The Role of Task Conflict in the Non-Colour Word Stroop Task

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Abstract

The aim of the current thesis was to investigate the role of task conflict in the non-colour word Stroop task using the study-test procedure that was first introduced by MacLeod (1996) and then developed by Sharma (2018). Task conflict was suggested by two findings: (a) Studied words can slow down the colour-responding to unstudied words in a block with studied words compared to those in a block without studied words; (b) Within the studied block comprising of studied and unstudied words, the slowdown can also occur on a trial-by-trial basis when responses are made to two successively presented studied words – a reversed pattern of sequential modulation effect.

The thesis reports on three sets of manipulations and their effects on task conflict: the effect of using different (10 or 30) numbers of studied items (Chapter 4), the effect of varying the number of non-word rectangle stimuli (Chapter 5), and the effect of using emotionally salient words: anxiety-related and addiction-related words (Chapter 6).

Chapter 4 provided further evidence of colour naming interference from studied words and a reversed sequential modulation effect. There was a tendency that using 30 words produced less task conflict than using 10 words. Chapter 5 provided some evidence that task conflict increased with an increase in the proportion of rectangle stimuli. Chapter 6 again found evidence for task conflict indicated by interference from salient and/or studied words as well as a reversed sequential modulation effect.

The thesis explores how these findings can be explained by connectionist models of the Stroop task with particular emphasis on the proactive-control/task-conflict model by Kalanthroff et al. (2015). I also explore the role of individual differences and its role in top-down and bottom-up processes.

Contents

Summary

Chapter 1 provides a review of how the Stroop effect can be explained in a single-stage account model (Cohen, Dunbar & McClelland, 1990) that considers the Stroop interference is solely attributed to the response conflict arising at the response layer between the colour and word units. I then review the development of the connectionist models that built on Cohen et al.'s (1990) model (Cohen & Huston, 1994; Botvinick, Braver, Barch, Carter & Cohen, 2001; De Pisapia & Braver, 2006; Wyble, Sharma & Bowman, 2008).

Chapter 2 looks at the role of task conflict in the colour word Stroop task evidenced in Goldfarb and Henik (2007) who provided behavioural data that corresponded with the brain imaging data where congruent trials produced more interference than non-word control trials. I review evidence in support of the existence of task conflict (Kalanthroff, Goldfarb & Henik, 2013; Kalanthroff & Henik, 2014; Entel & Tzelgov, 2018) and introduce a multi-stage account model (Kalanthroff, Avnit, Henik, Davelaar & Usher, 2015) that takes both response conflict and task conflict into account and implement task conflict as the influence of the bottom-up reactive activation of the word reading task demand unit at the task demand layer.

Chapter 3 looks at the effect of priming on the non-colour word Stroop task. Early studies using the study-test procedure on a trial-by-trial basis (i.e., a study item that is immediately followed by a test item) suggest that test items semantically related to study items can produce more colour naming interference than those unrelated to study items

(Warren, 1972, 1974; Conrad, 1974). I review the work of Sharma (2018) who applied the study-test technique on a block-by-block basis (i.e., study items are presented prior to all of the test items) and found a slowdown for a block with studied words than a block without studied words as well as a slowdown for responses that were made to two consecutively presented studied words (i.e., a reversed sequential modulation effect). Based on the PC-TC model, Sharma suggested that the slowdown by studied words was due to task conflict, revealing the role of task conflict in the non-colour word Stroop task. In addition, Chapter 3 reviews previous works on the effects of priming on the emotional Stroop task and the addiction Stroop task.

Chapter 4 presents a series of three experiments that attempted to replicate Sharma's (2018) findings applying the same design but with a working memory load manipulation by using 10 and 30 studied words (low load and high load, respectively) compared to the 20 studied words used by Sharma:

a) In Experiment 1 (low load) where there were 10 studied words and each of the two test blocks contained 80 trials (compared to 160 trials by Sharma), I replicated the finding of a general slowdown in the studied block compared to the unstudied block but I did not observe the reversed sequential modulation effect.
b) In Experiment 2 (high load), I used 30 studied words and each of the two test blocks had 240 trials. Unlike Experiment 1, the colour-responding for the studied

block was not slower than the unstudied block, and there was no reversed sequential modulation effect.

c) In Experiment 3, I revised the design to equalise the number of trials in each test block with 80 trials for the low and high working memory load conditions. I found a general slowdown in the studied block and a reversed sequential modulation effect. However, the amount of the general slowdown did not differ between the low and high conditions even though there was a tendency that the higher the working memory load the less the amount of the slowdown.

Chapter 5 presents a series of three experiments using the study-test procedure that aimed to extend previous works that revealed the existence of task conflict by manipulating the proportion of non-word stimuli versus word stimuli in a block (Goldfarb & Henik, 2007; Entel, Tzelgov, Bereby-Meyer & Shahar, 2015). Rectangles were used as non-word stimuli and were mixed with neutral words in each of two blocks where one block consisting of 75% rectangles and 25 % words (the 75/25 block), and the other block comprising of 25% rectangles and 75% words (the 25/75 block). Task conflict was defined as the response latency difference between non-word and word stimuli.

a) In Experiment 4, I employed a within-subject design and found a 2-way interaction between Rectangle/Word (R/W) proportion and Stimulus type which suggested a larger amount of task conflict in the 75/25 block than the 25/75 block.

