Priming can affect naming colours using the study-test procedure. Revealing the role of task conflict

Dinkar Sharma

Correspondence:

School of Psychology. Centre for Cognitive Neuroscience and Cognitive Systems. University of Kent, Canterbury, Kent, CT2 7NZ. Email: d.sharma@kent.ac.uk; Phone: +44 (0)1227 823084

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Abstract

The Stroop paradigm has been widely used to study attention whilst its use to explore implicit memory have been mixed. Using the non-colour word Stroop task we tested contrasting predictions from the Proactive-Control/Task-Conflict model (Kalanthroff, Avnit, Henik, Davelaar & Usher, 2015) that implicate response conflict and task conflict for the priming effects. Using the study-test procedure 60 native English speakers were tested to determine whether priming effects from words that had previously been studied would cause interference when presented in a colour naming task. The results replicate a finding by MacLeod (1996) who showed no differences between the response latencies to studied and unstudied words. However, this pattern was predominately in the first half of the study where it was also found that both studied and unstudied words in a mixed block were slower to respond to than a block of pure unstudied words. The second half of the study showed stronger priming interference effects as well as a sequential modulation effect in which studied words slowed down the responses of studied words on the next trial. We discuss the role of proactive and reactive control processes and conclude that task conflict best explains the pattern of priming effects reported.

Keywords: Stroop effect; Implicit Memory; Proactive control; Task conflict; Priming effect

Priming can affect naming colours using the study-test procedure. Revealing the role of task conflict

The Stroop paradigm has been developed to investigate how salient task-irrelevant stimuli can trigger failure of selective attention (Stroop, 1935; MacLeod, 1991). The Stroop task requires responding to the ink colour in which a word is written whilst ignoring the meaning of the word. The word can refer to colour or be a non-colour word (Klein, 1964). The general finding is that colour naming response latencies and accuracy are affected by the meaning of the word. Researchers have identified two types of conflicts that slow down responses. An informational conflict arises due to the contradictory information in the word and colour (e.g. when the word RED interferes with naming the ink colour green). A second type of conflict occurs between two potentially competing tasks (task conflict). For example, naming the ink colour (the relevant task) competes with the irrelevant but automatic word reading task (MacLeod & MacDonald, 2000; Kalanthroff, Goldfarb, & Henik, 2013; Kalanthroff, Goldfarb, Usher, & Henik, 2013). Task conflict occurs because certain stimuli become associated with certain tasks. For example, words are strongly associated with the task of reading and thus automatically activate the tendency to read written words (MacLeod & MacDonald, 2000).

Connectionist models have been developed to explain informational conflict (Cohen, Dunbar, & McClelland, 1990; Botvinick, Braver, Barch, Carter, & Cohen, 2001). At their core connectionist models involve competition between units in a response layer (response conflict). The response units are themselves activated by stimulus units from the input layer (word and colour input units). Informational conflict occurs due to the greater automaticity in reading words than responding to ink colours that is typically implemented as stronger connection weights between the word input layer and the response layer relative to the colour input layer and the response layer. A task demand layer is included to bias responses based on the instructed task goal. Depending on the task goal the network can bias responding to the ink colour or to the word.

Early models typically involved the flow of information from input to response in a bottom-up fashion. However, later models (e.g. the conflict monitoring model: Botvinick, et al., 2001; and the dual mechanisms of control model: Braver, 2012; De Pisapia & Braver, 2006) introduced a proactive top-down control mechanism to maintain goal-relevant information. Botvinick, et al. (2001) implemented proactive control by increasing activation to the task goal (usually the colour naming unit) in the task demand layer (see figure 1). Importantly they showed that proactive control could be activated by the degree of response conflict (measured using the Hopfield energy equation as the product of activation strength of competing responses from the response layer). Empirical support for this mechanism comes from several sources. In the sequential modulation effect (aka the Gratton effect) incongruent trials (e.g. the word RED written in green ink) are responded to more quickly when the previous trial is also incongruent than when congruent (Gratton, Coles, & Donchin, 1992; Kerns et al., 2004; Botvinick, Braver, Barch, Carter, & Cohen, 2001). In the proportion congruency effect increasing the number of colour word trials can decrease interference (Tzelgov, Henik, & Berger, 1992). Furthermore, Padmala, Bauer & Pessoa (2011) have shown that negative stimuli can reduce the sequential modulation effect that indicates a reduced level of top-down proactive control. Support also comes from other studies using non-colour words such as negative emotional words. In the slow effect (McKenna, 1986; McKenna & Sharma, 2004; Algom, Chajut & Lev, 2004; Phaf & Kan, 2007) a negative emotional stimulus triggers a relaxation in maintaining the colour naming goal to increase response latencies on subsequent emotionally neutral trials (Wyble, Sharma & Bowman, 2008).

