American Psychological Association

Journal of Experimental Psychology: Learning, Memory, and Cognition

ISSN: 0278-7393

http://dx.doi.org/10.1037/xlm0000790

When Working Memory Meets Control in the Stroop Effect

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It was suggested that 2 preconditions promote proactive control: a pending plan to control performance and availability of working memory (WM) storage resources. In 4 experiments, we applied these preconditions to the Stroop task. Using a new approach, we focused on task conflict while manipulating not only the different stimuli proportions, but also participants' expectations (experience with or without incongruent trials in practice), external cues (experimental break), and WM load. In Experiment 1, we found that preexperimental exposure to incongruent stimuli triggered proactive control, resulting in a negative facilitation effect. However, once the first experimental block ended, indicating the end of the episode requiring control, proactive control ended. A regular facilitation emerged, supporting the idea that proactive control occurs for well-defined control episodes (Experiments 1 and 2). In Experiment 3, we found that applying proactive control in the Stroop task requires availability of WM resources and when such resources are limited, no control is applied and regular (rather than negative) facilitation is found. These results were replicated in Experiment 4. Therefore, it appears that experiencing incongruent trials is essential but not sufficient to recruit proactive control; available WM resources are also needed. These findings, specifying the importance of preconditions for proactive control, were replicated in Experiment 4. The current study enhances our understanding of conflict monitoring and allows us to examine the common conflict monitoring models from a different point of view.

Keywords: Stroop, task conflict, informational conflict, proactive control, working memory

Supplemental materials: http://dx.doi.org/10.1037/xlm0000790.supp

Cognitive control describes our ability to strategically bias information in line with internal goals (Chiu & Egner, 2019). The mostly common task used to demonstrate cognitive control is the Stroop task (Stroop, 1935; Tzelgov, Henik, & Berger, 1992). In the traditional Stroop task, participants are required to name the color of the ink that stimuli are presented in and ignore their meaning. Commonly, the reaction time (RT) to a neutral stimulus—an illegible pattern or a colored word that is not a color word (e.g., *lion*)—is faster than to an incongruent stimulus, such as the color name *red* written in blue text, a concept known as the *inhibition* or the *interference effect*. The RT for congruent stimuli (e.g., *blue* written in blue text) is faster than that for neutral stimuli (e.g., MacLeod, 1991) and is known as the *facilitation effect.* Both effects indicate that participants read the word despite being instructed not to do so. Reading of an irrelevant word reflects two conflicts—*informational conflict* and *task conflict* (e.g., Goldfarb & Henik, 2007; MacLeod & MacDonald, 2000; Steinhauser & Hübner, 2009). It has been suggested (Rogers & Monsell, 1995; Waszak, Hommel, & Allport, 2003) that stimuli can evoke the performance of specific tasks strongly associated with those stimuli. For skilled readers, words are much more closely associated with reading than is color naming. Consequently, when one is presented with readable stimuli and must perform the less familiar color-naming task, task conflict occurs between the color-naming task and the word-reading task that is automatically evoked. This conflict arises regardless of the congruency relation between the meaning of the word and its color. In addition, when an incongruent stimulus is read and its meaning is accessed, the two tasks performed (i.e., color naming and reading) provide conflicting information (e.g., when participants are required to name the ink color of the word *blue* written in green text, the information provided by the irrelevant word *blue* contradicts the relevant information provided by the green color). This is the source of informational conflict (MacLeod, 1991). The term *task conflict* describes situations in which participants perform an irrelevant task in parallel to the required task. Note that this analysis implies that in the Stroop task, congruent trials cause task conflict without inducing informational conflict.

Consistent with the task conflict notion, readable word stimuli should interfere more with performing the color-naming task than nonword neutrals should (for an in-depth discussion of this issue, see Levin & Tzelgov, 2016). This happens when minimal control

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This research was supported by Grant 146/16 from the Israeli Science Foundation. We thank Klaus Oberauer and Yoav Kessler for their insights and very helpful discussions.

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of conflict is applied (see Entel, Tzelgov, Bereby-Meyer, & Shahar, 2015; Goldfarb & Henik, 2007), thereby resulting in longer RTs in the congruent than in the neutral condition, that is, in a negative or reversed facilitation effect. Note that whenever the Stroop effect is obtained it shows that the word was read thereby indicating task conflict. Nevertheless, task conflict is usually not visible at the behavioral level, where the facilitation effect is quite frequent, apparently due to involvement of control processes. Yet, brain-imaging findings show that the anterior cingulate cortex (ACC) is more activated by incongruent and congruent conditions than by nonword neutrals (MacLeod & MacDonald, 2000; but see Levin & Tzelgov, 2016). It is assumed that the ACC is activated when conflicts arise (for a review see Bush, Luu, & Posner, 2000; MacLeod & MacDonald, 2000; and for a different view stating that the ACC is responsive to time-on-task, not conflict per se, see Grinband et al., 2011). Hence, the increased ACC activation implies that not only an incongruent stimulus but also a congruent stimulus causes more conflict that a neutral stimulus.

List-Wide Proportion Congruency Effect

One of the most frequently used manipulations in the Stroop task is varying the ratio of congruent trials versus incongruent trials within an experimental block. A high percentage of incongruent trials (i.e., a mostly incongruent [MI] block) results in reduced Stroop interference compared with a mostly congruent (MC) block (e.g., Bugg, 2014; Bugg, Jacoby, & Chanani, 2011; Bugg, McDaniel, Scullin, & Braver, 2011; Kane & Engle, 2003; Logan, Zbrodoff, & Williamson, 1984; Shor, 1975; West & Baylis, 1998). This effect is known as the *list-wide proportion congruent effect*. The common explanation for this effect suggests that the activation of control is modified by the predictability of certain trial types within a block (Lindsay & Jacoby, 1994; see also Botvinick, Braver, Barch, Carter, & Cohen, 2001). Participants who encounter a high proportion of incongruent trials focus their attention on the relevant dimension (i.e., color reading; Lindsay & Jacoby, 1994; Logan & Zbrodoff, 1979; Lowe & Mitterer, 1982; for alternative views, see Blais & Bunge, 2010; Bugg, Jacoby, & Toth, 2008; Schmidt, 2013, 2014).

Another technique can be used when neutral trials are also included in the experimental design. In this case, one can vary the ratio of color words (both congruent and incongruent trials) to neutrals while preserving the ratio of congruent-to-incongruent stimuli (Tzelgov et al., 1992). Using this manipulation, Goldfarb and Henik (2007) were the first to show negative facilitation as a behavioral marker of task conflict in the Stroop task. To achieve that they reduced the proportion of trials eliciting task conflict by increasing the percentage of neutral trials (nonword, four-letter string stimuli) relative to color word stimuli to 75%. In addition, in 50% of the trials they provided a valid cue for whether the coming trial would be neutral or would reflect task conflict by being readable (congruent or incongruent). They showed that decreasing the task conflict led to a slow-down in RTs for congruent compared with nonword neutral trials, thereby leading to a negative facilitation effect and revealing the task conflict in the noncued trials. Entel et al. (2015) provided further evidence for the existence of the two types of conflict. Taking as the starting point the assumption that all readable stimuli generate task conflict, they decomposed the Stroop effect to its components (task conflict and informational conflict) by using the orthogonal contrasts approach, which allows to provide a quantitative estimation of task and informational conflicts to the Stroop effect. They manipulated the two conflicts orthogonally by varying the proportion of color (congruent and incongruent) words versus nonletter neutrals and informational conflict by varying the congruent-to-incongruent trial ratio. Although both conflicts existed in all experimental conditions, negative facilitation effects as a behavioral marker of task conflict were observed under specific conditions in which task conflict dominated behavior (due to decreased task control), explaining most of the variability between congruency conditions and demonstrating that this effect is typical for extreme cases of task conflict. In these conditions, at most 50% of the stimuli were color words, among which 50% or more were incongruent trials. Namely, when task conflict was low enough (no reading was expected) and informational conflict was high enough (the words seen were mostly incongruent), task conflict was indicated behaviorally by shorter RTs for neutral trials than for congruent trials, that is, negative facilitation.

Models of Cognitive Control in the Stroop Task

Cohen, Dunbar, and McClelland (1990) were the first to suggest a model (see also Cohen & Huston, 1994) describing the mechanism behind the effects observed in the Stroop task. According to their model, interference arises from conflicting responses generated by the relevant and irrelevant response processing pathways. To explain the list-wide congruency effect, Botvinick et al. (2001) extended Cohen et al.'s model by including a conflict monitoring unit (believed to be located in the ACC) that is sensitive to the amount of conflict (for an alternative account, see Verguts & Notebaert, 2008). Increase in the amount of incongruent trials rises the level of conflict, leading to increased control activation, thereby suppressing the irrelevant reading.

Based on the notion that the Stroop effect involves both informational and task conflicts, we (Entel & Tzelgov, 2018) have recently suggested a modified framework of the conflict monitoring model. The new model suggests that conflict arises due to activation of two different responses by incongruent stimuli at the response layer, thus reflecting the response/informational conflict.[1] Control is recruited increasing the focus on the relevant task (i.e., color naming), that is, control activation over the task conflict (see also Levin & Tzelgov, 2014).

Dual Mechanisms of Control

A different model was proposed by Braver, Gray, and Burgess (2007; see also Braver, 2012). According to the dual mechanisms of control framework (DMC), there are two different control mechanisms, proactive and reactive, which may act independently. Proactive control relies upon the anticipation and prevention of interference before it occurs. That is, it is a preparatory control

[1] In the present study, *informational conflict* refers to the difference in information provided by the color of the word and its meaning in the case of incongruent trials. However, incongruent trials as used in our experiments also include an additional source of conflict, that is, a response conflict, because each of the stimuli dimensions lead to a different response. Thus, in the classic Stroop task as used in our study, informational conflict cannot be separated from response conflict.

exerted via sustained maintenance of goal-relevant information within the lateral prefrontal cortex (PFC). Therefore, this control mechanism biases the processing of incoming information according to task goals in advance, before the stimuli onset (i.e., it suppresses the activation of the irrelevant reading process in the Stroop task). In contrast, reactive control is a late correction mechanism; task goals are retrieved only after the event has occurred. Namely, reactive control is activated within the anterior cingulated cortex (ACC) after the stimuli onset. These two mechanisms of control are complementary and have both benefits and costs; hence, the best mode of control changes in accordance with the situation (Braver, Gray, & Burgess, 2007). Proactive control is best fitted for early selection of task-appropriate information over distracting information.[2] However, it also requires high working memory (WM) capacity and is less sensitive to changes in stimulus contingencies, ignoring goal-irrelevant stimulus features. In contrast, reactive control does not require high-WM capacity (De Pisapia & Braver, 2006). Therefore, reactive control is beneficial when conflicting trials (i.e., incongruent stimuli) are rare.

Possible Determinants of Proactive Control Implementation: Working Memory Resources and Intentional Planning

Meiran, Cole, and Braver (2012) proposed that plans to execute performance (i.e., task goals such as color naming or word reading) could be stored in WM (see Oberauer's [2001, 2002, 2009] work for the suggested model). *Working memory* refers to a cognitive mechanism that provides temporary storage, active manipulation, and retrieval of information (Baddeley, 1992; Unsworth & Engle, 2008) and is positively correlated with control of attention (Engle & Kane, 2004). It has been demonstrated that individuals with high-WM capacity are less prone to interference in a Stroop task than individuals with low-WM capacity (Kane & Engle, 2003; Long & Prat, 2002; Unsworth, Redick, Spillers, & Brewer, 2012). To explain this discrepancy, Engle and Kane (2004) suggested that low-WM capacity individuals are less able to maintain goal-relevant information in WM during task completion, with failures of control such as slower response times and more errors (see also, Wiemers & Redick, 2018). Several researchers have shown that when control is less crucial, high- and low-WM capacity individuals perform similarly (Kane, Bleckley, Conway, & Engle, 2001; Unsworth, Schrock, & Engle, 2004). Evidence for the link between proactive control and WM were reported by several researchers (e.g., Bugg, 2014; Gonthier, Zira, Colé, & Blaye, 2019). For instance, there is evidence for age-related deficits in proactive control while reactive control is intact with the age, whereas item-specific effects are often observed in both (Bugg, 2014).