However, it was not clear what caused the interaction since there was no latency difference for both rectangle and word stimuli between the two blocks.

b) In Experiment 5, I employed a between-subject design in which during the test phase one group (studied block group) saw studied words whereas the other group (unstudied block group) saw unstudied words. The main effect of the between-subject factor was not significant. Although I found the 2-way R/W proportion × Stimulus type interaction, the latencies of word stimuli remained unaffected by the proportion manipulation across the two blocks, whereas the latencies of rectangle stimuli were faster in the 75/25 block compared to the 25/75 block.

c) In Experiment 6, the number of trials in each test block was reduced to half to test whether the null priming effect in Experiment 5 was due to the larger trial number. However, the results indicated a replication of the findings in Experiment 5.

Chapter 6 presents Experiment 7 and 8, which was the first study to consider the role of task conflict in the emotional Stroop effect and the addiction Stroop effect, respectively. I employed a design that was built on Sharma (2018) where the test phase had two extra blocks in addition to the original two (studied and unstudied) neutral blocks – one unstudied salient block consisting of unstudied negative emotional/marijuana-related words and unstudied neutral words, and one studied salient block comprising of studied negative emotional/marijuana-related words and unstudied neutral words.

a) In Experiment 7, participants were separated into the low and high trait anxiety groups. The recall data showed that the two groups performed similarly on the explicit memory. However, the findings from the Stroop task indicated a different pattern for the two groups on the implicit memory. The low anxiety group demonstrated a general slowdown in the studied (negative and neutral) blocks compared to the unstudied neutral block, an indication of task conflict from proactive control. Whereas the high anxiety group showed a limited general slowdown but exhibited an attentional bias towards studied negative words. Moreover, within the studied negative block, there was a reversed sequential modulation effect where studied negative words were slower to respond to when preceded by studied negative words than unstudied neutral words, a demonstration of task conflict in a reactive mechanism.

b) In Experiment 8, participants were divided into the marijuana user and non-user groups. For the explicit memory recall task, the two groups did not differ from each other. However, for the implicit Stroop task, the two groups illustrated different patterns in colour-responding. For the non-user group, studying marijuana-related words activated a general marijuana schema where response latencies to the unstudied neutral block were faster compared to all the other three blocks, showing an effect of task conflict in a proactive mechanism. For the user group, studying marijuana-related words activated a marijuana schema that led to a slowdown in the two (unstudied and studied) marijuana blocks compared to the unstudied neutral block, indicating the influence of task conflict from proactive control. Moreover, within the two marijuana blocks users displayed a strong attentional bias towards marijuana-related words and there was a tendency in which marijuana-related words became slower when preceded by marijuana-related words compared to neutral words, an illustration of task conflict from reactive control.

The general discussion is in four parts. The first presents a summary of the thesis findings. Part two first briefly summarise previous evidence of the proportion congruent effect and the sequential modulation effect that support Botvinick et al.'s (2001) conflict monitoring account to explain the Stroop effect in the colour word Stroop task. Then, the second part presents the implications of my findings by the proportion manipulation and the reversed sequential modulation effect for the conflict monitoring account in the non-colour word Stroop task. The third part discusses the implications of task conflict resulting from the priming effect for the PC-TC model of Kalanthroff et al. (2015). The fourth part looks at the role of task conflict in the selective attention in anxiety and addiction, and presents the implications of the PC-TC model for my findings of the emotional Stroop effect and the addiction Stroop effect.

Chapter 1: Colour word Stroop Task and Single-stage account model

The Stroop paradigm has been developed broadly as a tool to examine the mechanisms underlying selective attention. In the classic Stroop task, colour words are used as stimuli, and participants are asked to name the word's ink colour while ignoring its meaning. Response latencies to incongruent stimuli in which the ink colour and the word meaning are incompatible (e.g., RED written in green) are longer in comparison to congruent stimuli in which the ink's colour is compatible with the word's meaning (e.g., BLUE written in blue). This congruency effect (i.e., $RT_{incompatible} – RT_{compatible}$) is referred to as the *Stroop effect*. When compared to neutral stimuli which act as a baseline condition (e.g., a string of symbols, pseudo words or non-colour words), slower reaction times to incongruent stimuli than to neutral stimuli are attributed to Stroop interference, whereas faster reaction times to congruent stimuli than to neutral stimuli are attributed to Stroop facilitation. In the colour naming task, the word interferes with colour-responding which results in delay. By contrast, the colour does not intervene in reading the word in the word reading task. This is known as the asymmetry of Stroop interference (Stroop, 1935; MacLeod, 1991). In addition, the word stimuli used in the Stroop paradigm can also refer to non-colour words (Klein, 1964).

Posner and Snyder (1975) proposed that word reading is an automatic process, which is involuntary and does not require attention, whereas colour naming is a controlled process, which is voluntary and demands attention. Therefore, the processes of reading words are faster than naming colours, which leads to the Stroop effect. That is, participants read words even though they are instructed to ignore the meaning of word stimuli.

MacLeod and MacDonald (2000) suggested that, in the Stroop task, there are two components that affect performance: informational/response conflict and task conflict. *Informational/Response conflict* occurs when the information in the task-irrelevant word contradicts that in the task-relevant ink colour in which the word is written. For instance, when naming the colour of the word RED written in green, the task-irrelevant information word 'RED' contradicts the task-relevant ink colour 'green'. Accordingly, interference arises (MacLeod, 1991). *Task conflict* arises when the goal-irrelevant task competes with the goal-relevant task. It suggests that a stimulus can activate or induce the action of performing a task that is strongly associated with the stimulus (Monsell et al., 2001; Rogers & Monsell, 1995; Waszak, Hommel, & Allport, 2003).