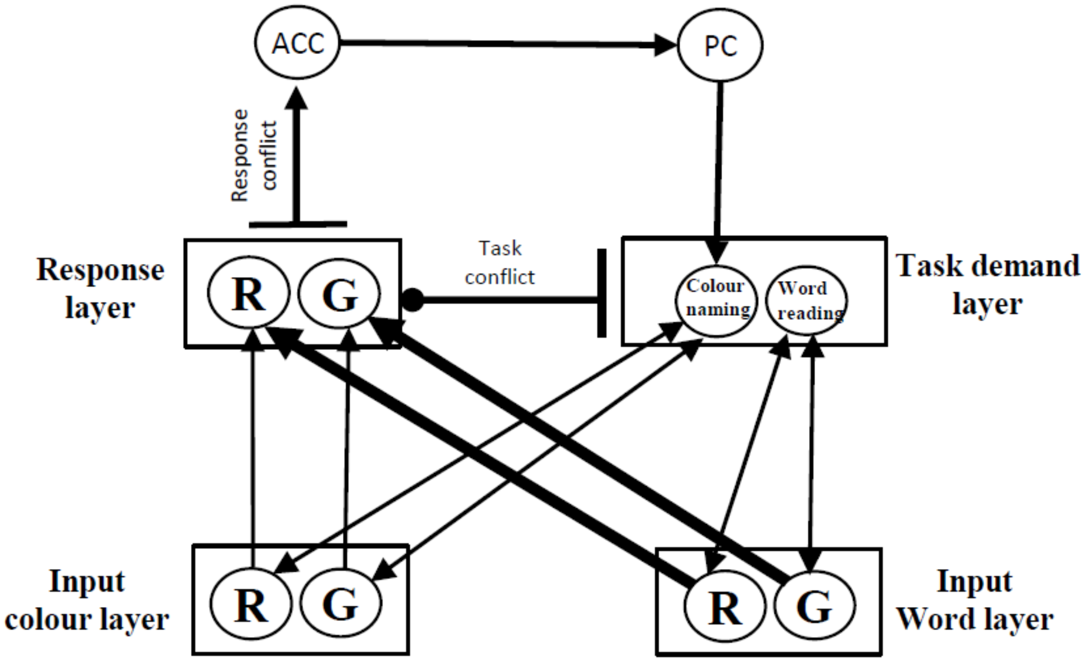


Figure 1: Proactive-control/task-conflict (PC-TC) model. Adapted from Kalanthroff et al. (2015). Task conflict is represented as the inhibitory connection between the task demand layer and the response layer. Response conflict triggers additional activation via the anterior cingulate (ACC) unit to modulate top-down the activation of the colour naming unit as in Botvinick et al., (2001). R=red, G=green

In the Proactive-control/task-conflict (PC-TC) model (Kalanthroff, Avnit, Henik, Davelaar & Usher, 2015) additional features are added to implement the effects of task conflict (see figure 1). Task conflict is implemented as an inhibitory connection between the task demand layer and the response layer. The amount of inhibition is modelled as the strength of competition between the word reading and colour naming task demand units (again measured using the Hopfield energy equation as the product of activation strength of competing task demand units). In addition, bilateral connections between the task demand layer and the stimulus (colour and word) input layer are added to enable a level of reactive control.

To illustrate the workings of the model with respect to task conflict Kalanthroff et al (2015) describe how when proactive control (PC) to colour naming is high the task demand colour naming unit is given additional activation top-down and thus the influence of bottom-up connections into the task demand units is negligible. However, when PC to colour naming is low this allows the bottom-up connections from the word input units to the word reading units to increase competition in the task demand layer and thus inhibit units in the response layer. One of the predictions of this task conflict mechanism is that the response latency to incongruent and congruent trials is increased when PC is low than when PC is high. The prediction that there is increased interference (longer reaction times to incongruent than a nonword control trial) and a reversed facilitation (i.e. longer response latencies to a congruent trial than a nonword, XXXX, trial) effect under low PC conditions has been recently supported (Goldfarb & Henik, 2007; Kalanthroff, Goldfarb, & Henik, 2013; Kalanthroff, Goldfarb, Usher, & Henik, 2013; Kalanthroff & Henik, 2014; Kalanthroff et al., 2015). Although not previously considered it is interesting to note that in the PC-TC model when word reading is activated proactively, inhibition (as task conflict) is high and any reactive control is negligible. Only when PC to word reading is low will there be an influence of task conflict that is reactive to the stimulus inputs.