In this study, we refer to *intentional plans*, which are intended to be performed as part of the required task (see also Bargh, 1992; Tzelgov, 1997). In terms of the Stroop paradigm, the relevant color-naming task (intentional plan) is activated by the task requirement and as such, is represented in WM. The irrelevant yet well-practiced reading task is activated from long-term memory, thus causing interference.

In line with the literature introduced in the preceding text, Meiran et al. (2012) suggested that intentional plans promote proactive control, which implies focusing on the relevant color-naming task and suppressing the processing of the irrelevant reading, thereby reducing the proportion congruency effect. Following this view, proactive control can take place when the following two main conditions apply:

- The plan to control performance is pending and the goal has not yet been achieved. If the goal has been achieved (i.e., end of the episode planned to be executed), proactive control would no longer apply.
- Availability of WM storage resources: Proactive control can be eliminated when WM is kept busy by requirements to perform another task (e.g., if in addition to the Stroop task, participants would have been required to perform a secondary number task).

The Present Study

In a recent series of experiments (Entel & Tzelgov, 2018), we focused on the task conflict component of the Stroop effect in an attempt to discover whether task conflict is monitored in the absence of the informational conflict. This was done by manipulating the congruent-to-neutral ratio. In our first experiment, we did not include incongruent stimuli in the experimental blocks and no implications were provided by instructions, thereby allowing examining what happens in a pure task conflict situation. Namely, we focused on cases in which there were at least two possible tasks to be performed, but there was no contrasting information or response. The results showed two different facilitation effects—an unusually strong facilitation when most of the trials were congruent and a smaller, yet significant facilitation in the mostly neutral condition. In our second experiment, we additionally manipulated the type of trials in the practice block. Half of the participants were not exposed to incongruent trials during practice, whereas the other half performed a practice block that included incongruent trials, thus, manipulating preexperimental expectations for informational conflict. Our findings revealed that the impressive facilitation effect that was originally found in the mostly congruent condition of Experiment 1 was much smaller in the first experimental block of Experiment 2, immediately after participants were exposed to incongruent trials during practice. In the mostly neutral condition, experiencing incongruent trials during practice resulted in a negative facilitation effect, which disappeared in the second block, revealing once again faster responses for congruent trials. These results suggest that in the absence of informational conflict, task conflict was apparently not monitored, and therefore control was not recruited. Experiencing or at least expecting informational conflict was essential in order to reveal and control task conflict. Similar results were reported by Levin and Tzelgov (2016).

The finding that experiencing informational conflict in the pre-experimental practice is enough to recruit task control that lasts through an entire experimental block that does not include incon-

[2] Note that in Braver et al.'s (2007) dual mechanism model, proactive control was implemented as a long-term aggregator of response conflict. This allowed the model to be sensitive to longer term statistics of conflict signals and explain phenomena like list-wide proportion congruency effects. Because there is no actual response conflict in our experiments, but only pre-experimental experience with incongruent trials, we refer to *pure proactive control* as a form of preparatory control exerted via sustained maintenance of goal-relevant information activated by pre-experimental experience alone.

gruent trials, led us to the present study in which we attempt to understand how this preexperimental recruitment of task control is applied. Note that, in line with our previous results (Entel et al., 2015), we observed negative facilitation as a behavior marker of task conflict when, during practice, a high proportion of neutrals was combined with incongruent trials. Thus, such preexperimental practice is equivalent to the extreme conditions that lead to the experimental conditions causing negative facilitation. Let us reemphasize that task conflict exists each time a readable stimulus is presented while negative facilitation characterizes conditions in which task conflict is visible behaviorally and it dominates performance (see Entel et al., 2015). That is why we focus on negative facilitation in the present study.

Based on the literature described in the preceding text, we hypothesized that experiencing incongruent trials in preexperimental practice triggers proactive control by priming task-relevant processing pathways prior to stimulus onset, in a preparatory fashion (De Pisapia & Braver, 2006). In terms of intentional planning, the preexperimental exposure to incongruent trials triggers proactive control of applying the plan to name the color of the ink, which is recruited in advance, prior to the block onset, due to the activation of the instructions in WM. In addition, in such conditions greater demand is placed on WM to actively maintain the goal across congruent and neutral (C/N; i.e., nonconflicting) trials. As argued by Botvinick et al. (2001), the increased amount of conflict that participants experience, whereas performing mostly incongruent blocks provides constant reminders of the relevant task goal to name the color rather than the word. In contrast, in the mostly congruent blocks, greater demand is placed upon WM to actively maintain the goal across congruent (i.e., nonconflicting) trials (see also, Hutchison, 2007).

To test this hypothesis, we applied the two conditions stated in the preceding text—a plan to execute an episode (Experiments 1 and 2) and availability of WM resources (Experiments 3 and 4). Namely, we examined whether the reduced facilitation in the mostly congruent condition and the negative facilitation in the mostly neutral condition would still be observed when the participants believe that the plan is no longer relevant, or their WM resources are occupied. In our third experiment, we applied a secondary task that occupied WM storage resources. In our fourth experiment, we manipulated both participants' beliefs and WM availability, thus providing a more comprehensive picture of the recruitment of proactive control.

The present work differs from existing literature on the three-way relationship between WM, proactive control and list-wide effects in the Stroop task due to its focus on task conflict and negative facilitation on congruent trials as a behavioral marker of task conflict. We use a new approach by manipulating not only the different stimuli proportions but also participants' expectations (experience with or without incongruent trials during practice), external cues (experimental break), and WM load. How WM and proactive control affect pure task conflict is an important question that has not yet been addressed, which we are trying to answer it in the present study. This is an important issue because, according to the contemporary dominant view, automatic processes can be controlled. This view is based at least partly on studies of the Stroop phenomenon (e.g., Logan & Zbrodoff, 1979: Lowe & Mitterer, 1982). These studies, in most cases, tested the controllability of the difference between incongruent and congruent trials (which is the measure of informational conflict) as a paradigmatic example of automatic processing. However, it could be the case that these studies reflect not the sensitivity of task conflict (which is the marker automatic reading) to control, but the sensitivity of the other component of the Stroop phenomenon (i.e., informational conflict). In fact, this is implied by the conflict monitoring framework (Botvinick et al., 2001). Evaluating the controllability of the components of the Stroop phenomenon has implications for understanding the architecture behind this phenomenon and its control.

Experiment 1

Based on our previous results (Entel & Tzelgov, 2018), in this experiment we manipulated the type of preexperimental practice block. During the experiment, the participants were presented with C/N stimuli for color naming. The stimuli were mostly congruent for one group of participants and mostly neutral for the other group. During preexperimental practice, half of participants were exposed to incongruent trials, whereas the other half were not. Subtle environmental cues, such as a break in a condition, may be sufficient to terminate the recruitment of proactive control (i.e., the plan to execute an episode). We specifically refer to an experimental break that interferes with a goal being achieved. Therefore, as done previously (Entel & Tzelgov, 2018), we used 120 trials but this time we added an experimental break after the first 60 trials. According to our analysis in the preceding text, we expected to observe a decreased facilitation effect immediately after participants were exposed during practice to incongruent trials in the mostly congruent condition. In the mostly neutral condition, experiencing incongruent trials during practice should result in a negative facilitation effect. In line with our previous results, we expected this effect to be reversed after an experimental break, which would finish the control episode and result in speeding up response to congruent trials after the break. These predictions follow directly from the hypothesis that the reduced facilitation in the MC condition and the negative facilitation in the MN condition in the Stroop task reflected proactive control. We expected to see this pattern of results regardless of the number of the experimental trials. Namely, it should not matter if the blocks consisted of 60 trials or 120 trials (as in the original study of Entel & Tzelgov, 2018) because the episode would no longer be relevant (i.e., the break ends the subjective timeframe of the proactive control plan).

Method

Participants. Students ($N = 72$) from Ben-Gurion University of the Negev took part in the experiment. All were native speakers of Hebrew and reported normal or corrected-to-normal eyesight, with normal color vision. All participants gave written informed consent and were awarded course credit. The experiment was approved by the Ethics Committee of the Psychology Department at Ben-Gurion University of the Negev.

Stimuli. The colors used in the experiment were red, green, blue, and yellow. All words were in Hebrew and their names consisted of four letters each. Congruent stimuli were generated by printing each of the color words in its own ink color. The incongruent stimuli were generated by printing each color name in ink colors of the three other colors. The pattern "####" served as an illegible stimulus, and, hence, it was a task conflict-free neutral stimulus. This was done to eliminate the possibility that our neutral stimuli would rouse automatic reading in the mostly neutral condition. In other words, we focused on the facilitation effect (i.e., readable congruent trials) and its modulation by manipulating the different task conflict levels. All stimuli appeared in boldface, 18-point, Courier New font.

Design and procedure. Each participant in the experiment performed the color-naming task. Four between-participant experimental conditions were created, and 18 participants were randomly selected to participate in each experimental condition. These conditions resulted from crossing two factors, congruent-to-neutral ratio—MC (mostly congruent C/N = 90/10) or MN (mostly neutral C/N = 10/90)—and practice type (with or without incongruent trials). Congruency (congruent or neutral) and block (first or second) were manipulated within participants. The experiment began with 48 randomly ordered practice trials. The proportions of the congruent and of the neutral trials in the practice block were close to those presented during the experimental blocks (44 neutrals [92%] and four congruent trials [8%] in the MN condition and exactly the opposite in the MC condition). To expose the participants in the relevant group to incongruent trials in preexperimental practice, four incongruent trials were added to the total number of trials during practice (i.e., 52 trials among which 44 were neutral, four were congruent, and four were incongruent trials). After practice, the participants completed two blocks of 60 trials (48 neutral trials and 12 congruent trials in the MN condition and, exactly the opposite, 48 congruent trials and 12 neutral trials in the MC condition) with a short break between the blocks. After the first 60 trials, a slide appeared on the screen stating: "This part is over. Take a short break. To continue to the next part of the experiment, press any key." Note that such wording may be interpreted as an episode-termination and result in the shutting down of proactive control (see Table 1). The different stimuli (C/N) were selected at random.

The participants sat facing a 17-in. widescreen CRT monitor with a 1024 × 768 resolution. The experimental trials started with a fixation point—a white plus sign at the center of a black screen, presented for 500 ms, approximately 80 cm from the participant's eyes. After that, the stimulus appeared at the center of the screen and remained visible until the participant made a response into a microphone. Responses were measured in milliseconds via a microphone attached to the computer keyboard through a "voice key" device. In addition, the experimenter typed all the vocal responses using the keyboard so that the errors could be also evaluated.