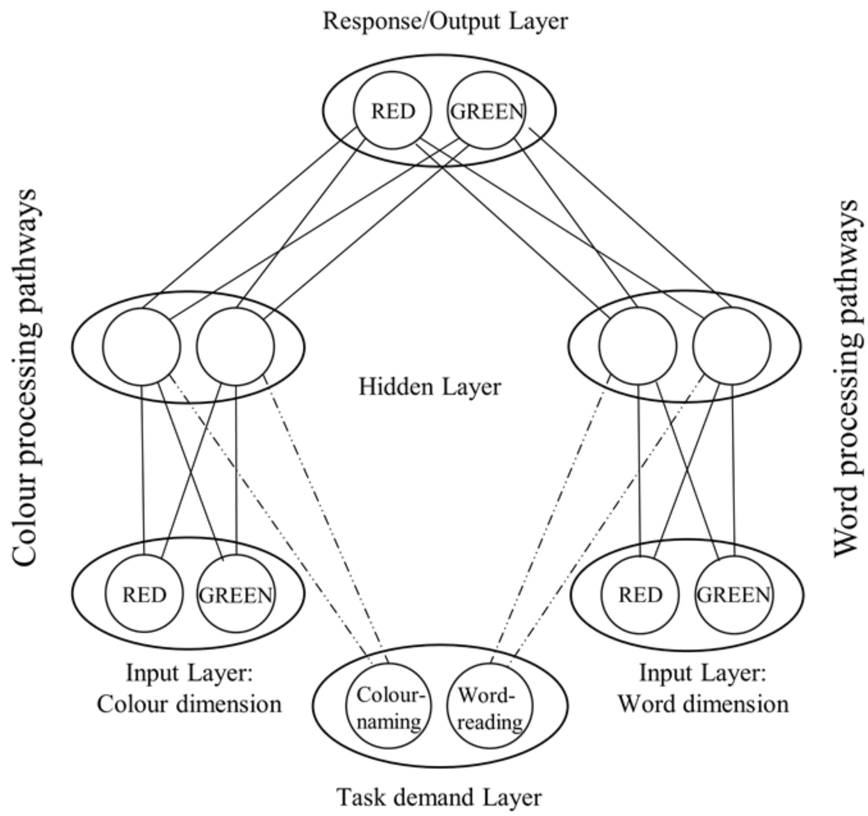
Single-stage account model: Informational/Response Conflict

The Connectionist Model of Cohen et al. (1990)

Cohen et al. (1990) created a connectionist model to account for the Stroop effect by adapting McCleland's (1979) parallel distributed processing (PDP) model. The architecture of this model is a feed-forward network which consists of three layers: the input layer at the bottom, the hidden layer at the middle and the output or response layer at the top (see Figure 1.1).

Figure 1.1

The architecture of Cohen et al.'s (1990) connectionist model.



There are two processing pathways: one is for colour information, and the other is for word information. Each of the units in the input layer is connected to the units in the hidden layer in the same processing pathway (colour or word). Additionally, each of the hidden units is connected to each of the output/response units. Moreover, there is a task demand layer, which contains a colour naming task unit and a word reading task unit. Each of the task demand units is connected to the hidden units in their corresponding processing pathways. The connection weights between the task demand layer and the hidden layer are identical.

Depending on the task goal, when a task demand unit is activated, extra attention or activation is allocated to the corresponding processing pathway. Furthermore, because word reading is practised more than responding to the ink's colour, the weights of the connections in the word processing pathway are set higher than those in the colour processing pathway.

When a colour word stimulus is presented, the colour and word input units are activated. Subsequently, the activations in the two processing pathways flow forward from the bottom to the top between units. The strength of the activation varies by the connection weights and is also modulated by the task units. A response is produced when one of the output units receives sufficient activation to exceed its threshold. Interference occurs when both colour and word processing pathways are activated simultaneously and produce different patterns of activation (RED blue) at the response layer where two pathways intersect. On the other hand, facilitation arises when the two active pathways generate the same patterns of activation (RED red) at their intersection.

Argument for Horse Race Models and the Relative Speed of Processing

This model suggests that the asymmetry between the colour naming task and word reading task is due to the differences in processing strength. That is, the speed of a pathway's processing depends on its strength, which is in line with Dunbar and MacLeod (1984), suggesting that the horse race and the relative speed of processing models can only partially account for the Stroop effect and the asymmetry of Stroop interference. The Stroop task shows a word interfering with a colour when responding to the ink colour resulting in Stroop interference, whereas the colour does not affect the reading of a word. The horse race model and the relative speed of processing model suggest that Stroop interference occurs because word information is processed before colour information. By slowing down the speed that words are read and by increasing the processing speed of the ink colour, it is possible to reverse the asymmetry between colour naming and word reading. That is, colour can influence word reading, whereas a word has less effect on colour (Morton & Chambers, 1973; Posner & Snyder, 1975).

To test the hypothesis of the horse race and the relative speed of processing models, Glaser and Glaser (1982) had half of the participants perform the colour naming task and the other half conduct the word reading task with the manipulation of the stimulus onset asymmetry (SOA, which refers to the time interval between the onset of the colour and the word). The level of SOA was varied across 9 conditions: ±400ms, ±300ms, ±200ms, ±100ms, 0ms. That is, depending on the task, an irrelevant stimulus (colour or word) was either presented before a relevant stimulus when the SOA level was -400ms, -300ms, -200ms, -100ms, or simultaneously with a relevant stimulus at 0ms SOA, or after a relevant stimulus with 100ms, 200ms, 300ms or 400ms SOA. The results showed that although the ink colour was presented prior to the word by 400ms, no effect of colour on word reading was found.

Nevertheless, the word still interfered with colour naming. This finding did not support the horse race and the relative speed of processing models' accounts of Stroop effect.