Although the Stroop task has been predominately used to examine attentional processes (Cohen, Dunbar, & McClelland, 1990), it has also been used to investigate memory. The main aim of this study was to explore the extent to which memory processes could be investigated using a Stroop like task as an indirect measure of memory. One way in which this has been done is by investigating the role of priming in the non-colour word Stroop task (MacLeod, 2005). Priming is a typical method used to investigate implicit memory as the influence of previously studied items can be seen on subsequent colour naming test trials. To investigate priming in the Stroop task non-colour words are typically used as distractors during testing. These distractors can be from a previously studied word set or a new unstudied set of words. Any difference in response time to name the colour of the studied and unstudied words is often attributed to implicit memory processes. The intuition that studied words will distract more than unstudied words and thus produce slower response latencies on a colour naming task has been validated in a number of studies (Warren, 1972, 1974, Conrad, 1974; Henik, Kellog , & Friedrich 1983; Whitney, 1986, Whitney & Kellas, 1984). Though see also Burt (1994, 1999, 2002) for situations that can produce facilitation.

Burt (2002) discussed how priming effects could be considered in connectionist models. Early connectionist models did not incorporate a task conflict mechanism therefore Burt resorted to explaining priming effects as increased competition in the response layer (the response conflict hypothesis). Burt speculated that expanding the number of units in the response layer to include non-colour word units might allow studied words to compete more strongly than unstudied words. Burt also suggested that priming facilitation could not be explained by the connectionist models and suggested decreased competition when repeating a prime word during test (e.g. due to expectancy) to explain facilitation.

Since the role of task conflict has not been considered in previous research on priming it is possible that priming could also be due to task conflict. In the PC-TC model task conflict occurs because of the competition in the task demand layer between colour naming and word reading and the resulting inhibition of the response layer. If it is assumed that studied words (compared to unstudied words) produce greater activation of the word reading task demand unit then the PC-TC model predicts greater competition in the task demand layer and hence greater inhibition of the response layer. This would then explain the longer response times to studied (than unstudied) words that have been reported previously. In addition the PC-TC model suggests that competition in the task demand layer may also be increased proactively. This might happen because of the requirement to memorise words that could then interfere with maintaining the goal to ignore the words even though they are irrelevant to the task of colour naming. One implication in this case would be a reduced level of reactive control but a general slowdown of both studied and unstudied words compared to an experimental context that did not include studied words. It is clear from the above description that as the PC-TC model is based on earlier connectionist models priming interference (slower response latencies to studied than unstudied words) could be explained as resulting from increased response conflict as well as from increased task conflict.

MacLeod (1996) noticed that much of the earlier work used a trial-by-trial method to investigate priming. That is, a method where on each trial a study item (or a small number of study items) is presented prior to responding to the ink colour of the test item. He therefore explored whether using a blocked format could also produce a slowdown in responding to studied words. The blocked format involves an initial study phase in which all study items are presented followed by a test phase in which studied and unstudied items are presented in a random order. MacLeod used two tasks during the test phase, colour naming and word reading and showed across three studies that priming was not detected using the colour naming task but did appear when using the word reading task. MacLeod (1996) resorted to a 'process-specific' account for his findings. That is, reading the words during the study phase facilitates reading the same words during the word reading test. However, when reading the word is irrelevant to the task (as in colour naming) then primed words do not disrupt the task. In terms of the PC-TC model this would be consistent with a high level of PC to colour naming. Although it is possible that a ‘process-specific’ account could explain the null results it is not parsimonious with earlier studies that do show a priming effect. Here we explore the role of task conflict as an alternative explanation to the null effect found by MacLeod (1996).

The current study attempted to replicate MacLeod’s (1996) design, in which participants learn a list of words during a study phase followed by a test phase in which colour responses were given to a mix of studied and unstudied words (the mixed block). A second block of pure unstudied words was also included. We hypothesized a replication of MacLeod’s finding in the mixed block, namely that the reaction times to studied words would not differ to those of the unstudied words.