Results and Discussion

For each participant, mean RTs of correct responses and the percentage of errors (PE) in each experimental condition were calculated. RTs of error trials were omitted (less than 1% of all responses) as were RTs slower than 2,500 ms and faster than 250 ms (less than 2% of all responses). All effects were tested at a significance level (α) of .05. A four-way mixed-model analysis of variance (ANOVA) with congruency and block as within participant factors, and type of practice and C/N ratio as between participant factors showed a significant main effect for congruency, revealing faster responses for congruent trials than for neutrals, $F(1, 68) = 92.14$, $MSE = 2{,}204$, $p < .001$, $\eta_p^2 = .58$. The interactions between congruency and C/N ratio, $F(1, 68) = 46.30$, $MSE = 2{,}204$, $p < .001$, $\eta_p^2 = .40$, and congruency and practice type, $F(1, 68) = 15.90$, $MSE = 2{,}204$, $p < .001$, $\eta_p^2 = .19$, were significant, as were the interactions between congruency, block, and practice type, $F(1, 68) = 5.20$, $MSE = 1{,}010$, $p = .03$, $\eta_p^2 = .08$, and congruency, block and C/N ratio, $F(1, 68) = 6.12$, $MSE = 1{,}010$, $p = .02$, $\eta_p^2 = .07$. The four-way interaction between congruency, block, C/N ratio and practice type was also significant, $F(1, 68) = 8.20$, $MSE = 1{,}010$, $p < .006$, $\eta_p^2 = .11$ (see Figure 1). Note that there was no significant difference in the case of neutral trials, that is, the manipulations we used affected only the congruent trials (Fs < 1). No additional effects were significant (see Table 2 and Table S1 in the online supplemental material).

Focusing first on the conditions in which participants did not experience incongruent trials in practice (see the left panels of Figure 1) revealed a significant simple interaction between congruency and C/N ratio, $F(1, 34) = 11.53$, $MSE = 2{,}455$, $p < .002$, $\eta_p^2 = .25$. This interaction was due to a very impressive facilitation of 119 ms in the MC condition (see the upper left panel of Figure 1), $F(1, 17) = 44.07$, $MSE = 3{,}426$, $p < .001$, $\eta_p^2 = .79$. Bayesian analysis (Rouder, Speckman, Sun, Morey, & Iverson, 2009) provided very strong evidence for our hypothesis. The posterior probabilities of the alternative hypothesis versus our hypothesis, i.e., Bayes Factor (BF_{10}) = 4,784.78.[3] This facilitation was much larger than the 80 ms facilitation observed in the MN condition (see the bottom left panel of Figure 1), $F(1, 17) = 8.30$, $MSE = 2{,}166$, $p = .01$, $\eta_p^2 = .33$, $BF_{10} = 5.20$. These results replicate our previous results (Entel & Tzelgov, 2018; Entel, Tzelgov, & Bereby-Meyer, 2014), indicating that experiencing informational conflict (i.e., incongruent trials) is essential in order to recruit control over task conflict. In line with our predictions and our previous results (Entel & Tzelgov, 2018), we observed an impressive facilitation effect when most of the trials were congruent and a smaller yet significant facilitation in the MN condition, providing evidence for lack of (or at least reduction of) control recruitment.

The pattern of the results was different when incongruent stimuli were included in practice (see the right panels of Figure 1). A significant simple three-way interaction between congruency, block, and C/N ratio was observed, $F(1, 34) = 17.37$, $MSE = 827$, $p < .001$, $\eta_p^2 = .34$. Further analysis revealed no interaction between congruency and block in the MC condition ($F > 1$). A facilitation effect of 66 ms was found in this condition (see the upper panel on the right side of Figure 1), $F(1, 17) = 26.93$, $MSE = 815$, $p < .001$, $\eta_p^2 = .61$, $BF_{10} = 369.32$.

Focusing on the MN condition (see the bottom right panel of Figure 1) revealed a significant simple interaction between congruency and block, $F(1, 17) = 26.93$, $MSE = 815$, $p < .001$, $\eta_p^2 = .61$. In this condition, a significant negative facilitation effect of 36 ms was observed in the first block, $F(1, 17) = 8.88$, $MSE = 1{,}280.23$, $p < .008$, $\eta_p^2 = .34$, providing a behavioral marker of task conflict. Bayesian analysis (Rouder et al., 2009) provided substantial evidence for our hypothesis ($BF_{10} = 5.51$). This effect

[3] For theoretically critical effects (negative facilitation or a regular facilitation effects), Bayes factors were calculated (following Rouder et al., 2009) to assess the amount of evidence in favor of a prior null distribution with an r scale for fixed effects set to 0.707.

Table 1
Experimental Design for Experiments 1, 2, 3, and 4

Experiment 1	Experiment 2	Experiment 3	Experiment 4
Two blocks with an experimental break in between Participants were aware of the transitions between the practice blocks and the experimental blocks	Without experimental break	Without experimental break	Two blocks with an experimental break in between Participants were aware of the transitions between the practice blocks and the experimental blocks

disappeared in the second block, revealing faster responses for congruent trials than for neutrals (facilitation of 34 ms), $F(1, 17) = 8.31$, $MSE = 1{,}273.84$, $p = .01$, $\eta_p^2 = .33$, $BF_{10} = 7.41$. It is also important to remind the reader that this effect was caused exclusively by the speed-up in processing of congruent stimuli because, as mentioned in the preceding text, the difference in processing neutrals in the experiment was insignificant.

In line with our hypothesis, the present results support the notion of a plan-to-execution episode, showing that an experimental break influences performance, ending the goal-related episode. We see that the negative facilitation effect observed in the first block in the MN condition disappeared in the second block, that is, after the break.

As it happened only in the condition in which participants were exposed to incongruent trials in practice, it also clearly demonstrates that task conflict was not detected, and its control was not recruited in the absence of incongruent trials, thus supporting our previous results (Entel & Tzelgov, 2018; Entel et al., 2015). It seems that in the absence of incongruent stimuli, participants apparently are more prone to read (for a detailed discussion see Entel & Tzelgov, 2018; see also Macleod & Macdonald, 2000).[4]

In fact, when incongruent trials were included in practice, we observed a negative facilitation effect in the first block in the MN condition, and the impressive facilitation previously observed in the MC condition significantly decreased, from 119 ms to 66 ms, indicating conflict detection and thereby control recruitment, $F(1, 34) = 8.27$, $MSE = 1{,}537.84$, $p < .007$, $\eta_p^2 = .20$.

Note that in our previous work (Experiment 2; Entel & Tzelgov, 2018), 17 participants were allocated to each of the experimental conditions. We conducted a power analysis before Experiment 1 to decide a priori on how many subjects to collect based on the G*Power program (Faul, Erdfelder, Lang, & Buchner, 2007). The analysis revealed that using seven participants per condition is sufficient in order to observe the effect in which we were interested, that is, the negative facilitation effect we found in the mostly neutral condition (99% probability to observe the effect if it existed, with an effect size of 0.7). Accordingly, in the present experiment, we used 18 participants per condition. We applied this analysis to all our following experiments and found that seven participants per condition were enough.

The PE was very low, averaging 0.82%. A four-way mixed-model ANOVA with C/N ratio and practice as between participant factors, and congruency and block as within participant factors, revealed no significant effects.

Experiment 2

The findings of our first experiment showed that recruitment of proactive control over the task conflict is episode-related and can be terminated by environmental cues, namely, the pattern of results changed after the break, which participants as we believe, referred to as the end of the episode. The aim of Experiment 2 was to test whether eliminating the break between the two blocks would reveal a different pattern of results. This time participants were exposed to 240 trials in succession. Such a design will also strengthen our conclusion that an experimental break influences performance, ending the goal-related episode, that is, the notion of the plan-to-execution episode.

Method

Seventy-two students of Ben-Gurion University of the Negev, who were native speakers of Hebrew, participated in the experiment. All had normal or corrected-to-normal eyesight, without color blindness. Participation in the experiment was in partial fulfillment of course requirements. In all other respects, Experiment 2 was similar to Experiment 1.

Results and Discussion

For each participant, mean RTs of correct responses and the PE in each experimental condition were calculated. RTs of error trials were omitted (less than 1% of all responses) as were RTs slower than 2,500 ms and faster than 250 ms (less than 2% of all responses). A four-way mixed-model ANOVA with congruency and experimental block as within participant factors, and congruent-to-neutral ratio and practice type as between participant factors revealed faster responses for congruent trials than for neutral trials, $F(1, 68) = 27.13$, $MSE = 2{,}860$, $p < .001$, $\eta_p^2 = .28$. A significant effect for congruent-to-neutral ratio was also ob-

[4] It should be noted that our interpretation of the data is based on the assumption that subjects are trying to perform the color-naming task, and word reading to some level unintentionally intrudes on that task (i.e., the inadvertent reading hypothesis; for deeper insight on this point see Entel & Tzelgov, 2018; Levin & Tzelgov, 2016; MacLeod & MacDonald, 2000), both under the MN and MC conditions, which facilitates color naming in congruent trials. To be sure that participants did not strategically apply intentional word reading in the mostly congruent conditions, ignoring the pre-experimental instructions (with rare non-word trials, where they have to switch task to a color-naming task), we examined whether participants took particularly long to respond when a neutral trial followed a congruent trial (and vice versa), as compared with two neutral or congruent trials occurring in a row. A two-way ANOVA with congruency (congruent or neutral) and type of trial (switch or repeat) revealed no significant interaction in the mostly congruent condition, $F(1, 68) = 1.3$, $MSE = 3{,}571.84$, $p = .28$, $\eta_p^2 = .11$, BF01 = 3.22, supporting the hypothesis that participants were trying to carry out ink color naming, with word reading just influencing response times inadvertently. Similar results were also observed in the mostly neutral condition ($F < 1$).

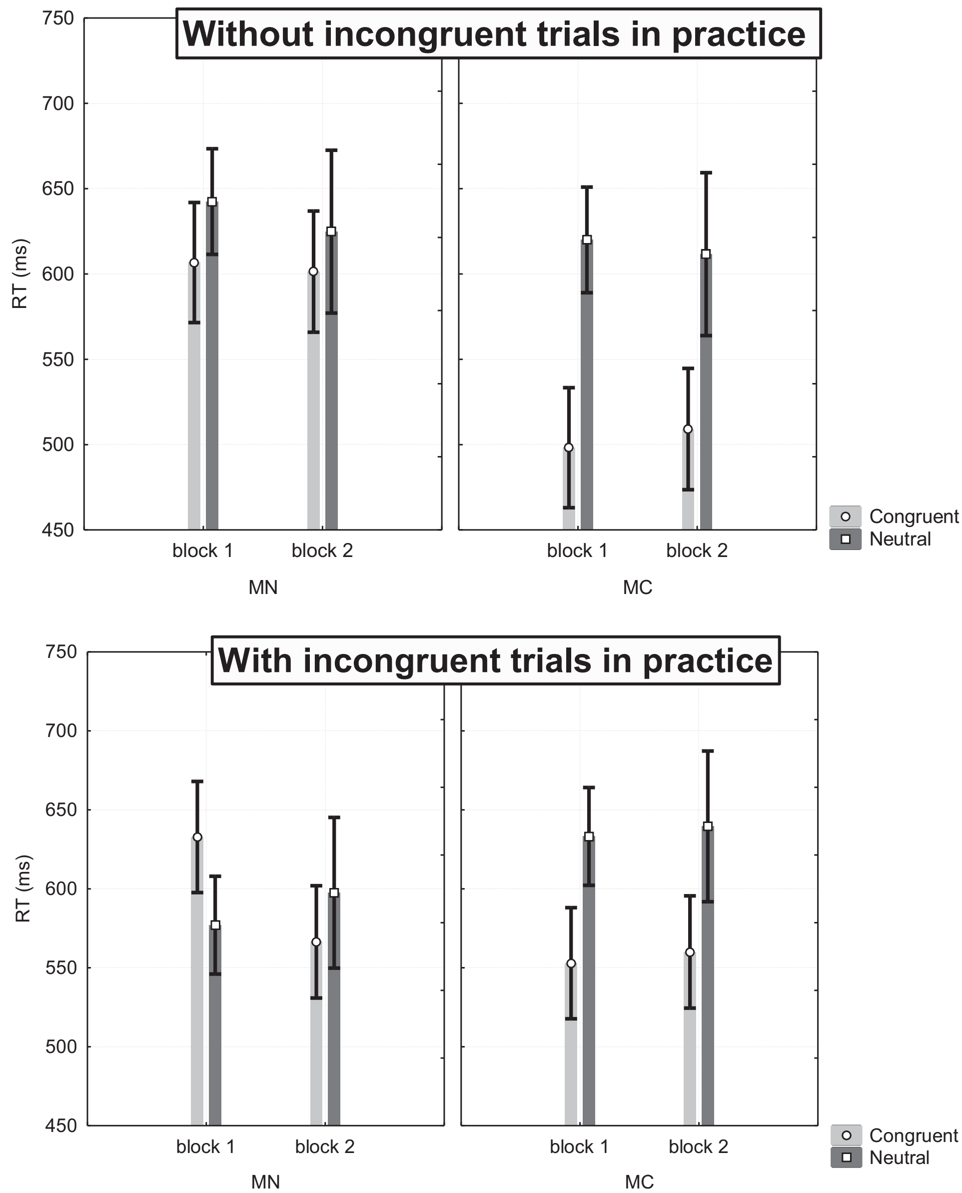

Figure 1. Mean reaction times (RTs) for congruency as a function of congruent-to-neutral ratio, practice type, and block in Experiment 1. Error bars are one standard error of the mean. MC = mostly congruent condition; MN = mostly neutral condition.

