 1
Block 2
Block 3
Reaction Times (in ms)
900
800
700
600
500
400
T+1 T+2 T+3 T+4 T+5 T+6 T+7 T+8 T+9 T+10 T+11 T+12 T+13 T+14 T+15 T+16 T+17 T+18 T+19
Trial
C
Block 1
Block 2
Block 3
Reaction Times (in ms)
900
800
700
600
500
400
T+1 T+2 T+3 T+4 T+5 T+6 T+7 T+8 T+9 T+10 T+11 T+12 T+13 T+14 T+15 T+16 T+17 T+18 T+19
Trial
D
Stroop
Simon
Flanker
difference (in ms)
150
100
50
0
-50
T+1 T+2 T+3 T+4 T+5 T+6 T+7 T+8 T+9 T+10 T+11 T+12 T+13 T+14 T+15 T+16 T+17 T+18 T+19
Trial

Figure 2. Experiment 1: Impact of incongruent trials on subsequent congruent trials. Trial T refers to the incongruent trial in block 2, and subsequent trials (represented here) are labelled T+1, T+2, etc. Error bars represent within-subject confidence intervals (see Cousineau, 2005; Morey, 2008). (A, B, C) Mean reaction times on congruent trials from block 1 (empty squares), block 2 (filled circles) and block 3 (empty diamonds). (A) Stroop task. (B) Simon task. (C) Flanker task. (D) Trajectory of the post-conflict slowing for each task (Stroop, Simon, and Flanker). This slowing was computed as the difference between performance in block 2 and performance averaged across blocks 1 and 3. Filled symbols indicate a significant slowing (the alpha level of 0.05 was Bonferroni adjusted to 0.003 to account for the multiple comparisons).

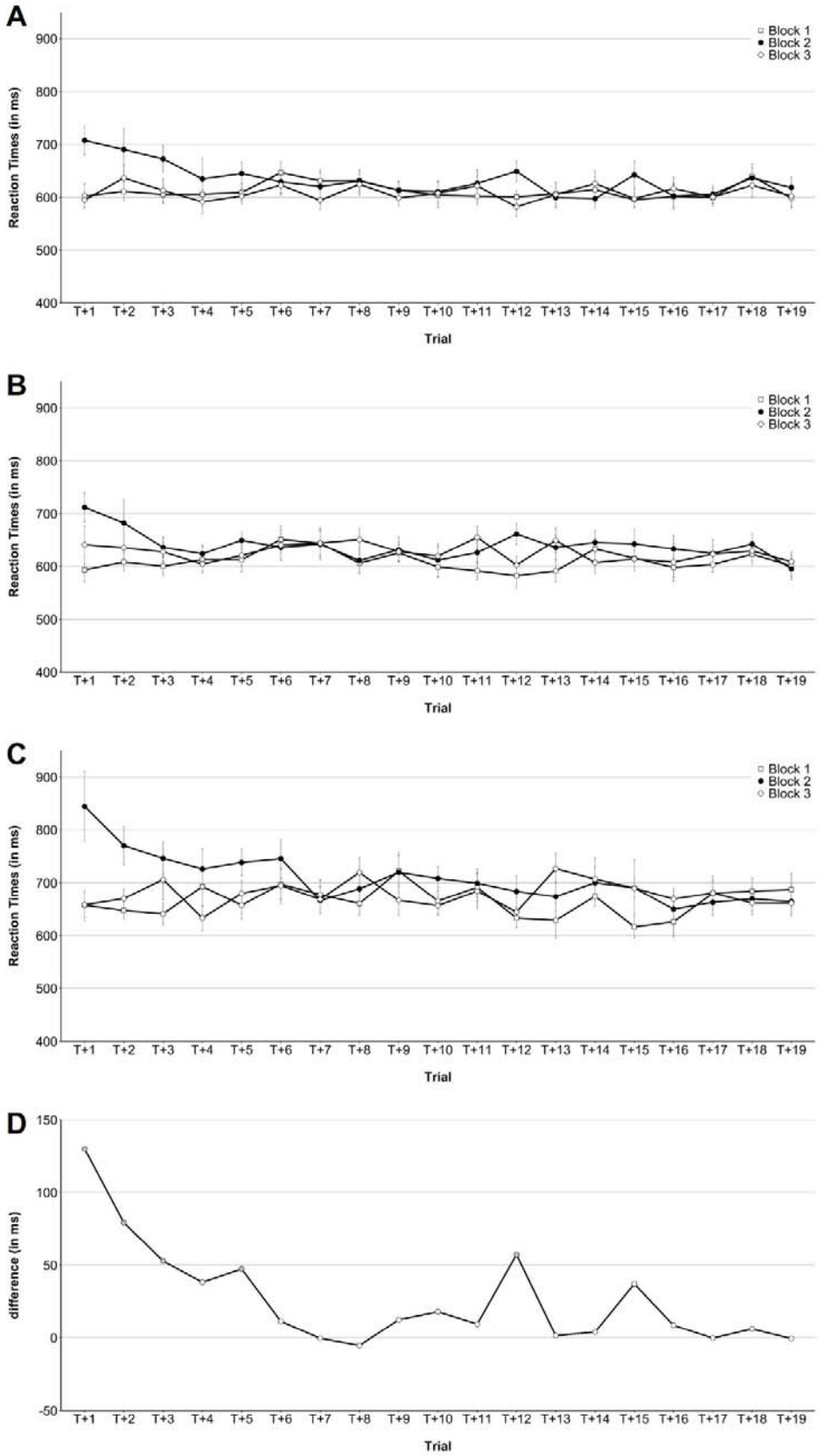
A
B
C
D
Block 1
Block 2
Block 3
Reaction Times (in ms)
difference (in ms)
Trial
T+1 T+2 T+3 T+4 T+5 T+6 T+7 T+8 T+9 T+10 T+11 T+12 T+13 T+14 T+15 T+16 T+17 T+18 T+19