To explain the null result found with the block method a number of suggestions can be made. First, if there is a greater level of PC to colour naming as suggested by the process-specific hypothesis then not only is reactive control reduced but response latencies will be generally faster in a block with studied words than to another block without studied words. However, it is also possible to contrast this prediction with one where there is a high level of proactive control to word reading. It might be argued that although the non-colour word Stroop task involves ignoring the word, in an experimental context where there is a requirement to read and remember words and/or noticing that studied words are being shown during the colour naming task, may help to maintain activation in the word reading units. In either case there would again be reduced reactive control but, in contrast to the response conflict hypothesis (faster responding resulting from PC to colour naming), the task conflict (resulting from PC to word reading) hypothesis would predict a general slowdown in response latencies in a block with studied words than a block without studied words. MacLeod’s study did not include a block without studied words so it is not possible to distinguish the PC to colour naming (response conflict hypothesis) from the PC to word reading (task conflict hypothesis) explanations for the null result.

However, if studied words do have an effect in a more reactive fashion then it might be possible that this occurs during the course of the study. A comparison was therefore made between performance in the first and second half of each block (block-half). It is not possible to say a-priori whether proactive control would be greater in the first or second half, however, one prediction from the PC-TC model is that if PC (to colour naming or word reading) is high in a mixed block then there will be no difference between the studied and unstudied words. If PC (to colour naming or word reading) is low in a mixed block then studied words may take longer to respond to than unstudied words. Whether priming occurs in the first or second half the PC-TC model could explain the slow down to studied words when PC is low as due to response conflict or task conflict.

One way to distinguish between the response conflict and task conflict hypotheses is to compare performance across mixed and pure blocks as described above. Another way might be to investigate the nature of the trial-by-trial effects within a mixed block. One hallmark of response conflict is the adjustment in the trial-by-trial control as seen in the sequential modulation effect. If response conflict is triggered by studied words then this predicts a sequential modulation effect in which studied words are responded to faster after a studied word than after an unstudied word. However, if studied words trigger task conflict then the opposite pattern is predicted: studied words will increase the response latencies of subsequent studied words. A sequential analysis was therefore also carried out to distinguish between the two hypotheses.

Method

Participants

Sixty native English-speaking students from the University of Kent took part in the study for course credit. One participant was removed from analysis due to high error rates. The remaining sample comprised 49 females and 10 male students aged 18–52, with a mean age of 21.02 (SD = 5.31). Ethical approval was given by the School of Psychology Ethics committee at the University of Kent.

Design

A 3 × 2 mixed factorial design was employed. Study type (studied word mixed block, unstudied words mixed block, unstudied words pure block) was the within-subject factor, and. Block order (mixed-pure, pure-mixed) was the between-subject factor. The dependent variable was the mean correct response latency to identify the ink colour of the word.

Apparatus and materials

The experiment program was written in E-Prime 2.0 and presented on a 60cm Dell widescreen monitor. Reaction time was measured during the Stroop tasks. The manual responses and the presentation and randomisation of the words were controlled by E-Prime 2.0.

Table 1: Word lists used in the study

Word lists				
A	B	C	D	E
body	easy	head	club	near
deal	text	wall	face	main
past	type	tape	move	play
hear	sell	less	page	upon
note	told	room	open	care
issue	class	phone	based	voice
often	hours	basic	price	large
cover	party	south	child	heard
small	times	learn	north	among
trade	space	clear	paper	taken
search	series	office	future	effect
record	driver	matter	couple	happen
become	normal	market	states	posted
result	united	format	across	making
design	groups	member	resume	amount
science	command	numbers	include	project
library	machine	auction	anybody	package
section	playing	usually	outside	advance
company	country	general	running	current
minimum	similar	various	contact	product

100 neutral words were chosen from the English Lexicon Project (Balota et al., 2007) and were divided into five lists of 20 words (see Table 1). Each word set contained an equal number of 4, 5, 6 and 7 letter words and were matched for word frequency (average Log frequency HAL of 11.4), which was in the midrange for the corpus of words (Range 0–17) (Balota et al., 2007). The words were presented in lowercase and in bold using Courier New

Font point size 18.

Procedure

Each participant was given an information sheet and a consent form to sign upon arriving at the lab. The participant was asked to read the instructions on the computer screen. The experiment comprised three phases: the study phase, test phase and recognition phase.

Study phase: Each participant was shown 20 words from one of the five word lists and asked to do their best to memorise them for a later memory test. On each trial a fixation cross was presented for 800 ms followed by a word in black print on a white background at the centre of the screen for 1500 ms. This was immediately followed by another 800ms fixation cross before being asked to rate the word on a five point scale (1 = 0%, 2 = 25%, 3 = 50%, 4 = 75% and 5 = 100%) indicating how strong the word referred to themselves. The rating task remained on screen until response, followed immediately by 800ms fixation cross to start the next trial.