served, revealing faster responses in the MC condition than in the MN condition, $F(1, 68) = 5$, $MSE = 1{,}712{,}073$, $p = .03$, $\eta_p^2 = .07$. In addition, we also found a main effect for block, showing faster responses in the second experimental block, $F(1, 68) = 19.52$, $MSE = 1{,}162$, $p < .001$, $\eta_p^2 = .22$. The interactions between congruency and practice, and between congruency and block were significant, $F(1, 68) = 19.52$, $MSE = 2{,}860$, $p < .002$, $\eta_p^2 = .22$, and $F(1, 36) = 14.38$, $MSE = 622$, $p < .001$, $\eta_p^2 = .17$, respectively, as was the interaction between block and practice type, $F(1, 68) = 14.92$, $MSE = 1{,}220$, $p < .001$, $\eta_p^2 = .18$. The three-way interaction between congruency, congruent-to-neutral ratio, and practice type was also significant, $F(1, 68) = 8.80$, $MSE = 515$, $p < .005$, $\eta_p^2 = .11$. The four-way interaction between congruency, block, congruent-to-neutral ratio, and practice type was significant as well, $F(1, 68) = 7.20$, $MSE = 515$, $p = .009$, $\eta_p^2 = .10$ (see Figure 2). There was no significant difference in the case of neutral trials, that is, the manipulations we used affected only the congruent trials (Fs < 1). No additional effects were significant (see Table 3 and Table S2 in the online supplemental material).

Focusing on the conditions in which participants did not experience incongruent trials (see the left side of Figure 2) revealed two significant simple interactions. The first one between congruency and block, $F(1, 34) = 21.88$, $MSE = 348$, $p < .001$, $\eta_p^2 = .39$, was due to a larger facilitation effect in the second experimental block,

Table 2
Mean Reaction Time (RT; in ms) and Percentage Error (PE) for Congruency as a Function of Practice Type, Congruent/Neutral (C/N) Ratio, and Block in Experiment 1

Practice type	C/N ratio	Congruency	Block	*M* RT (*SD*)	PE (*SD*)
Without incongruent trials in practice	MC	Congruent	1	508.91 (66.09)	.17 (.57)
			2	503.62 (44.77)	.00 (.00)
		Neutral	1	628.33 (52.72)	.00 (.00)
			2	621.72 (75.9)	.33 (1.154)
	MN	Congruent	1	598.68 (70.72)	.167 (.57)
			2	599.13 (41.64)	1.75 (4.98)
		Neutral	1	619 (69.4)	.58 (1.24)
			2	617.89 (85.76)	2.58 (4.72)
With incongruent trials in practice	MC	Congruent	1	543.72 (38.39)	.5 (.90)
			2	562.59 (54.74)	1.25 (4.025)
		Neutral	1	609.97 (52.72)	1.75 (4.86)
			2	621.75 (50.24)	2.75 (7.12)
	MN	Congruent	1	636 (66.09)	.00 (.00)
			2	581.76 (64.46)	.5 (.90)
		Neutral	1	600.46 (66.09)	.17 (.58)
			2	616.06 (76.36)	.33 (.78)

Note. MC = mostly congruent; MN = mostly neutral.

$F(1, 34) = 21.88$, $MSE = 348$, $p < .001$, $\eta_p^2 = .39$, $BF_{10} = 3.16$. The second simple interaction appeared between congruency and C/N ratio, $F(1, 34) = 7.81$, $MSE = 4{,}167$, $p < .008$, $\eta_p^2 = .19$. This interaction was due to a larger facilitation effect in the MC condition than in the MN condition, $F(1, 34) = 31.8$, $MSE = 4{,}167$, $p < .001$, $\eta_p^2 = .48$, $BF_{10} = 7{,}961.312$ (see the upper panel on the left side of Figure 2). By revealing regular facilitation effects, these results replicated the findings of Experiment 1, demonstrating no conflict detection, and thereby no control recruitment in the absence of incongruent trials. Moreover, the strong facilitation observed in the MC condition supports the notion that instead of control over the reading process, participants were more prone to read (i.e., inadvertent reading, Entel & Tzelgov, 2018; see also Macleod & Macdonald, 2000).

The picture was different when incongruent trials were added to practice (see the right side of Figure 2). A significant simple three-way interaction between congruency, block and C/N ratio was found, $F(1, 34) = 5.31$, $MSE = 682$, $p < .02$, $\eta_p^2 = .14$. Decomposing this interaction revealed a significant simple two-way interaction between congruency and block in the MC condition (see the upper panel on the right side of Figure 2), $F(1, 17) = 5.04$, $MSE = 274$, $p < .04$, $\eta_p^2 = .23$. This interaction was due to a facilitation effect that grew larger in the second block, $F(1, 17) = 19.29$, $MSE = 333$, $p < .001$, $\eta_p^2 = .53$, $BF_{10} = 110$. There was no significant interaction between congruency and block in the MN condition ($F > 1$). A negative facilitation was observed in this condition (see the bottom panel on the right side of Figure 2), $F(1, 17) = 21.07$, $MSE = 2{,}225$, $p < .002$, $\eta_p^2 = .55$, $BF_{10} = 156.42$. As hypothesized and in line with our first experiment and previous studies (Entel & Tzelgov, 2018; Entel et al., 2015), exposure to incongruent trials during practice resulted in negative facilitation, providing further support to our claim that incongruent trials are essential to detect and control task conflict.

The PE was very low, averaging 0.4%. A four-way mixed-model ANOVA with C/N ratio and practice as between participant factors, and congruency and block as within participant factors, revealed no significant results.

The main finding of the present experiment—a negative facilitation observed across the different experimental blocks—clearly supports the hypothesis that the activation of proactive control over the task conflict is episode-related. In the absence of an experimental break that would indicate to the participants that the episode was over, the same pattern of results across the different blocks was observed.

Experiment 3

As suggested by Meiran et al. (2012; see also Cohen-Kdoshay & Meiran, 2007), an additional precondition for a novel plan to be activated in WM is the availability of (limited) WM resources. Therefore, the purpose of the present study was to test whether loading WM resources would eliminate the effects observed immediately after experiencing incongruent trials in practice, but before the experimental break in Experiment 1, that is, a decreased facilitation in the MC condition and a negative facilitation effect in the MN condition. This was done by loading WM with a secondary go/no-go task instruction (we used a secondary task that was used in Cohen-Kdoshay & Meiran, 2007, Experiment 4). Specifically, in addition to instructing participants to carry out a Stroop task, each block also included a novel go/no-go task to be performed on rare occasions. This task involved clearly distinguishable target stimuli (Numbers 1 to 9) and required a "go" response if the stimulus met a certain criterion (such as being divisible by three). We compared two experimental groups. In the high-WM load group, instructions were different for each go/no-go trial (i.e., each trial where a number was presented). In this way, instructions could not be simply memorized, but they needed to be stored in WM all over again. For example, the instructions were to indicate yes or no when a number that was/was not divisible by two or three appeared on a different slide (nine slides overall) and disappeared before the number trial appeared. After a response, a new instruction slide appeared and its instructions were relevant until the next number trial, so that participants had to keep the instructions in WM. A different instruction slide appeared after the participants'

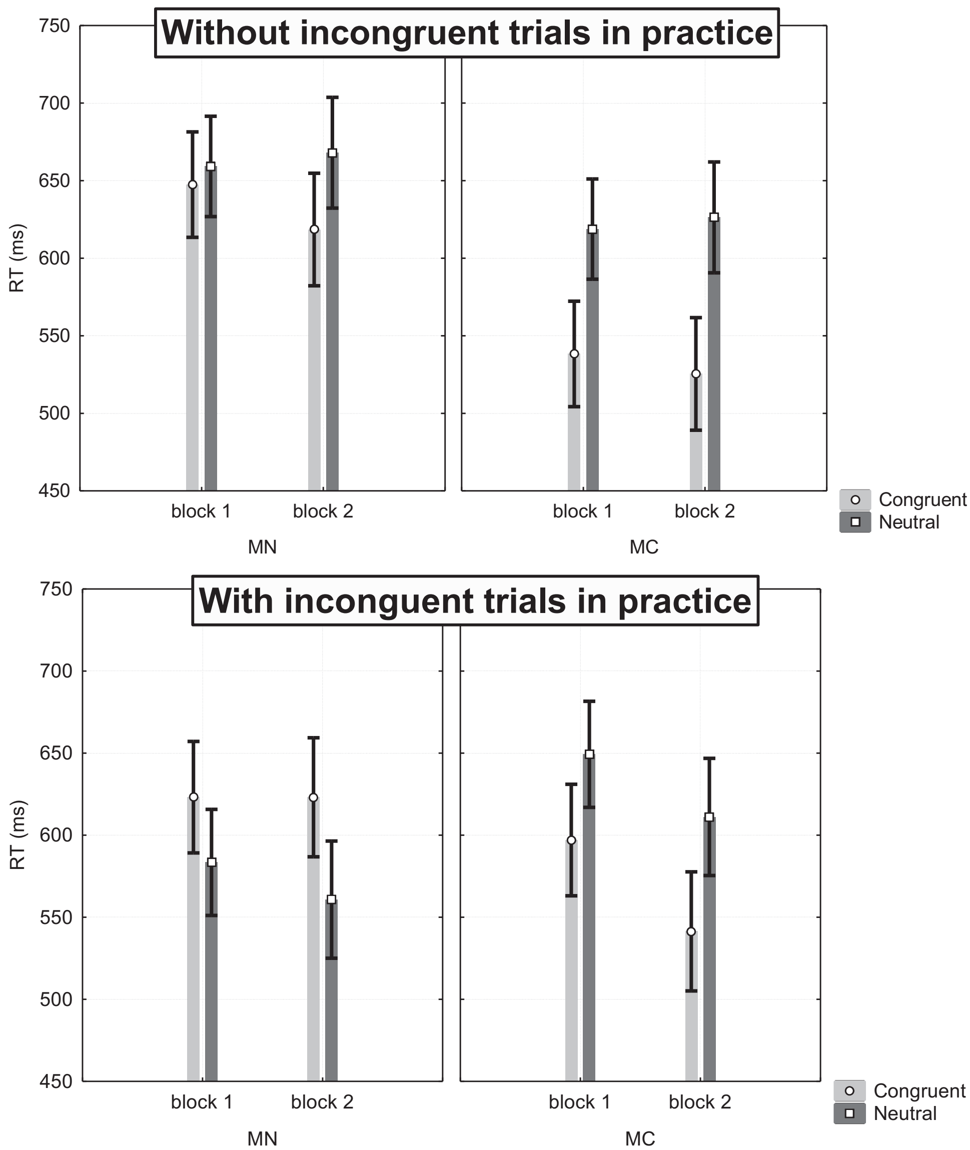

Figure 2. Mean reaction times (RTs) for congruency as a function of congruent-to-neutral ratio, practice type, and block in Experiment 2. Error bars are one standard error of the mean. MC = mostly congruent condition; MN = mostly neutral condition.

response. In the low-WM load group, the go/no-go task instructions remained the same throughout the experiment (e.g., the instructions were to indicate yes only when a number that was divisible by two appeared at the beginning of the experiment, and was relevant to all number trials). In this group, the load increased multitasking demands but did not load WM (because the load task could have been represented in long-term memory). In the high-WM load condition, we expected to find a strong facilitation effect in the MC condition and a regular facilitation effect in the MN condition, regardless of the different practice type conditions. In the low-WM condition, however, we expected a different pattern of results. Namely, we expected to find a decreased facilitation in the MC condition and a negative facilitation in the MN condition after participants experienced incongruent trials in practice, suggesting that only when WM is fully available will proactive control become activated.