Glaser and Glaser's (1982) data was simulated by Cohen et al.'s (1990) connectionist model to demonstrate that the relative speed of processing itself is insufficient to elucidate the Stroop effect and the asymmetry of Stroop interference. The finding of Glaser and Glaser (1982) can be explained that, in this connectionist model, because the connection weights/strength are stronger in the word processing pathway than in the colour processing pathway, when none of the task demand units are activated, stronger activation is produced at the response/output layer by the word processing pathway compared to the activation produced by the colour processing pathway. Therefore, even when a colour stimulus is presented before a word stimulus, the activation produced by the colour processing pathway is still weaker relative to word activation.

Effects of Practice on Processing Strength

The relative strength of processing account suggests that the asymmetry of Stroop interference results from the difference in processing strength between colour and word dimensions. Following this account, Cohen et al. emphasised practice effects, proposing that the strength of processing can be altered through practice or training.

The effects of practice were investigated by MacLeod and Dunbar (1988), using coloured shapes as stimuli, which is analogous to the Stroop task where participants could name the shape or the colour. In the experiment, participants were required to carry out 20 sessions of practice on the shape and colour name association spread over 20 days, and were tested on two tasks – shape naming and colour naming only on Day 1, 5 and 20. In the shape naming task, participants were asked to name the shape stimuli that had been associatively trained to various colour names; in the colour naming task, they were instructed to respond to the ink colour. The results of response latencies to incongruent trials (e.g., a shape named PINK printed in blue colour) demonstrated that: At the beginning of the training (Day 1), shape naming (say PINK) was slowed down by the incongruent colour, whereas colour naming (say blue) was not affected by the incongruent shape. On Day 5, both of the shape and colour interfered comparably with each other. By the end of the training (Day 20), shape became dominant and interfered in colour naming, whereas the influence of colour on shape naming was reduced. The finding provided evidence that the Stroop effect is a result of our extensive practice at word reading relative to colour naming, and suggested that practice effects have an impact on the Stroop effect.

MacLeod and Dunbar's (1998) data was simulated by Cohen et al.'s (1990) model to illustrate that the role of practice is represented as training effects in the connectionist model which as a result would change the processing strength/connection weight in a pathway. The training for the link between shapes and colour names was conducted for 2,520 trials/shape. The results showed that at the early stage (72 trials/shape), the connection weight in the shape pathway was still much weaker than that in the colour pathway. As a consequence, the reaction times to shape naming were longer than colour naming by 100ms, and the pattern of congruency implied that colour had effects on shape naming. At the middle stage (504 trials/shape), as the magnitude of the processing strength in the shape pathway had increased to the degree that was equivalent of the colour pathway, the pattern of congruency and the reaction times to shape naming were similar to colour naming. At the late stage (2,520/shape), the connection weight in the shape pathway became much stronger than that in the colour pathway. Accordingly, the roles of shape and colour were swapped. That is, the response latencies to shape naming became shorter than colour naming, and the pattern of congruency indicated that the shape interfered with colour naming. The simulation of MacLeod and Dunbar's (1998) data showed that in the connectionist model, the strength of processing in a pathway can be varied through training.

The Gratton effect or sequential modulation effect of incompatible stimuli

Eriksen and Eriksen (1974) reported a congruency effect ($RT_{incompatible} - RT_{compatible}$) that is similar to the Stroop effect by using Eriksen flanker task, which is a spatial analogue to the Stroop task. In the flanker task, a stimulus array composed of a target letter in the central and a number of distractor letters that flank the target letter is presented and participants are required to respond to the target while ignoring the distractors. The stimulus array can either be compatible (e.g., KKKKKKK) or incompatible (HHHKHHH). It was found that the reaction times to incompatible arrays were longer relative to compatible arrays, which provides further evidence that involuntary processing of the goal-irrelevant information has an impact on performance on the goal-relevant task.

By using Eriksen Flanker task, Gratton, Coles and Donchin (1992) was the first to examine the congruency effect on the trial-by-trial basis and report a sequential modulation on the reaction times (RTs) and error rate, resulting from a top-down and context-driven processing. Gratton and colleagues had participants perform the flanker task using 5-letter arrays with letter 'S' and 'H' as stimuli and hypothesised that participants would shift their attention towards the target or distractor depending on the array type (compatible, incompatible) presented on the previous trial. Accordingly, it was predicted that:

a) If the array type of the previous trial is compatible (e.g., SSSSS), participants would focus on the distractor when responding to the following trial. As a result, when the following trial is also a compatible array, their responses would be faster; but in the case that the following array type is incompatible, they would produce more errors.
b) By contrast, if the array type is incompatible (e.g., SSHSS) on the previous trial, attention would be shifted towards the target for the next trial. As a consequence, when the next trial is a compatible array, slower response for Incompatible-Compatible stimulus than Compatible-Compatible stimulus (e.g., HHHHH) would

be observed; however, if it is an incompatible array presented on the next trial, less errors would be made.