Test phase: Practice trials were provided to familiarise participants with the Stroop task. Five repeated letter strings (e.g., eeee, tttttt, uuuu, ppp, aaaaaaa) were printed in each of four colours (red, green, blue and yellow) on a white background. These 20 trials were repeated three times, resulting in 60 trials that were presented in a random order. Participants were asked to ignore the letter strings and respond to the ink colour as quickly and as accurately as possible using the two middle fingers from each hand placed on top of four keys on the keyboard (z = red, x = green, n = blue, m = yellow). Each trial started with a 800ms fixation cross followed by the letter string which remained on the screen for 1500ms followed immediately by the fixation cross for the next trial.

The general instructions and procedure for the experimental trials were identical to the practice trials. During the Stroop task, there were two blocks. The mixed block consisted of 20 studied and 20 unstudied words. The pure block included two sets of 20 unstudied words. Each block contained 40 words from two word lists. All 40 words were presented four times, once in each of the four colours which resulted in 160 trials per block. Each trial was presented in a random order for each participant.

As soon as the first block was finished, identical instructions for the second block were given to the participant, who then began the second task by pressing the space bar. The order of the two blocks was counterbalanced across participants.

Recognition phase: The recognition phase followed the test phase. Each participant was shown 40 words: the 20 studied words plus a new set of 20 unstudied words not seen in the study or test phases. On each trial one of four judgements were made as to whether the word shown was from the study phase (1 = Seen this word before with high confidence, 2 = Seen this word before but not sure, 3 = Not seen this word before with high confidence, 4 = Not seen this word but not sure). Each word was presented with the four grading options displayed which remained on the screen until the response was made. This was followed by a 800ms fixation cross before seeing the next word.

Each of the 20 words was taken from one of the five word lists (see Table 1). Assigning the word lists to the mixed block (studied or unstudied), pure block (two unstudied lists) and recognition phase was counterbalanced using a Latin square design. Participants were assigned randomly to one of the counterbalanced orders.

Results

The recognition data were converted to d-prime and bias scores using the method described by Macmillan and Creelman (1991). This showed a high level of discrimination with a low level of bias (d-prime: M=.93, SE=.03; bias: M=-.06, SE=.02).

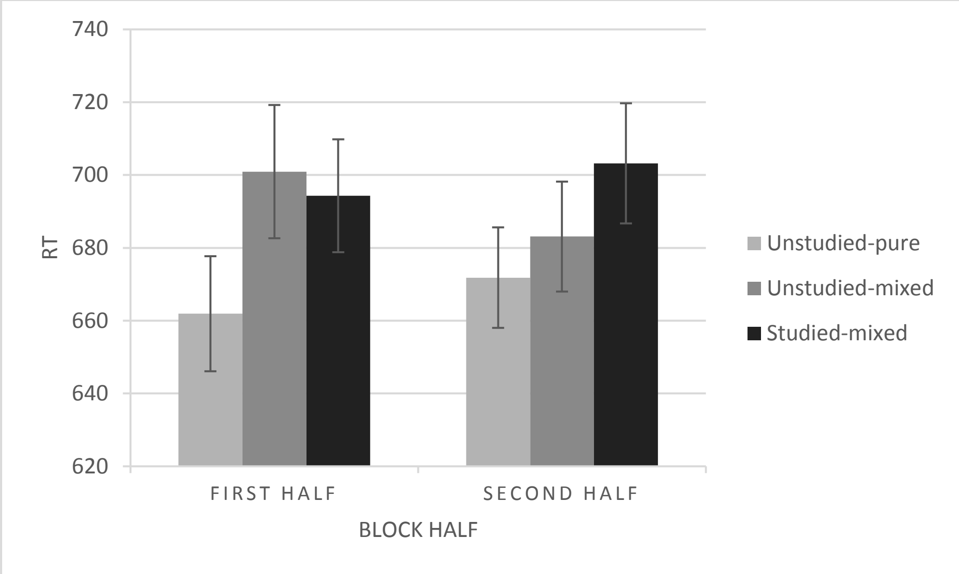
Analysis of the Stroop task

Data preparation: One participants' data was removed due to a high number of errors (20%). The error rate of the remaining 59 participants was 5.17%. Analysis was conducted on the mean correct response latencies after removing (a) the first trial from each block due to long responses and (b) outliers (RT's less than 300ms and greater than 3000ms) which removed 0.5% of the trials.

The mean correct RT's were analysed using a three-way mixed ANOVA, with Study type (studied-mixed, unstudied-mixed, unstudied-pure) as a within-subject factor, Block half (first half, second half) and Block order (mixed-pure, pure-mixed) as a between-subject factor. Greenhouse-Geisser corrected values were reported when the sphericity assumption was not met.