Method

Participants. Students from Ben-Gurion University of the Negev ($N = 144$), who had not participated in Experiments 1 and 2 participated in this experiment. All were native speakers of Hebrew and had reported normal or corrected-to-normal eyesight, with normal color vision. The participant criteria were the same as for Experiment 1.

Design and procedure. Three independent variables, congruent-to-neutral ratio (MC or MN), practice type (with incongruent trials or without incongruent trials), and WM load

Table 3
Mean Reaction Time (RT; in ms) and Percentage Error (PE) for Congruency as a Function of Practice Type, Congruent/Neutral (C/N) Ratio, and Block in Experiment 2

Practice type	C/N ratio	Congruency	Block	*M* RT (*SD*)	PE (*SD*)
Without incongruent trials in practice	MC	Congruent	1	538.28 (74.65)	1.2 (1.4)
			2	525.41 (85.88)	1.5 (1.58)
		Neutral	1	618.78 (59.37)	.00 (.00)
			2	626.32 (70.18)	.2 (.42)
	MN	Congruent	1	647.43 (74.95)	.8 (2.53)
			2	618.48 (83.29)	.00 (.00)
		Neutral	1	659.19 (99.67)	.1 (.32)
			2	668.01 (115.06)	.00 (.00)
With incongruent trials in practice	MC	Congruent	1	597.05 (83.79)	.00 (.00)
			2	541.4 (82.76)	.00 (.00)
		Neutral	1	649.29 (64.32)	.1 (.32)
			2	611.14 (63.58)	.00 (.00)
	MN	Congruent	1	623.17 (51.60)	.00 (.00)
			2	623.11 (51.35)	.00 (.00)
		Neutral	1	583.45 (35.8)	.8 (2.53)
			2	560.76 (29.38)	1.6 (3.37)

Note. MC = mostly congruent; MN = mostly neutral.

(high-WM load or low-WM load) were manipulated between participants, thus generating eight between participant experimental conditions. Eighteen participants were randomly assigned to each of them. Congruency (congruent or neutral) was manipulated within participants. The experiment began with a practice block of 46 trials that was divided into two parts (see Cohen-Kdoshay & Meiran, 2007). The first part included 28 Stroop stimuli (24 congruent and four neutral trials in the MC condition; 24 neutral and four congruent trials in the MN condition). In conditions with incongruent trials in practice, the first part consisted of 20 congruent, four incongruent and four neutral trials in the MC condition, and 20 neutral, four incongruent and four congruent trials in the MN condition. The second part included 18 trials of the secondary task. The task we used was a go/no-go task in response to numbers (1 to 9). The numbers were printed in black color, in boldface, 18-point, Courier New font. Each number appeared in the center of the screen along with the relevant instructions appearing at the top. In the low-WM load condition, the go/no-go task instructions remained the same throughout the experiment (e.g., say yes only when you see a number that is divisible by two). In contrast, we introduced a different set of instructions for each number trial in the high-WM load condition (e.g., say yes or no only when you see a number that is/is not divisible by two or three). We also changed the font used to display the numbers. After practice, the participants performed an experimental block of 138 trials—120 Stroop trials (108 congruent and 12 neutral trials in the MC condition; 108 neutral and 12 congruent trials in the MN condition), along with 18 number trials that appeared in random order (in the high-WM load condition, each number trial appeared with a different instruction, whereas the instructions were always the same in the low-WM load condition).

Results and Discussion

For each participant, mean RTs of correct responses and the PE in each experimental condition were calculated. RTs of error trials were omitted (less than 1% of all responses) as were RTs slower than 2,500 ms and faster than 250 ms (less than 3% of all responses). A four-way mixed-model ANOVA with congruency as a within participant factor, and congruent-to-neutral ratio, practice type and load as between participant factors revealed faster responses for congruent trials than for neutral trials, $F(1, 136) = 31.43$, $MSE = 2{,}380$, $p < .001$, $\eta_p^2 = .19$. A significant effect was observed for practice type, revealing faster responses when incongruent trials were not experienced in practice, $F(1, 136) = 20.16$, $MSE = 9{,}200$, $p < .001$, $\eta_p^2 = .13$. A marginally significant effect for load was also observed, revealing faster responses in the low-WM load condition, $F(1, 136) = 3.24$, $MSE = 9{,}200$, $p = .07$, $\eta_p^2 = .02$. The two-way interactions between congruency and practice type and between congruency and C/N ratio were also significant, $F(1, 136) = 5.71$, $MSE = 2{,}380$, $p = .018$, $\eta_p^2 = .19$, and $F(1, 136) = 58$, $MSE = 2{,}380$, $p < .001$, $\eta_p^2 = .29$, respectively, as was the interactions between congruency and load, and between practice type and C/N ratio, $F(1, 136) = 5.61$, $MSE = 10{,}826$, $p = .02$, $\eta_p^2 = .04$, and $F(1, 136) = 3.51$, $MSE = 10{,}826$, $p = .06$, $\eta_p^2 = .03$, respectively. The three-way interactions between congruency, C/N ratio and load, and between practice type, C/N ratio and load were also significant, $F(1, 136) = 5.60$, $MSE = 2{,}860$, $p = .02$, $\eta_p^2 = .04$, and $F(1, 136) = 7.39$, $MSE = 2{,}380$, $p < .008$, $\eta_p^2 = .05$, respectively. The three-way interactions between practice type, C/N ratio and load, and between congruency, C/N ratio and load were significant as well, $F(1, 136) = 5.40$, $MSE = 9{,}200$, $p < .02$, $\eta_p^2 = .04$, and $F(1, 136) = 6.11$, $MSE = 2{,}380$, $p < .02$, $\eta_p^2 = .04$, respectively. In addition, the four-way interaction between congruency, practice type, load, and C/N ratio was significant, $F(1, 136) = 7.55$, $MSE = 2{,}380$, $p < .007$, $\eta_p^2 = .05$ (see Figure 3). As before, there were no significant effects for the neutral stimuli (Fs < 1). No additional effects were significant (see Table 4 and Table S3 in the online supplemental material).

Looking first at the conditions in which participants did not experience incongruent trials in practice (see the upper panel of Figure 3) revealed a significant simple interaction between congruency and C/N ratio, $F(1, 68) = 14.19$, $MSE = 2{,}219$, $p < .001$, $\eta_p^2 = .17$. This interaction was due to a simple facilitation effect that was larger in the MC condition than in the MN condition, $F(1, 68) = 25.85$, $MSE = 2{,}436.23$, $p < .001$, $\eta_p^2 = .28$, $BF_{10} = 5{,}575.987$. The three-way interaction between congruency, C/N ratio and load was not significant ($F < 1$).

The picture was different when incongruent trials were added to practice (see the bottom panel of Figure 3). A simple three-way interaction between congruency, C/N ratio and load was observed, $F(1, 68) = 13.95$, $MSE = 2{,}324$, $p < .001$, $\eta_p^2 = .17$. Decomposing this interaction, focusing on the MC condition, revealed a facilitation effect, $F(1, 34) = 42.48$, $MSE = 1{,}748$, $p < .001$, $\eta_p^2 = .55$,

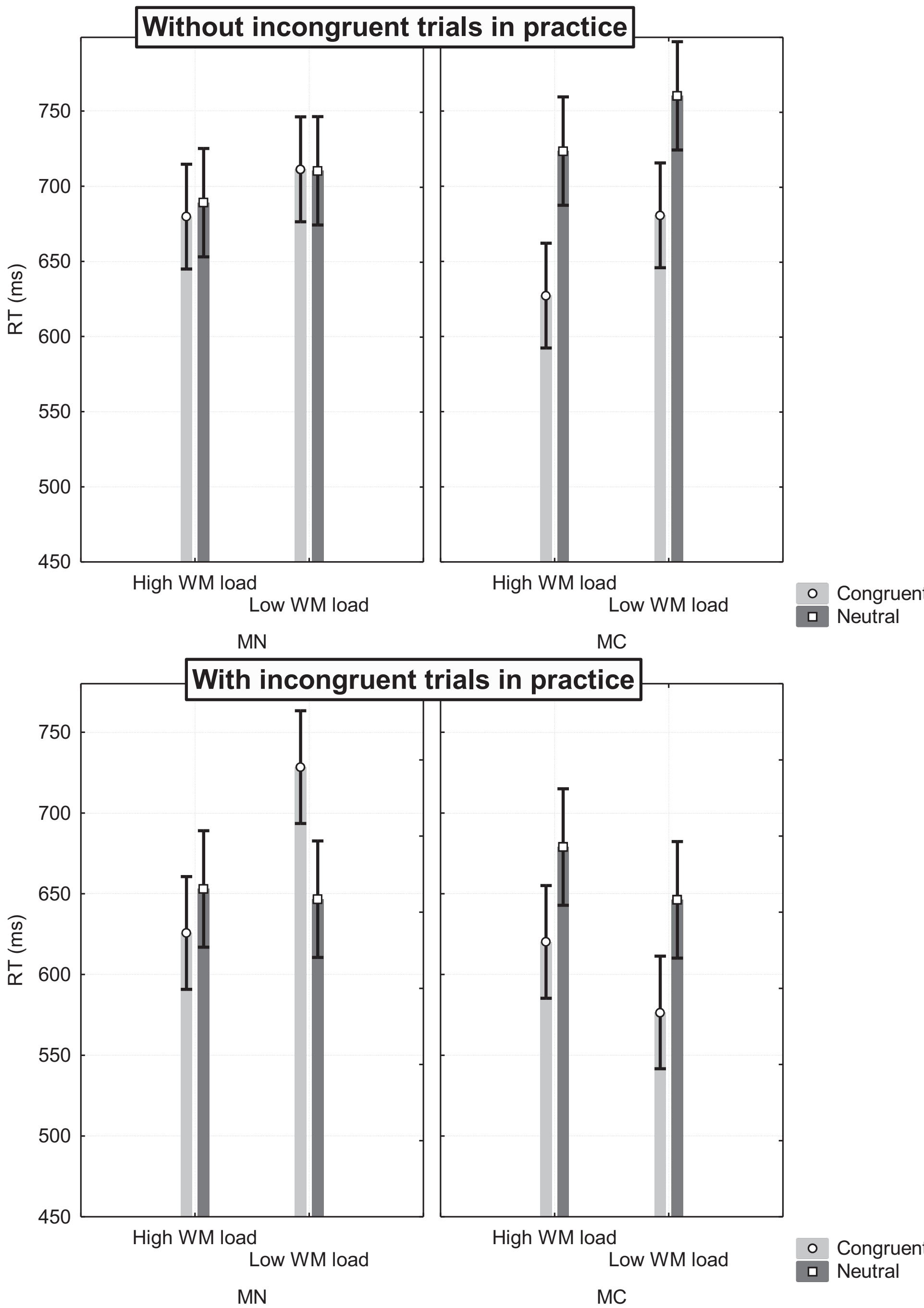

Figure 3. Mean reaction times (RTs) for congruency as a function of congruent-to-neutral ratio, practice type and load in Experiment 3. Error bars are one standard error of the mean. MC = mostly congruent condition; MN = mostly neutral condition; WM = working memory.