The hypothesis was supported by the finding of the sequential modulation on the RTs and error rate. The significant 2-way Previous × Current interaction demonstrated that:

a) The congruency effect ($RT_{incompatible} – RT_{compatible}$) was significantly larger when compatible arrays were presented on the previous trials (55ms) than when incompatible arrays were presented on the previous trials (42ms), $F(1, 5) = 15.80$, $p < .05$ (see Figure 1.2, left panel); and

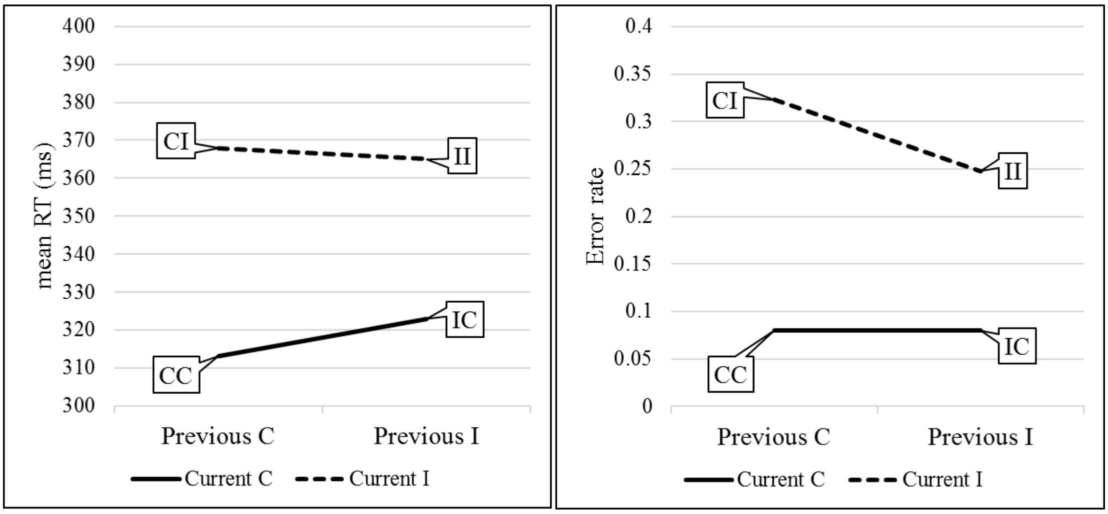
b) The RTs to compatible arrays that followed incompatible arrays (IC) were slower relative to compatible arrays that followed compatible arrays (CC); and

c) Interestingly, the RTs to incompatible arrays that followed incompatible arrays (II) were faster compared to incompatible arrays that followed compatible arrays (CI); further,

d) There was a decrease in the error rate by 0.075 to incompatible arrays when the previous array type was also incompatible (II) compared to when it was compatible (CI) (see Figure 1.2, right panel).

Figure 1.2

The sequential modulation effect on reaction times (left panel) and error rate (right panel) in Gratton, Coles and Donchin (1992).



Gratton, Coles and Donchin (1992) discussed how the findings of congruency effect and sequential modulation can be considered within Cohen et al.'s (1990) connectionist model. They suggested that Cohen et al.'s model can account for the congruency effect, but it lacks an account of sequential modulation where attention can be shifted from trial to trial in response to a change in the activation of processing. That is, the deployment of attention in Cohen et al.'s model is only reflected in task requirements where the corresponding task demand units sensitise units in the goal-relevant processing pathways while units in the goal-irrelevant processing pathways remain unsensitised and there is no other indication of the adjustment of attention.

The following will illustrate the development of single-stage account connectionist models built on Cohen et al.'s (1990) model and how the account of sequential modulation can be incorporated into the model.

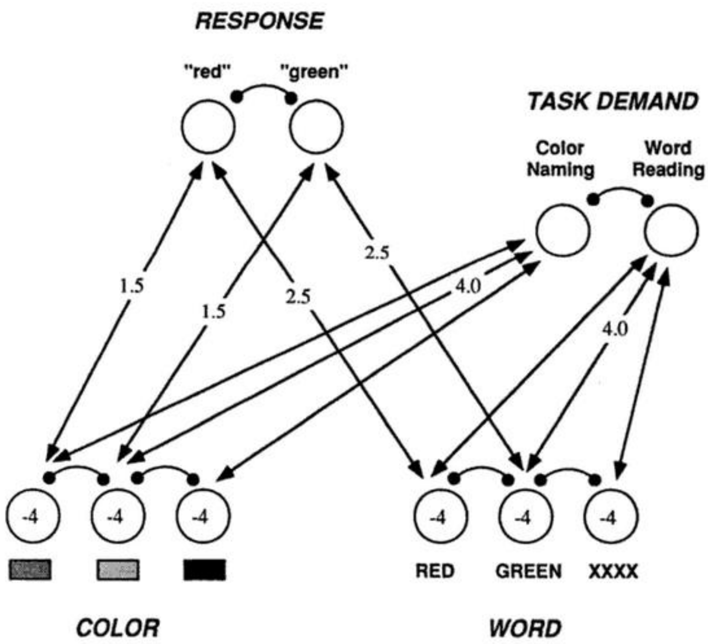
The development of single-stage account model

The GRAIN Model of Cohen and Huston (1994)

Cohen and Huston (1994) developed the GRAIN (Graded, Random, Activation-based, Interactive and Non-linear) model for the Stroop task by revising the model of Cohen et al. (1990). The components of the GRAIN model consist of two task demand units, a set of input units and a set of output/response units for processing colour and word information respectively, which are similar to the original network (see Figure 1.3).

Figure 1.3

The architecture of Cohen and Huston's (1994) GRAIN model.



Units are categorised into modules (input, response and task demand). However, first, the role the hidden units play in the original model is incorporated into the input units in the GRAIN model. Second, unlike the original model's 'feed-forward/bottom-up' fashion in which the direction of information flow is only from bottom to top, the excitatory connections between modules are bidirectional in the GRAIN model. That is, information can proceed from input units to response units as well as from response units to input units. In the same way, information from input units can influence the top-down attention from task demand units. Third, bidirectional inhibitory connections are added between input units within each module (colour and word). Accordingly, competition arises from the lower level due to input units mutually inhibiting each other compared to the original model in which competition occurs at the response layer. It assumes that a response is generated when one of the units stands out from the competition with its activation greater than the threshold. Furthermore, because of these bidirectional inhibitory connections, when one of the task demand units is activated, the corresponding processing pathway is sensitised, while the other processing pathway is desensitised simultaneously. For instance, in the colour naming task, the active colour task demand unit favours the activation of the colour processing pathway, while reducing the activity in the word processing pathway via the bidirectional inhibitory connections between units.