Figure 3. Experiment 2: Impact of incongruent trials on subsequent neutral trials. Trial T refers to the incongruent trial in block 2, and subsequent trials (represented here) are labelled T+1, T+2, etc. Error bars represent within-subject confidence intervals (see Cousineau, 2005; Morey, 2008). (A, B, C) Mean reaction times on neutral trials from block 1 (empty squares), block 2 (filled circles) and block 3 (empty diamonds). (A) Stroop task. (B) Simon task. (C) Flanker task. (D) Trajectory of the post-conflict slowing. This slowing was computed as the difference between performance in block 2 and performance averaged across blocks 1 and 3. Filled symbols indicate a significant slowing (the alpha level of 0.05 was Bonferroni adjusted to 0.003 to account for the multiple comparisons).

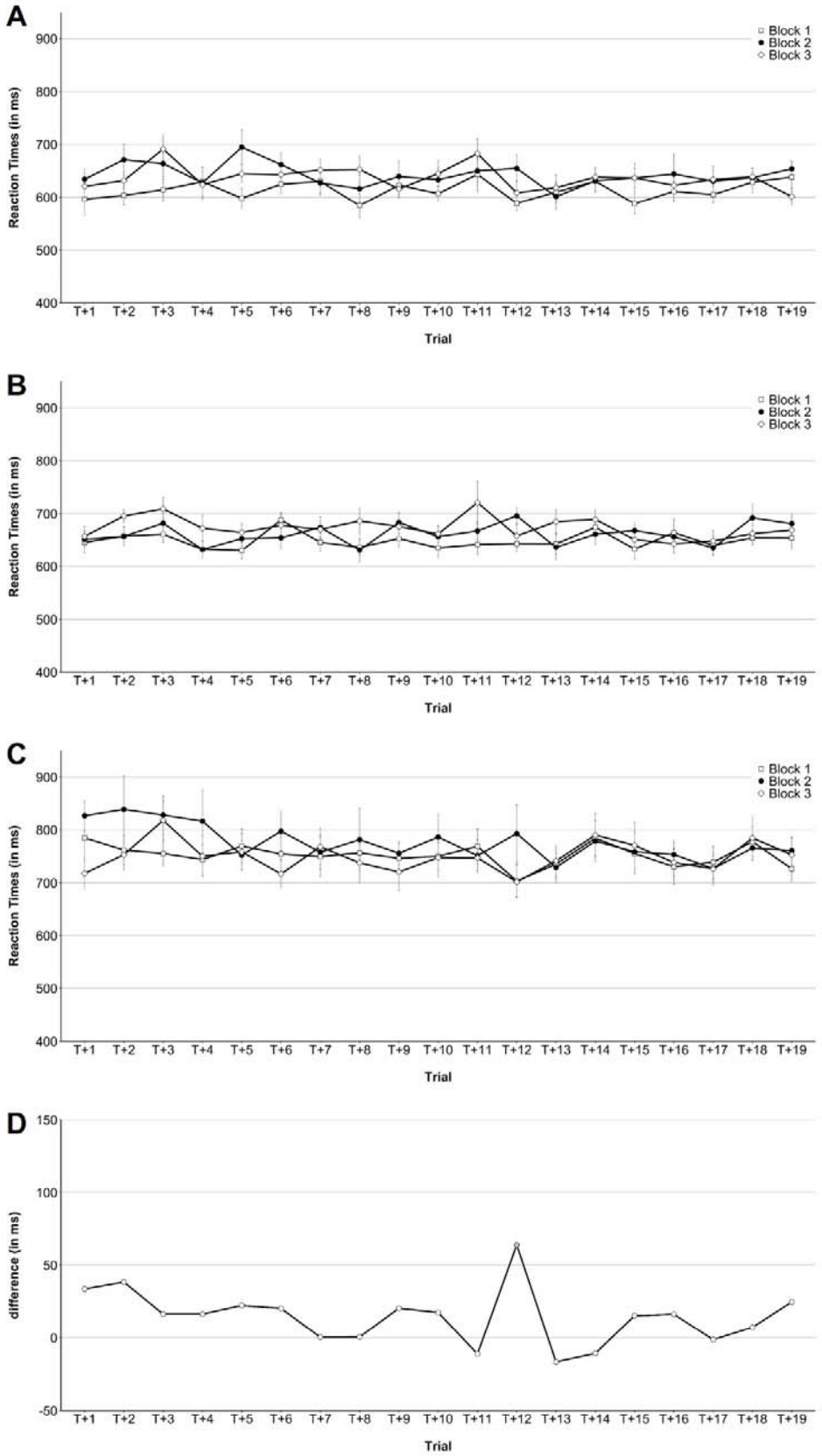
A
B
C
D
Block 1
Block 2
Block 3
Reaction Times (in ms)
difference (in ms)
Trial
T+1 T+2 T+3 T+4 T+5 T+6 T+7 T+8 T+9 T+10 T+11 T+12 T+13 T+14 T+15 T+16 T+17 T+18 T+19