The analysis revealed a significant main effect of Study type, F(1.64, 93.44) = 8.16, MSe=4983.344, p = 0.001, η_p^2= .13. Bonferroni corrected t-tests indicated that within the mixed block, there was no significant difference between the studied (M=698.76ms, SE=15.16) and unstudied (M=692.02ms, SE=15.96) words (p = 0.27). However, the unstudied-pure block (M=666.86ms, SE=14.34) significantly differed from the studied-mixed block (p = 0.001), and the unstudied-mixed block (p = 0.007). The was also an interaction between Study type and Block half, F(1.93,109.76)=3.70, MSe=2050.92, p=.03, η_p^2=.061 (see figure 2). Simple effects analyses indicated that there were simple main effects of Study type in both the first half (p<.001) and the second half (p=.014). Bonferroni corrected t-tests indicated that in the first half both the studied-mixed (p=.003) and unstudied-mixed (p=.001) words took longer to respond to than the unstudied-pure block. However, in the second half only the studied-mixed words took longer than both the unstudied-mixed words (p=.048) and unstudied-pure words (p=.011). The two unstudied words did not differ from each other (p=.26).

Figure 2: Showing the mean correct reaction time (ms) as a function of Study type and Block half. Error bars are ±1 standard error



No other main or interaction effects were significant: Main effects of Block order, F(1,57) = 0.096, MSe=73241.68, p = 0.76, η_p^2= .002, Block Half, F(1,57)=.002, MSe=4084.97, p=.96, η_p^2<.001. The 2-way interaction between Study type and Block order, F(1.64, 93.44) = 0.47, MSe=4983.34, p = 0.59, η_p^2= .008. The 3-way interaction between Study type, Block order and Block half, F(1.93,109.76)=.091, MSe=2050.92, p=.91, η_p^2=.002. We also checked for a carryover effect across blocks. For the unstudied words in the pure block there was no significant difference (p=.6) when appearing after the mixed block (M=659.94ms, SE=20.10) compared to before the mixed block (M=673.79, SE=20.45).

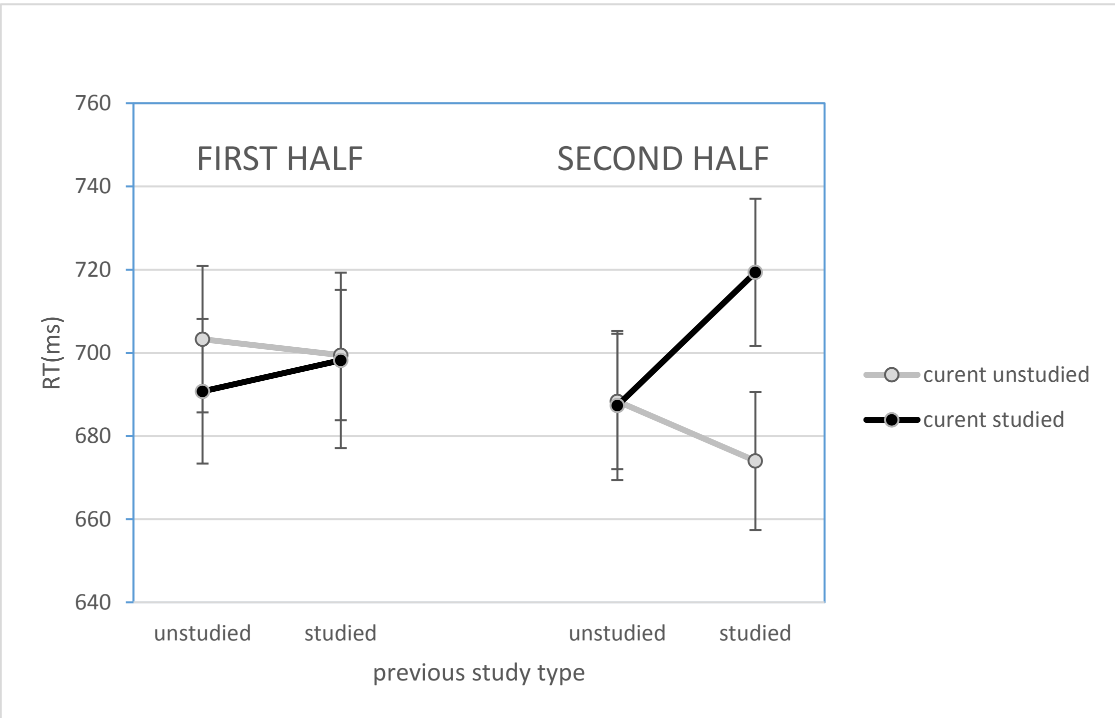
A 3-way mixed ANOVA was also carried out on the mean proportion of errors. This showed no main effect of Study type, F(2,114) = 0.09, MSe=.001, p = 0.92, η_p^2= .001, Block order, F(1,57) = 0.073, MSe=.007, p = 0.79 η_p^2= .001, or Block half, F(1,57) = 0.008, MSe=.001, p = 0.93 η_p^2< .001. However, there was a significant interaction between Block order and Study type F(2,114) = 5.801, MSe=.001, p = 0.004 η_p^2= .092. This was due to lower error rates in the mixed block when first in the order mixed-pure ($M_{studied\text{-}mixed}$ =.047, $M_{unstudied\text{-}mixed}$ =.045, $M_{unstudied\text{-}pure}$ =.06) than when second in the order pure-mixed ($M_{studied\text{-}}$