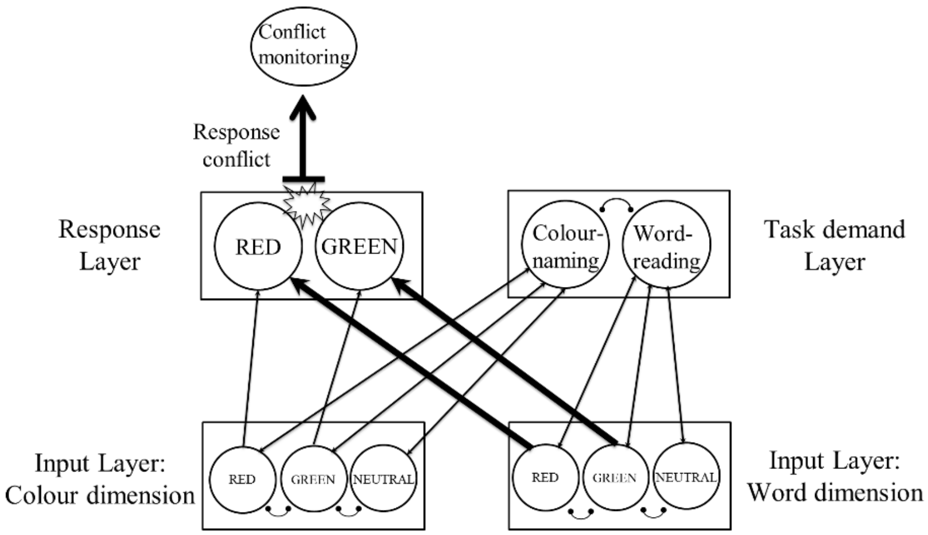
The Conflict Monitoring Model of Botvinick et al. (2001)

Most of the early studies on connectionist models of the Stroop task theoretically assume that there is a mechanism in the background which monitors the 'crosstalk interference' at the response/output layer where colour and word processing pathways intersect and recruits top-down control to alleviate this interference. With this as the rationale, based on the brain studies (Bench et al., 1993; Bush, Luu & Posner, 2000; Carter, Mintun & Cohen, 1995; Carter et al., 2000) on the anterior cingulate cortex (ACC) which is assumed to become active upon the presence of conflict, Botvinick et al. (2001) extended the GRAIN model of Cohen and Huston (1994) to account for how and under what circumstances the recruitment of top-down control is needed.

In the first simulation of the Stroop colour naming task, Botvinick et al. (2001) focused on the response/output competition at the response/output layer, hypothesising that the activation of the ACC can indicate the amount of conflict at the output layer. A conflict monitoring unit which represents the ACC's role is added above the response/output layer of the GRAIN model, and it receives inputs from the response/output layer (see Figure 1.4).

Figure 1.4

A conflict monitoring unit is added to the architecture of Cohen and Huston's (1994) GRAIN model.



The degree of activation of the conflict monitoring unit is calculated by the function of Hopfield energy defined by Hopfield (1982), which represents the amount of conflict between colour and word units in the response/output layer.

$$-\sum\sum a_i a_j w_{ij},$$

According to the function, a) The level of energy remains at zero when neither the colour nor the word unit is active, or when there is only one unit active, which demonstrates the absence of conflict and b) The level of energy grows above zero when both colour and word units are activated and compete with each other, resulting in conflict.

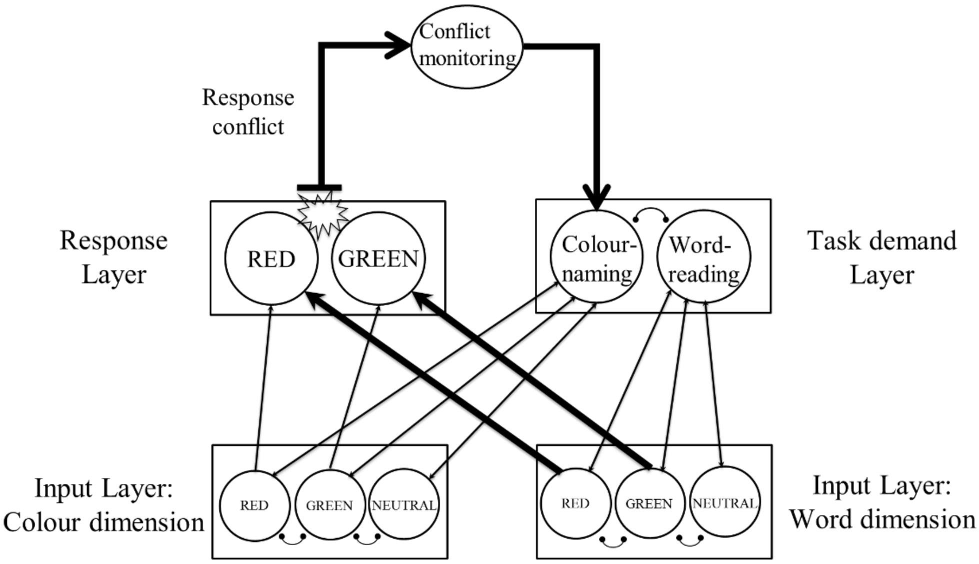
The result illustrated that the level of Hopfield energy was higher in the incongruent trials than the congruent or control trials, which supports the hypothesis that the competition between colour and word units at the response/output layer raises the activation of the ACC. Furthermore, by reducing the degree of activation of the colour task demand unit in the colour naming task, the level of Hopfield energy goes even higher in the incongruent trials, which implies that the ACC's activation is affected by the strength of top-down cognitive control. Carter et al. (2000) provided a picture of the relationship between ACC activation and cognitive control by having participants perform two blocks of the colour naming task in which the proportion of incongruent trials was manipulated. During the task, the ACC's activation was measured by fMRI. The functional neuroimaging data supported the implication that the ACC's activation was lower when responding to the block with a higher proportion of incongruent trials. That is, when the incongruent trials appeared more frequently, it made participants focus more on the ink colour (higher control). As a result, the response conflict was reduced. The result demonstrated that the frequency of the incongruent trials has an impact on the recruitment of cognitive control, resulting in the change in the ACC's activation.