Figure 4. Experiment 3: Impact of congruent trials on subsequent incongruent trials. Trial T refers to the congruent trial in block 2, and subsequent trials (represented here) are labelled T+1, T+2, etc. Error bars represent within-subject confidence intervals (see Cousineau, 2005; Morey, 2008). (A, B, C) Mean reaction times on incongruent trials from block 1 (empty squares), block 2 (filled circles) and block 3 (empty diamonds). (A) Stroop task. (B) Simon task. (C) Flanker task. (D) Trajectory of the “post-infrequency” slowing. This slowing was computed as the difference between performance in block 2 and performance averaged across blocks 1 and 3. Filled symbols indicate a significant slowing (the alpha level of 0.05 was Bonferroni adjusted to 0.003 to account for the multiple comparisons).

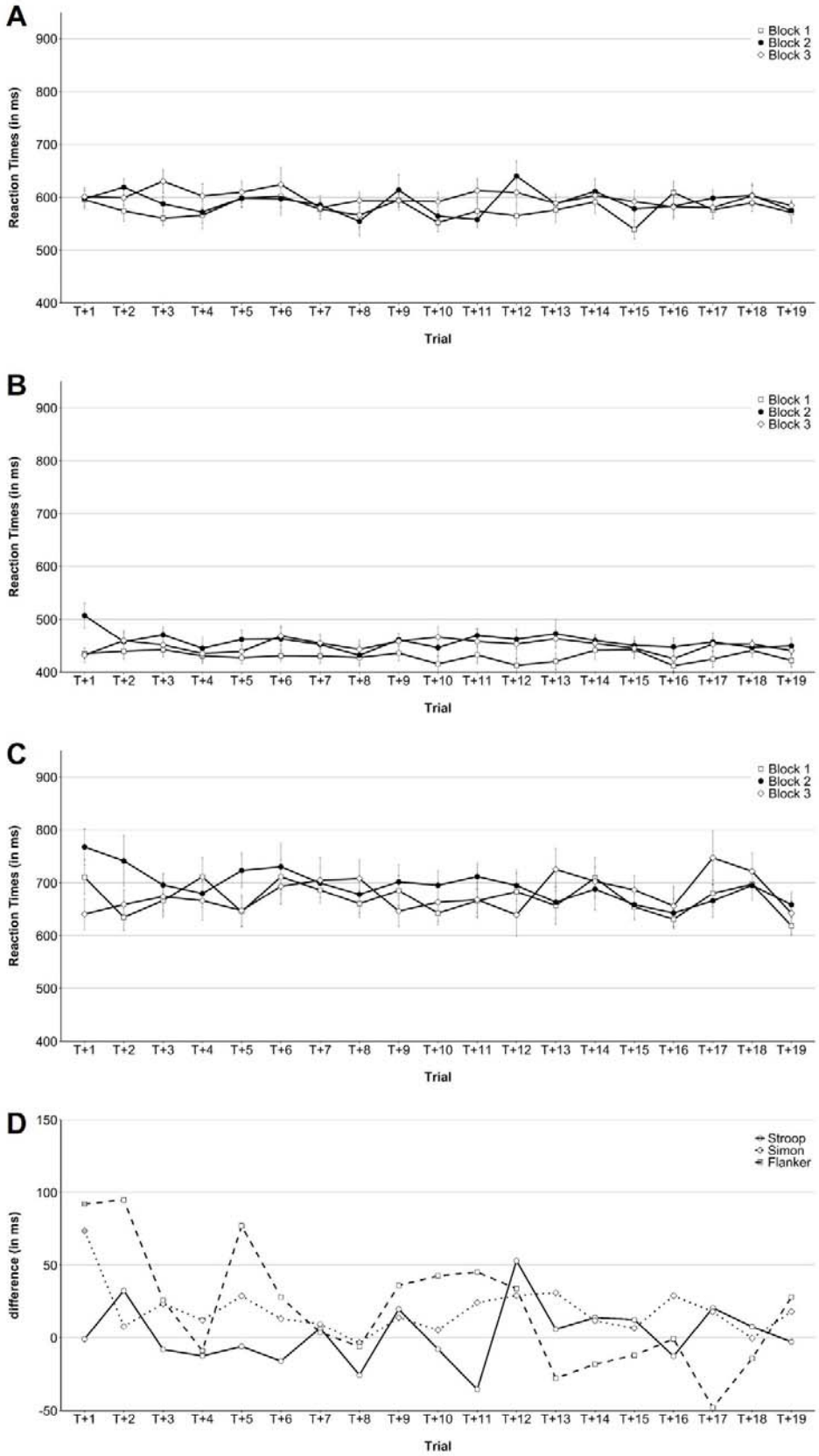
A
Block 1
Block 2
Block 3
Reaction Times (in ms)
900
800
700
600
500
400
T+1 T+2 T+3 T+4 T+5 T+6 T+7 T+8 T+9 T+10 T+11 T+12 T+13 T+14 T+15 T+16 T+17 T+18 T+19
Trial
B
Block 1
Block 2
Block 3
Reaction Times (in ms)
900
800
700
600
500
400
T+1 T+2 T+3 T+4 T+5 T+6 T+7 T+8 T+9 T+10 T+11 T+12 T+13 T+14 T+15 T+16 T+17 T+18 T+19