$_{mixed}$ =.055, $M_{unstudied\text{-}mixed}$ =.06, $M_{unstudied\text{-}pure}$ =.044) and therefore indicates an effect of fatigue. No other interaction effects were significant (all F's<2.19, p's>.1).

Analysis within the mixed block: A 4-way mixed ANOVA was conducted with Previous study type (studied, unstudied), Current study type (studied, unstudied) and Block half (first half, second half) as within-subject factors, and Block order (mixed-pure, pure-mixed) as a between-subject factor.

The analysis showed a significant 2-way interaction between Current study type and Block half, $F(1, 57) = 5.24$, MSe=4759.23, $p = 0.03$, η_p^2= .08 indicating (as shown in figure 2) that in the first half there was no difference between studied words (M=694.47ms, SE=15.58) and unstudied words (M=701.36ms, SE=18.26), but in the second half there was a significant difference between studied (M=703.33, SE=16.78) and unstudied (M=681.15, SE=14.89) words.

Figure 3. Showing the mean correct reaction time (ms) as a function of previous and current study type and Block half. Error bars are ±1 standard error



The analysis also showed a significant 2-way interaction between the Previous study type and Current study type, F(1, 57) = 4.55, MSe=5364.84, p = 0.04, η_p^2= .07. Further post-hoc tests revealed that only the studied words preceded by studied words (M=708.76, SE=15.11) showed significantly (p=.01) longer reaction times compared to the unstudied words preceded by studied words, (M=686.72ms, SE=17.43), or studied words preceded by unstudied words (M=689.04ms, SE=16.35) but not (p=.18) compared to the unstudied words preceded by unstudied words (M=695.78, SE=15.60). Although the Previous study type x Current study type interaction did not significantly interact with Block half (F(1,57)=1.69, MSe= 5362.43, p=.198, η_p^2= .029) we explored whether the simple Previous study type x Current study type interaction was significant in each Block half (see Figure 3). Simple effects analysis showed that it was not significant in the first half, F(1,57)=.350, MSe= 5300.31, p=.56, η_p^2= .006, but was significant in the second half, F(1,57)=5.83, MSe= 5426.96, p=.019, η_p^2= .093, where studied words preceded by studied words were slower to respond to than the other three conditions.

All the other effects were not significantly different from each other (all p's>.1).

Discussion

The results demonstrate four important findings. First, in a mixed block, studied and unstudied words do not differ in their colour responding. However, this was mainly in the first half of the block, in the second half of the mixed block studied words took longer to respond to than unstudied words. Second, in the first half the mixed block (both studied and unstudied words) take longer to respond to than a pure block of unstudied words. However, in the second half only the studied words in the mixed block took longer than unstudied words in the mixed or pure blocks. Third, within the mixed block a studied word takes longer than an unstudied word but only when it is preceded by a studied word. Fourth, unstudied words in a pure block were not affected by block order, that is, whether a mixed block appeared before or after the pure block.

The results firstly replicate the findings of MacLeod (1996) who showed that when using the study-test format colour naming studied words do not produce longer latencies compared to unstudied words. This null effect also generalises across response modality as MacLeod used a vocal response and our study used a manual response. MacLeod suggested that this null result may be due to process specific processing. The process specific account suggests that words are irrelevant in a task that requires responding to the colour. A strong version of this hypothesis would require an early selection filter to prevent words from interfering; our results indicate this is unlikely. However, a weaker version would be consistent with an alternative account in which proactive control to colour naming reduces the impact of the words by reducing the resulting response conflict. The PC-TC model also suggests that the null result could be explained by greater proactive control to word reading. To differentiate these two accounts an additional block of trials was included containing no studied words (the unstudied pure block). The response conflict hypothesis predicts that the mixed block will be responded to more quickly than the pure block whereas the task conflict hypothesis predicts a slower response to the mixed block than the pure block. Our results support the task conflict explanation for the null effects in the mixed block.