In the second simulation of the Stroop task, Botvinick et al. (2001) hypothesised that top-down cognitive control could be modulated by the conflict monitoring unit, as its activation could be interpreted as an indication that the current degree of activation of the colour task demand unit is not strong enough for colour information to dominate processing, resulting in response competition at the output layer. Consequently, an increase in the strength of top-down cognitive control is required.

The GRAIN model revised in the first simulation was further extended to a feedback loop by adding a connection between the conflict monitoring unit and task demand layer (see Figure 1.5). This means that, in turn, the activation of the task demand units can be adjusted in response to input from the conflict monitoring unit.

Figure 1.5

Following the first simulation, a connection between the conflict monitoring unit and task demand layer is added to form a feedback loop (Botvinick et al., 2001).



The model was tested by simulating the data of Tzelgov et al. (1992). In the experiment, participants had to perform three blocks of the colour naming task. Each of the blocks was comprised of different proportions of incongruent trials: a) High proportion with 37.5% congruent, 37.5% incongruent and 25% neutral trials; b) Medium proportion with 25% congruent, 25% incongruent and 50% neutral trials; and c) Low proportion with 12.5% congruent, 12.5% incongruent and 75% neutral trials. The pattern of the simulation results was comparable to the behavioural data of Tzelgov et al. (1992) that, among the three conditions, the amount of interference in the block with a high proportion of incongruent trials was the smallest, whereas the amount of interference in the block that had a low proportion of incongruent trials was the highest. The amount of interference in the medium condition was in between. This illustrates that the response conflict which arose with the presence of incongruent trials was detected by the conflict monitoring unit. Through the feedback from the conflict monitoring unit, the input to the colour task demand unit was strengthened. Accordingly, the higher the proportion of incongruent trials in a block, the larger the amount of response conflict was observed and, thus, the more strength that was placed on the colour task demand unit. The simulation supports the hypothesis that the level of the recruitment of top-down cognitive control could be modulated by the degree of ACC activation.

Furthermore, in contrast to Cohen et al.'s (1990) model, with the implementation of the conflict monitoring unit, the deployment of attention is now able to change from trial to trial in Botvinick et al.'s (2001) model. Accordingly, the sequential modulation effect of Gratton et al. (1992) can be explained within the model. That is, the response conflict monitored on the previous trial would increase the top-down cognitive control on the colour naming task demand unit. As a result, if another incongruent stimulus is also presented on the current trial, the response to the stimulus would be faster due to the strengthened colour processing pathway.

Dual Mechanism of Control Model of De Pisapia and Braver (2006)

De Pisapia and Braver (2006) and Braver (2012) introduced a dual mechanism of control (DMC) to account for the cognitive processes in the Stroop task. The DMC framework hypothesises that top-down cognitive control can be recruited via two mechanisms, that is, proactive control and reactive control. In proactive control, attention is continuously recruited to strengthen the task-relevant information processing prior to the performance of a task which consumes cognitive resources. In this way, an individual is primed and prepared for the task's goal before a stimulus is presented. On the other hand, in reactive control, attention is recruited to inhibit the activation of task-irrelevant information during the execution of a task which is not resource consuming but must be recruited repeatedly when needed. As a result, when a stimulus that contains goal-irrelevant information is displayed, an individual can suppress the goal-irrelevant information to make the correct response.

The network of the dual feedback loop mechanism proposed by De Pisapia and Braver (2006) was adapted from the model of Botvinick et al. (2001). The main differences between the two models are as follows:

a) In the original model of Botvinick et al. (2001), there is only one conflict monitoring unit representing the role of the ACC, whereas in the DMC model, there are two units standing for the ACC's activation. One monitors conflict over a long time-scale, and the other detects conflict across a short time-scale;

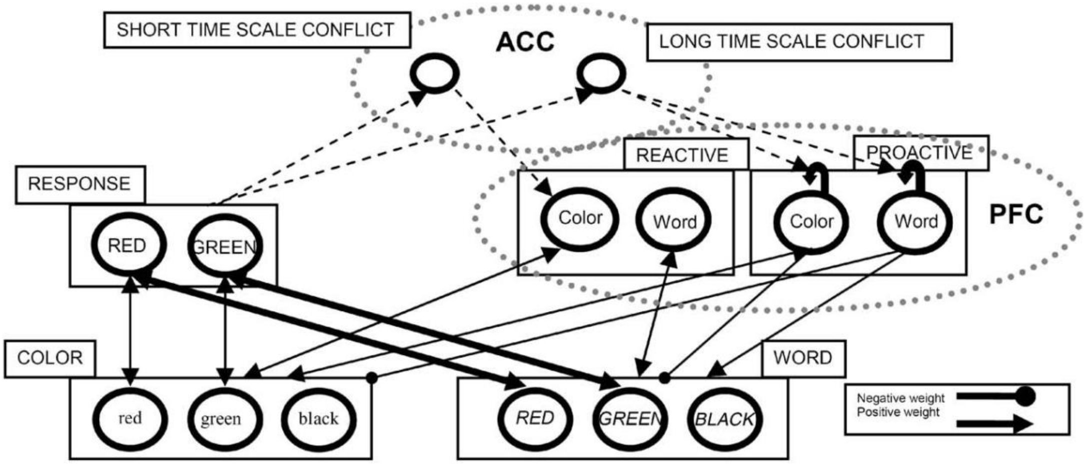
b) In the original model, there was only one task demand layer with two units for the colour naming and word reading tasks, respectively. The task demand layer performed the role of top-down cognitive control (prefrontal cortex), in which the units were modulated by the conflict monitoring unit. In comparison with the original model, two task demand layers are introduced to the DMC model: one is the proactive layer, and the other is the reactive layer. The two task demand units in the proactive layer are regulated by the long time-scale conflict monitoring unit, whereas those in the reactive layer are tuned by the short time-scale conflict monitoring unit;