Trial
C
Block 1
Block 2
Block 3
Reaction Times (in ms)
900
800
700
600
500
400
T+1 T+2 T+3 T+4 T+5 T+6 T+7 T+8 T+9 T+10 T+11 T+12 T+13 T+14 T+15 T+16 T+17 T+18 T+19
Trial
D
Stroop
Simon
Flanker
difference (in ms)
150
100
50
0
-50
T+1 T+2 T+3 T+4 T+5 T+6 T+7 T+8 T+9 T+10 T+11 T+12 T+13 T+14 T+15 T+16 T+17 T+18 T+19
Trial

Figure 5. Experiment 4: Impact of neutral trials on subsequent congruent trials. Trial T refers to the neutral trial in block 2, and subsequent trials (represented here) are labelled T+1, T+2, etc. Error bars represent within-subject confidence intervals (see Cousineau, 2005; Morey, 2008). (A, B, C) Mean reaction times on congruent trials from block 1 (empty squares), block 2 (filled circles) and block 3 (empty diamonds). (A) Stroop task. (B) Simon task. (C) Flanker task. (D) Trajectory of the “post-infrequency” slowing for each task (Stroop, Simon, and Flanker). This slowing was computed as the difference between performance in block 2 and performance averaged across blocks 1 and 3. Filled symbols indicate a significant slowing (the alpha level of 0.05 was Bonferroni adjusted to 0.003 to account for the multiple comparisons).