Table 4
Mean Reaction Time (RT; in ms) and Percentage Error (PE) for Congruency as a Function of Practice Type, Congruent/Neutral (C/N) Ratio, and Block in Experiment 3

Load	Practice type	Condition	Congruency	*M* RT (*SD*)	PE (*SD*)
Low-WM load	Without incongruent trials in practice	MC	Congruent	680.62 (92.86)	.00 (.00)
			Neutral	760.10 (73.53)	.38 (.69)
		MN	Congruent	711.25 (95.61)	.55 (1.91)
			Neutral	710.23 (93.55)	.83 (.79)
	With incongruent trials in practice	MC	Congruent	576.49 (64.24)	.11 (.32)
			Neutral	678.9 (74.27)	.16 (.51)
		MN	Congruent	625.7 (56.94)	.00 (.00)
			Neutral	652.97 (57.29)	.28 (.58)
High-WM load	Without incongruent trials in practice	MC	Congruent	627.21 (90.85)	.06 (.24)
			Neutral	723.35 (104.79)	.00 (.00)
		MN	Congruent	679.75 (76.15)	.55 (.24)
			Neutral	689.05 (80.14)	.00 (.00)
	With incongruent trials in practice	MC	Congruent	620.17 (50.9)	.00 (.00)
			Neutral	678.9 (74.27)	.00 (.00)
		MN	Congruent	627.71 (90.85)	.00 (.00)
			Neutral	652.96 (57.29)	.00 (.00)

Note. WM = working memory; MC = mostly congruent; MN = mostly neutral.

BF_{10} = 95,294.25. This facilitation was not moderated by load in this condition ($F < 1$). In contrast, a significant simple simple interaction between congruency and WM load was found in the MN condition, $F(1, 34) = 18.44$, $MSE = 2{,}900$, $p < .001$, $\eta_p^2 = .35$. This interaction was due to negative facilitation in the low-WM load condition, $F(1, 34) = 20.74$, $MSE = 2{,}900.3$, $p < .001$, $\eta_p^2 = .38$, $BF_{10} = 385.45$. There was no significant difference between C/N trials in the high-WM load condition where participants' WM was kept busy by the changing instructions of the secondary number task, $F(1, 34) = 2.30$, $MSE = 2{,}900.3$, $p < .14$, $\eta_p^2 = .06$.

Analyzing the PE (averaging 11.8% overall) revealed fewer errors when there was no incongruent trials in practice, $F(1, 136) = 17.51$, $MSE = 162.92$, $p < .001$, $\eta_p^2 = .11$. Fewer errors were found in the MC condition, $F(1, 136) = 10.32$, $MSE = 162.92$, $p < .002$, $\eta_p^2 = .04$. In addition, there were less errors in the low-WM load condition, $F(1, 136) = 21.17$, $MSE = 162.92$, $p < .001$, $\eta_p^2 = .14$.

In line with all our previous findings, the results show that incongruent trials are essential in order to trigger control of (task) conflict. More important however, from the perspective of the present study, is the support of our hypothesis that high-WM load limits controllability.[5] We did not find any indication of control involvement (i.e., decreased facilitation effect or negative facilitation) in the case of high-WM load. We obtained negative facilitation as a behavioral marker of control of task conflict only when WM resources were also available (in the low-WM load condition). Therefore, it appears that experiencing incongruent trials and availability of WM resources are both needed to apply control. As in Experiments 1 and 2, we conducted a posteriori power analysis using the G-power program (Faul et al., 2007). Similar to our previous results, this analysis revealed that seven participants per condition were enough in order to observe the negative facilitation effect (100% chance to observe the effect if it exists, with an effect size of 0.7) in the low load condition.

Experiment 4

Experiment 3 showed that there was less (if at all) control recruitment when there were not enough WM resources (i.e., in the high-WM load condition). In the present experiment, we manipulated not only WM availability (Experiment 3) but also added an experimental break that could be interpreted as an episode-termination (Experiment 1), in order to provide a more comprehensive picture of the recruitment of proactive control. Because we were interested in the proactive control and our results until now clearly showed that such control was activated by experiencing incongruent trials, this time we exposed all participants to incongruent trials in the preexperimental practice. Similar to the third experiment, we kept WM busy by a secondary number task, this time using more complex secondary task instructions. In the high-WM load condition, participants were asked to decide whether the number they saw was divisible/not devisable by the last number they saw previously (e.g., say yes/no only if the number you see is/is not divisible by the last number you have seen). The instructions for the low-WM load group were constant (e.g., say yes only if the number you see is divisible by the **first** number you have seen). Similar to our first experiment, we employed 120 Stroop trials but added an experimental break after the first 60 trials. Each experimental part also included nine number

[5] The analysis of the secondary WM task in Experiment 3 (as a manipulation check) revealed faster responses in the low load condition, $F(1, 136) = 685.54$, $MSE = 26{,}047$, $p < .01$, $\eta_p^2 = .83$. In addition, in this condition, faster responses were observed when participants did not experience incongruent trials, $F(1, 70) = 4.37$, $MSE = 13{,}006$, $p = .04$, $\eta_p^2 = .06$. There was no significant difference, however, between the RTs for the numbers in the high-WM load condition, $F(1, 136) = 2.63$, $MSE = 37{,}893$, $p = .1$, *ns*, $\eta_p^2 = .04$. Analyzing the PE (averaging 11.8% overall) revealed fewer errors when there were no incongruent trials in practice, $F(1, 136) = 17.5$, $MSE = 162.92$, $p < .01$, $\eta_p^2 = .11$. Fewer errors were found in the low-WM load condition, $F(1, 136) = 21.2$, $MSE = 162.92$, $p < .01$, $\eta_p^2 = .14$. In addition, there were fewer errors in the MC condition, $F(1, 136) = 10.32$, $MSE = 162.92$, $p < .01$, $\eta_p^2 = .04$.

trials (i.e., Numbers 1 to 9) that appeared randomly (e.g., 48 congruent trials, 12 neutrals, and nine number trials in the MC condition; 48 neutral trials, 12 congruent trials, and nine number trials in the MN condition). In contrast to our previous design, in this experiment C/N ratio was manipulated within participants, thus allowing for a more sensitive analysis. If our hypothesis was correct and less (if at all) control was triggered in the high-WM load condition, we expected a regular facilitation across the levels of C/N ratio in this condition. In the low-WM load condition, however, we expected a negative facilitation in the MN condition that would disappear after the break, revealing faster responses for congruent trials than for neutrals. In addition, we expected to find the regular (simple) facilitation effect in the MC condition.

Method

Participants. Forty-eight students from Ben-Gurion University of the Negev, who had not participated in Experiments 1, 2, and 3, participated in this experiment. All were native speakers of Hebrew and reported normal or corrected-to-normal eyesight, with normal color vision. The participant criteria were the same as for our previous experiments.

Design and procedure. Load (high-WM load or low-WM load) was manipulated between participants. Congruency (congruent or neutral), block (1 or 2), and C/N ratio (MC or MN) were manipulated within participants. There was a day difference between the time the participants performed the MC and MN conditions. Participants performed the two conditions at the same hour of the day (the order of the conditions was counterbalanced). The experiment began with a practice block of 46 trials that was divided into two parts—first, participants performed 28 Stroop trials (20 congruent, four neutral, and four incongruent trials in the MC condition; 20 neutral, four congruent, and four incongruent trials in the MN condition), and then 18 number trials. After practice, the participants performed two experimental blocks of 69 trials (48 neutral trials, 12 congruent trials, and nine number trials in the MN condition; 48 congruent trials, 12 neutral trials, and nine number trials in the MC condition). Similar to our first experiment, after the first experimental break a slide appeared on the screen that stated the following: “This part is over. Take a short break. To continue to the next part of the experiment, press any key.”

Results and Discussion

For each participant, mean RTs of correct responses and the PE in each experimental condition were calculated. RTs of error trials were omitted (less than 3% of all responses) as were RTs slower than 2,500 ms and faster than 250 ms (less than 2% of all responses). All effects were tested at a significance level (α) of .05. A four-way mixed-model ANOVA with congruency, C/N ratio and block as within participant factors, and load as between participant factors, revealed a significant main effect for congruency, $F(1, 46) = 76.30$, $MSE = 3{,}365$, $p < .001$, $\eta_p^2 = .63$, with faster responses for congruent trials than for neutral trials. The two-way interaction between congruency and load was significant, $F(1, 46) = 7.08$, $MSE = 3{,}365$, $p = .01$, $\eta_p^2 = .13$, as was the interaction between block and load, $F(1, 46) = 8.17$, $MSE = 2{,}143$, $p = .006$, $\eta_p^2 = .15$. The interactions between congruency and C/N ratio, $F(1, 46) = 10.97$, $MSE = 1{,}937$, $p = .02$, $\eta_p^2 = .12$, and block and C/N ratio, $F(1, 46) = 8.56$, $MSE = 1{,}562$, $p = .005$, $\eta_p^2 = .16$, were also significant. In addition, the four-way interaction between congruency, C/N ratio, block and load was significant, $F(4, 184) = 5.89$, $MSE = 1{,}416$, $p = .02$, $\eta_p^2 = .11$ (see Figure 4). No additional effects were significant (see Table 5 and Table S4 in the online supplemental material).

The high-WM load condition (see upper panel of Figure 4) revealed a significant facilitation effect, $F(1, 23) = 61.04$, $MSE = 3{,}580$, $p < .01$, $\eta_p^2 = .73$, $BF_{10} = 168{,}727$. No other effects were significant.

Similar to the pattern observed in our third experiment, the low-WM load condition (see bottom panel of Figure 4) showed a significant simple three-way interaction among congruency, block, and C/N ratio, $F(1, 23) = 8.97$, $MSE = 1{,}534$, $p = .006$, $\eta_p^2 = .30$. Decomposing this interaction, revealed facilitation in the MC condition, $F(1, 23) = 22.5$, $MSE = 1{,}764.1$, $p < .001$, $\eta_p^2 = .50$, $BF_{10} = 414.08$, which was not moderated by block ($F < 1$). In contrast, we observed a significant simple simple interaction between congruency and block in the MN condition, $F(1, 23) = 14.4$, $MSE = 1{,}683.8$, $p < .001$, $\eta_p^2 = .38$. A significant negative facilitation effect was observed in the first block, $F(1, 23) = 13.71$, $MSE = 2{,}063.01$, $p < .01$, $\eta_p^2 = .37$, $BF_{10} = 44.14$. This effect was reversed into a regular facilitation after the break, $F(1, 23) = 11.79$, $MSE = 2{,}370.06$, $p < .01$, $\eta_p^2 = .34$, $BF_{10} = 25.02$, replicating our previous results (Entel & Tzelgov, 2018) and the results the present Experiment 1.