In addition to finding differences between the mixed block and the unstudied pure block we also found differences between the studied and unstudied words within the mixed block that varied in the first and second half. In the first half the mixed block (both studied and unstudied words) took longer than the pure (unstudied) block. In the PC-TC model this is consistent with the task conflict hypothesis in which there is greater proactive control to word reading. This might occur because of the experimental context where word reading units are activated by reading words during the study phase. Alternatively, noticing studied words during the colour naming task might also allow greater proactive control to word reading.

During the second half there was clear evidence of priming interference in which studied words took longer to respond than unstudied words from the mixed or pure blocks. The PC-TC model suggests that this is consistent with a reduced level of proactive control. With low proactive control this may allow studied words to slowdown responses compared to the unstudied words (in the mixed or pure blocks). It is interesting to note that in the second half the unstudied words in the mixed and pure blocks were not significantly different. This indicates that the PC to word reading in the first half is statistically eliminated by the second half. It also indicates that in the second half the studied words do not interfere with the processing of unstudied words in the mixed block.

The longer response latencies to studied (than unstudied) words in the second half could be due to response conflict or task conflict. We hypothesised that a second way to distinguish between a response conflict and task conflict explanation in the PC-TC model was by analysing the nature of the sequential modulation effects within the mixed block. The results indicated that there was a previous by current study type interaction that was due to response latencies being slowest for studied words preceded by studied words than for any other previous by current trial combination. The PC-TC model suggests that if priming is due to response conflict then this would result in a faster response latency to studied words that were preceded by studied words. This is not what was found and is therefore inconsistent with the response conflict hypothesis. However, our results are consistent with the task conflict hypothesis as this predicts slower response latencies to studied words that are preceded by a studied word. Although the previous by current study type interaction did not significantly interact with block half further analysis showed that it was significant in the second half but not the first half.

Although the results have been explained within the framework of the PC-TC model alternative explanations could also be considered. One possibility might be the presence of dual task interference. That is, the studied words might be held in working memory which may consume additional central executive resources that interfere whilst carrying out the non-colour word Stroop task. This explanation could explain why the mixed block takes longer than the pure block. However, this would also predict that the dual task interference would occur for a pure block when it appears before the mixed block. Our findings did not support the dual task interference account as there was no difference between the pure (unstudied) block when it appeared before or after the mixed block. Another possibility is that studied words slowdown responding to any subsequent word as has been shown with the slow effect for negative emotional words (McKenna & Sharma, 2004; Phaf & Kan, 2007). This could explain why there is no difference between studied and unstudied words in the mixed block as well as why the mixed block takes longer than the unstudied pure block. However, in a sequential analysis this suggestion would have predicted that studied words slow the responses of unstudied words on the next trial. Our results do not support this particular pattern.

Previous research had resorted to explaining priming interference as resulting from greater response conflict from studied words than unstudied words; our results suggest that task conflict may be a better explanation. What is less clear is how to explain priming facilitation. Burt (2002) has suggested that priming facilitation occurs in the trial-by-trial method when repeating the prime word at test. One suggestion is that within the PC-TC model priming facilitation could be considered to be due to sequential modulation arising from response conflict. That is, the prime word speeds up responding of the same word because of a proactive control mechanism that activates more strongly the colour naming task demand unit. Although we do not find evidence supporting the response conflict hypothesis it is theoretically possible as it may appear more strongly in the trial-by-trial method where the prime and target are in close temporal proximity. Further research is required to explore this possibility. Expectation might also explain priming facilitation. It would therefore be interesting to also investigate how this might affect both response conflict and task conflict.

This could be done by either using the cueing technique used by Goldfarb and Henik (2007) or manipulating the proportion of word (unstudied or studied) trials as in Tzelgov, Henik, & Berger (1992). It would therefore be interesting to investigate these possibilities experimentally as well as using simulations from the PC-TC model.

The main goal of this study was to investigate possible priming effects from studied words in a study-test blocked format. We have shown clear evidence that priming interference does occur using this format. The most important conclusion is that the general pattern of priming interference seen within and across blocks is consistent with the primary cause being task conflict rather than response conflict. Within the framework of the PC-TC model the important role played by proactive control processes and how this interacts with task conflict are revealed.

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