The PE was low, averaging 2.1%. A four-way mixed-model ANOVA with congruency, block, and C/N ratio as within participant factors and load as a between participant factor revealed no significant effects.

As expected, these findings replicated the results of our previous experiments (Experiments 1, 2, and 3), supporting the notion that the proactive ability to control performance depends on WM; it is episode-based and is significantly damaged (if not eliminated) when there are not enough WM resources.[6] Of course, incongruent trials are essential to detect and thereby control performance, but it is not enough, available WM resources are also needed to be able to recruit proactive (task) control.

General Discussion

In the present study, we investigated the relations between WM and the Stroop effect. The uniqueness of our study lays in its atypical design that assesses control via the negative facilitation effect rather than through incongruent trials (or the congruency effect). Only congruent color words were included in the experimental trials, which allowed focusing the study on the effects of task control in experimental blocks that do not included incongruent trials. In other words, we tested the effect of expectations for incongruent stimuli on the modulation of facilitation by the proportion of congruent versus neutral stimuli in the experimental block. Note that task conflict exists each time a readable stimulus is presented, and its magnitude can be estimated (Entel et al.,

[6] The analysis of the secondary WM Task in Experiment 4 (manipulation check) revealed faster responses for numbers in the low load condition, $F(1, 47) = 18.7$, $MSE = 11{,}951$, $p < .01$, $\eta_p^2 = .17$. Analyzing the PE (averaging 14.8% overall) revealed fewer errors in the low load condition, $F(1, 47) = 14.41$, $MSE = 217.13$, $p < .01$, $\eta_p^2 = .23$.

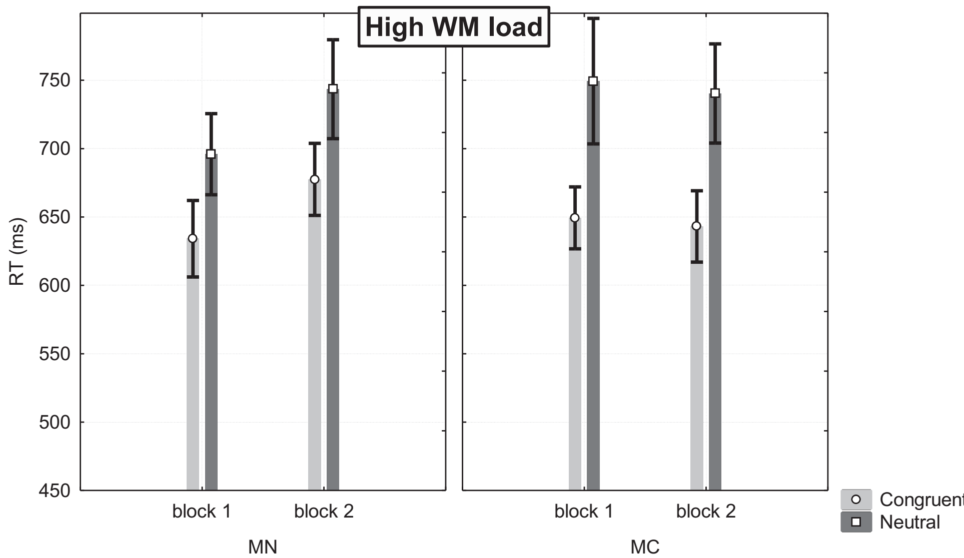

Figure 4. Mean reaction times (RTs) for congruency as a function of congruent-to-neutral ratio, load, and block in Experiment 4. Error bars are one standard error of the mean. All participants experienced incongruent trials in practice. MC = mostly congruent condition; MN = mostly neutral condition; WM = working memory.

2015). Negative facilitation is a unique case of task conflict because the conflict is dominant and hence it is visible behaviorally.

When the practice block generated no expectation for incongruent stimuli, a strong facilitation appeared in the mostly congruent condition and a smaller, yet significant, facilitation appeared in the mostly neutral condition. When incongruent trials were added to practice, a negative facilitation effect (a behavioral marker of task conflict) was observed in the first block in the mostly neutral condition. Negative facilitation disappeared in the second block after a break between the two blocks, supporting the notion of a "plan to execute an episode" (see also Meiran et al., 2012). In other words, the experimental break indicated that the episode was terminated and therefore after the break, proactive control was no longer applied. It should be noted that we did analyze the practice block in our experiments. The results were like those we found in first experimental blocks, but less strong and some did reach significance. For example, we observed negative facilitation in the practice block in the MN condition both in Experiment 1 and in Experiment 2, however it was less strong. Even so, it does support the notion of proactive control, demonstrating control involvement from the very beginning of the experiments. Descriptive analysis of the incongruent trials in the practice phase showed that participants did not tend to make more errors on those trials and it was truly the experience of informational conflict (without errors generally) that led to the differing pattern of results when incongruent trials were included (see Table 6).

Table 5
Mean Reaction Time (RT; in ms) and Percentage Error (PE) for Congruency as a Function of Practice Type, Congruent/Neutral (C/N) Ratio, and Block in Experiment 4

Load	Condition	Congruency	Block	*M* RT (*SD*)	PE (*SD*)
Low-WM load	MC	Congruent	1	598.68 (38.29)	.6 (.96)
			2	644.07 (45.25)	.3 (.68)
		Neutral	1	648.23 (51.01)	1.1 (2.47)
			2	705.66 (66.31)	1.1 (2.51)
	MN	Congruent	1	697.89 (59.95)	.5 (.71)
			2	628.51 (57.92)	.7 (1.059)
		Neutral	1	642.18 (48.69)	1.1 (2.51)
			2	713.84 (125.62)	1.00 (2.49)
High-WM load	MC	Congruent	1	634.16 (59.11)	2.3 (5.33)
			2	677.49 (80.5)	2.4 (3.86)
		Neutral	1	695.91 (57.65)	.9 (1.20)
			2	743.46 (77.38)	1.3 (2.50)
	MN	Congruent	1	649.37 (54.59)	.8 (1.32)
			2	643.13 (48.13)	.4 (.58)
		Neutral	1	749.38 (142.91)	1.3 (2.49)
			2	740.31 (121.93)	1.00 (1.15)

Note. WM = working memory; MC = mostly congruent; MN = mostly neutral.

Table 6
Mean Reaction Time (RT; in ms) and Percentage Error (PE) for Incongruent Trials in Practice in all Experiments

Experiment	Condition	Load	*M* RT (*SD*)	PE (*SD*)
1	MN		843.93 (133.28)	1.75 (2.05)
	MC		788.73 (65.55)	2.75 (3.02)
2	MN		902.28 (179.86)	2.50 (7.07)
	MC		847.91 (189.41)	1.75 (4.94)
3	MN	Low	992 (197.34)	.00 (.00)
	MC	Low	10,009.34 (169.46)	.30 (1.03)
	MN	High	980.15 (216.26)	.00 (.00)
	MC	High	991.72 (167.66)	.00 (.00)
4	MN	High	1,052 (192.92)	.38 (1.06)
	MC	High	891.43 (287.26)	.00 (.00)

Note. MC = mostly congruent; MN = mostly neutral.

An alternative interpretation for these results would be that proactive control continuously decreases throughout the first block, as participants discover that there are in fact no incongruent trials in the task. However, this conclusion is not supported by our second experiment in which we showed that in the absence of a break, the negative facilitation continued throughout the experiment. Performing an additional analysis of the data from the MN condition in Experiment 1 (in this condition negative facilitation was found in the first block, and a regular facilitation in the second block), we tested whether there was a step function or a continuously monotonous reduction of control until the break. This was done by analyzing the modification of the latency gap between C/N trials throughout the experiment. We divided each experimental block in this condition into three miniblocks (of 20 trials each), creating six miniblocks overall. First, we compared between the first three miniblocks and the last three miniblocks. A significant difference was found. There was no difference within the first three miniblocks (Miniblocks 1, 2, and 3), and within the last three miniblocks (Miniblocks 4, 5, and 6), showing that the level of control did not diminish monotonously throughout the experiment. Comparing between the latencies of the third miniblock and the fourth miniblock (just before the break and immediately after the break) revealed a significant step function (see Figure S1 in the online supplemental material). The change appeared after the experimental break, thus supporting our interpretation of the results.[7] Please note that the facilitation in the first three miniblocks was negative indicating that control was applied, whereas from the fourth block on, facilitation was positive indicating that there was not enough control.

Our results may seem to contradict the article by Cohen-Shikora, Diede, and Bugg (2018). In that study, control vanished after only six trials when the event signaling control (list-wide proportion congruency) disappeared. In their study, younger and older adults named the color of color words in abbreviated lists of trials. They manipulated the first part of the list (six experimental trials) changing the proportion of the congruent and incongruent stimuli (i.e., mostly congruent condition or mostly incongruent condition). The middle and late parts were 50% congruent in both conditions. Both younger and older adults demonstrated flexible acquisition and shifting of control as indexed by changes in the Stroop effect from one part of the list to another, shifting from a setting that corresponded to the initial MC/MI proportion in the first experimental part to a more neutral setting in the following parts. The main difference between Cohen-Shikora et al.'s and our studies rests in the manipulation of control. Their manipulation involved experience with incongruent stimuli throughout the experiment and hence, may involve also reactive control (Braver, 2012). However, this form of control is different from proactive control applied in our experiments because in our case it reflects experience acquired in a preexperimental episode.

Our results can be explained by the suggestion that proactive control, when it comes before the real experience (i.e., intentional planning), may actually prevent participants from processing highly relevant information, such as not noticing that there are no actual experiences with incongruent trials during the experiment (e.g., Goschke & Dreisbach, 2008; Meiran et al., 2012). A similar idea suggesting that a high level of proactive control could make reactive control irrelevant, and therefore less implemented by participants, was introduced by Hutchison, Bugg, Lim, and Olsen (2016).

Loading WM by additional processing requirements resulted in no sensitivity to the congruent versus neutral proportion and reduced facilitation to its regular size. This supports the hypothesis that availability of WM resources is needed for obtaining negative facilitation as a behavioral marker of task conflict. This finding is in line with the fact that cognitive control is costly in terms of cognitive resources (e.g., Botvinick et al., 2001; Braver et al., 2007).

It is worthy to note the fact that the proportion manipulation we used (congruent vs. neutral trials) affected only the congruent trials, emphasizing that the changes in performance (i.e., decreased facilitation and negative facilitation effects) should be attributed exclusively to the effects of control recruitment on the reading process. Specifically, this design (i.e., excluding incongruent trials from the experimental blocks) allowed us to focus exclusively on task conflict because congruent trials are free of informational conflict.

Based on these results, it can be assumed that individual differences in WM capacity will affect performance in the Stroop task, influencing the ability to trigger proactive control. As WM capacity is believed by many to reflect ability to control attention (e.g., Cowan et al., 2005; Kane et al., 2001), individuals with high-WM capacity should be able to exclude task-

[7] We divided each experimental block into three parts (20 trials per part), creating six miniblocks. Comparing between the first three miniblocks and the last three miniblocks (i.e., −1–1 −1 1 1 1), revealed a significant contrast, $F(1, 35) = 12.77$, $MSE = 24{,}211.6$, $p < .004$, $\eta_p^2 = .54$, $BF_{10} = 44.01$. We further estimated the relative contribution of this contrast to the total effect (i.e., the observed interaction between congruency and block) by dividing the sum of squares due to this contrast by the sum of squares due to the two congruency conditions, alternated by the different experimental blocks. Estimating the unique contribution of this contrast revealed that it explained 98% of the variability (in terms of r^2 alerting, Rosnow, Rosenthal, & Rubin, 2000). There was no significant difference within the first three miniblocks and within the last three miniblocks (the contrasts [–2 1 1 0 0 0; 0 1–1 0 0 0; 0 0 0–2 1 1; and 0 0 0 0–1 1] were all nonsignificant [*F*s < 1]). Moreover, comparing between the third miniblock and the forth miniblock (just before and immediately after the break; 0 0–1 1 0 0) revealed a significant contrast, $F(1, 35) = 5.89$, $MSE = 25{,}527.6$, $p < .05$, $\eta_p^2 = .31$, $BF_{10} = 3.22$. Therefore, we can conclude that the control did not diminish monotonously throughout the blocks. A significant transition appeared after the end of the first three miniblocks.

irrelevant information from the mind more effectively than can individuals with low-WM capacity. Namely, performance in the Stroop task should be faster and more accurate as WM capacity increases. Morey et al. (2012) compared relationships between WM capacity and a color-word Stroop task. They found that Stroop interference decreased as WM capacity increased in the high proportion of congruent trials condition. We suggest that this point should be further investigated from the task conflict perspective.

Control mechanisms are frequently classified as proactive or reactive. Proactive control is activated before the participant encounters the stimulus while reactive control is generated by the stimulus onset (Braver et al., 2007). In the DMC model (the dual mechanism model), proactive control is implemented as a long-term aggregator of (response) conflict. This allowed the model to be sensitive to longer term statistics of conflict signals and explain phenomena like list-wide proportion congruency effects. That idea explains why incongruent trials are necessary in the preexperimental practice to observe negative facilitation effects in the mostly neutral condition. The unique importance of our study lays in showing how control of automatic processing such as reading is applied through WM in the absence of actual response conflict. Our findings show that available WM resources are essential in order to recruit (proactive) control. In the absence of enough WM resources, the ability to control performance is significantly damaged. Given the relevant literature, it seems that low-WM resources make it difficult to actively maintain the plan to control behavior (and thus to implement control). Based on the assumption that instructions held in WM can lead to autonomous response activation even without any practice (Cohen-Kdoshay & Meiran, 2007, 2009), we may argue that such a process reflects a "goal directed" feedback loop based on extremely short-term links that were formed by the instructions alone and existed prior to actual task performance (a distinction between short-term and long-term links has been proposed in the literature, Cohen-Kdoshay & Meiran, 2009; see also De Houwer, 2004; Proctor & Vu, 2002; Tagliabue, Zorzi, Umiltà, & Bassignani, 2000).

Miller, Galanter, and Pribram (1960) expressed this definition of control in a generic feedback loop called a TOTE unit (i.e., "test, operate, test, exit,"). The loop involves a comparison of the current state with the goal state, followed by the execution of an operation intended to reduce the difference between the current state and the goal state, followed by another comparison of the current state with the goal state (test). If the current state matches the goal state, the task is completed, otherwise the operate phase is engaged again until the goal state is attained.

Botvinick et al. (2001) modeled the control in the Stroop task by extending Cohen et al.'s (1990) work. According to their model, increase of control is triggered when the conflict monitoring module detects conflict in the response layer. A modified version of their model has been recently suggested (Entel & Tzelgov, 2018; see also Levin & Tzelgov, 2014). According to this model, conflict arises due to activation of two different responses by incongruent stimuli, whereas its control acts by focusing on task demands, that is, focusing on the relevant task as a result of an input from the informational conflict. In other words, informational conflict is the one being monitored, whereas task conflict is the one directly controlled. The reduction of informational conflict is a byproduct of this control.

Our findings are in line with this modified version of the conflict-monitoring model. Besides emphasizing the importance of available WM resources, our findings also demonstrate, as already shown elsewhere (Entel & Tzelgov, 2018; see also Levin & Tzelgov, 2017), that in the absence of informational conflict, task conflict is not monitored and as a result, control is not trigged. Our third experiment clearly showed no control recruitment in the group that did not experienced incongruent trials in practice even though there were enough available WM resources. That is, experiencing or at least expecting informational conflict was essential for revealing and controlling conflict.

It is important to note that there is reduced reading of the word in congruent trials when there are incongruent trials and/or when the list is mostly neutral, not only when the two conditions are met simultaneously. The top right and bottom left panels of Figure 1 are a good example of this. Word reading is reduced when most stimuli are neutral, and/or when there is a chance of encountering incongruent trials. However, we argue that the reduced facilitation observed in the MN condition in the absence of incongruent trials does not reflect control. We believe that in the absence of incongruent trials, participants are more prone to inadvertently reading both in the MN and MC condition. In the MN condition, however, there are less color-words than in the MC condition and hence, less erroneous reading. There was no significant difference between the RTs for C/N trials in the MN condition (participants would only react to the color of the stimuli). This claim was supported by analyzing hypothetical "switch costs" that we performed in our first experiment.

A meta-analysis of the data taken from six experiments, including 329 participants overall (Experiments 1 and 2 from the present study; Experiments 1 and 2 [the first two experimental blocks of each condition] from Entel & Tzelgov, 2018; and two additional studies that we ran as a replication, which are briefly mentioned in a footnote in Entel & Tzelgov, 2018) strengthen our claim. A four-way mixed-model ANOVA with congruency and experimental block as within participant factors, and congruent-to-neutral ratio and practice type as between participant factors revealed once again a negative facilitation of 47 ms (BF_{10} = 569,632.5) in the first block in the MN condition when incongruent trials were added to practice. This negative facilitation was reversed into facilitation in the second experimental block. In the absence of incongruent trials, we observed a regular facilitation both in the MC and the MN condition (see Figure 5, Table 7, and Table S5 in the online supplemental material). This is in contrast to some claims (e.g., Kalanthroff, Avnit, Henik, Davelaar, & Usher, 2015; Kalanthroff, Goldfarb, Usher, & Henik, 2013).

In the study of Kalanthroff et al. (2013), participants carried out a Stroop task with a high proportion of nonword neutrals and with a cue indicating in 50% of the trials whether the subsequent trial would be neutral or a color word. Similar to our study, they did not include incongruent trials in their experimental design. The researchers found a negative facilitation in the noncued trials. Therefore, they concluded that task control was activated even in the absence of informational conflict,

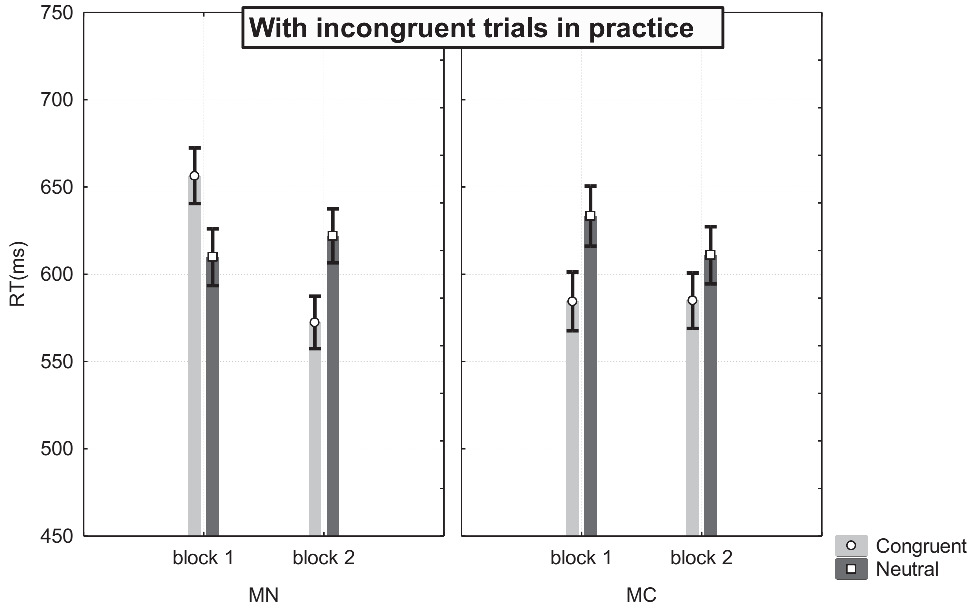

Figure 5. Mean reaction times (RTs) for congruency as a function of block, congruent-to-neutral ratio and practice type from a meta-analysis of the data taken from six experiments. Error bars are one standard error of the mean. MC = mostly congruent condition; MN = mostly neutral condition.

suggesting that the mechanism of task control is dissociable from that of informational conflict.

Control can be recruited even in the absence of informational conflict. However, we beg to differ with their conclusion as the negative facilitation they observed was relatively small (i.e., 15 ms) and a Bayesian estimate of the support for it (Rouder et al., 2009) was anecdotal ($BF_{10} = 2.93$).

In another research, Kalanthroff et al. (2015) showed that when proactive control is diminished, both increased Stroop interference and a negative facilitation are observed. In their study, participants performed a standard Stroop task combined with a concurrent n-back task, which was aimed at reducing available WM resources, and thus overloading proactive control. They observed common Stroop interference and facilitation in the low-load condition (zero-back). In the high-load condition (two-back), however, an increased Stroop interference and a negative facilitation effect were observed. Performing a Bayesian analysis revealed that in this study, similar to Kalanthroff et al. (2013), the negative facilitation was relatively small (i.e., 20 ms), and the Bayesian estimate of the support for it was anecdotal ($BF_{10} = 2.48$).

To conclude, we succeeded in demonstrating a clear connection between the recruitment of (proactive) control in the Stroop paradigm and WM. The effects we observed were episode-based and they depended on the availability of WM. The uniqueness of our study lays in its atypical design that assesses control via the negative facilitation effect rather than through incongruent trials. In addition, we also manipulated the participants' expectations (experience with or without incongruent trials in practice). This is important because it demonstrates the sensitivity of control to expectation, which allows rejecting alternative explanations of learning (e.g., Schmidt, 2013; Schmidt & Besner, 2008). It is also important because it supports the notion that in contrast to automaticity per se, control of automatic processing is effortful and needs to be planned, hence available WM resources are crucial (see Zbrodoff & Logan, 1986). Our results also emphasize the importance of informational conflict, showing that pure task conflict per se cannot be detected in the absence of incongruent trials because there is no danger of activating a wrong response by irrelevant information. This finding is important because consistent with

Table 7
Mean Reaction Time (RT; in ms) for Congruency as a Function of Practice Type, Congruent/Neutral (C/N) Ratio, and Block in the Meta-Analysis

Practice type	C/N ratio	congruency	block	*M* RT (*SD*)
Without incongruent trials in practice	MC	Congruent	1	526.28 (71.16)
			2	524.84 (62.49)
		Neutral	1	610.38 (81.10)
			2	598.91 (65.15)
	MN	Congruent	1	595.93 (80.62)
			2	581.46 (71.93)
		Neutral	1	639.32 (77.42)
			2	635.58 (79.21)
With incongruent trials in practice	MC	Congruent	1	595.93 (80.62)
			2	584.5 (72.55)
		Neutral	1	639.32 (77.42)
			2	635.58 (79.21)
	MN	Congruent	1	656.49 (74.16)
			2	572.43 (69.00)
		Neutral	1	609.81 (75.59)
			2	622.06 (76.15)

Note. MC = mostly congruent; MN = mostly neutral.

our previous results (see Entel & Tzelgov, 2018), it shows that automatic processes such as reading in the Stroop paradigm (i.e., task conflict) are not monitored. The informational conflict, which endangers task performance, is the one being monitored while its control results in reducing both task and informational conflicts by focusing on task demands (Botvinick et al., 2001; Levin & Tzelgov, 2014).

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Received January 4, 2019
Revision received September 19, 2019
Accepted September 24, 2019 ■