c) In the DMC model, there is a bidirectional connection between the reactive layer and input layer for the colour dimension and word dimension, respectively; and

d) In the DMC model, the colour input layer is inhibited by the word task demand unit in the proactive layer, whereas the word input layer is inhibited by the colour task demand unit in the proactive layer (see Figure 1.6).

Figure 1.6

The framework of De Pisapia and Braver's (2006) dual mechanism of control model.



The DMC model was tested by simulating the data of Braver and Hoyer's (2006) neuroimaging study, in which participants carried out three conditions of the Stroop colour naming task while undergoing an fMRI. The three conditions were: a) Mostly congruent (MC) with 70% congruent, 15% incongruent and 15% neutral trials; b) Mostly neutral (MN) with 15% congruent, 15% incongruent and 70% neutral trials; and c) Mostly incongruent (MI) with 15% congruent, 70% incongruent and 15% neutral trials. The pattern of simulation results for both the behavioural and functional imaging data was close to the pattern of the empirical data. The simulation of behavioural data showed that the response latencies to the incongruent trials were longer in the MC condition than in the MI condition. The simulation of functional imaging data demonstrated that, over the three conditions from MC to MI, there was a decrease in the activation of the short time-scale unit (ACC) as well as the reactive task demand units (lateral PFC). On the contrary, the activation of proactive task demand units significantly increased across the three conditions, from MC to MN to MI. This illustrates that the reactive control mechanism was triggered when the proportion of incongruent trials was low and it was taken over by the proactive control mechanism when the proportion of incongruent trials was high, which shows a shift in the mechanisms of top-down control, from reactive to proactive.

The Adaptive Attentional Control model of Wyble, Sharma and Bowman (2008)

Wyble, Sharma and Bowman (2008) proposed a model that is built on the connectionist model of Botvinick et al. (2001) to account for the mechanism underlying the trial-by-trial effect of emotional Stroop interference in addition to the account of standard Stroop interference. Wyble and colleagues suggested that the emotional Stroop interference is a result of the competition for the limited attentional resources between the top-down cognitive control to the ongoing colour naming task and the top-down automatic processing of negative emotional words.

The differences between the models of Wyble et al. (2008) and Botvinick et al. (2001) are as follows:

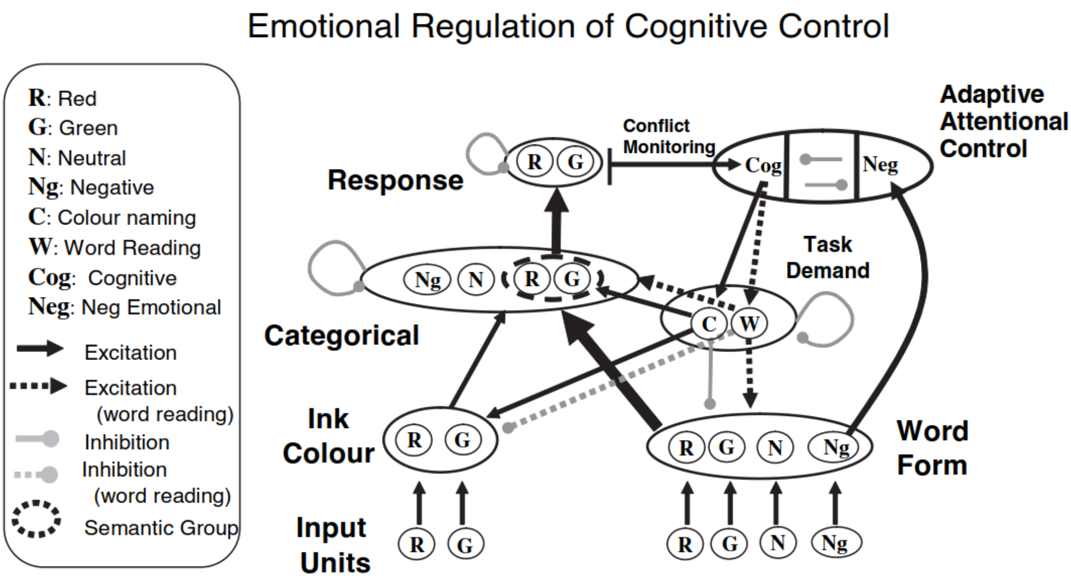
a) In the word input layer, a unit representing negative emotional words (Ng) is added along with the units representing colour words and neutral words.

b) Both colour and word units in the input layer project to their corresponding units in a category layer where non-colour words are allowed to interfere with colour through lateral inhibitory connections between units. That is, when two units are activated, they will suppress each other, thereby delaying a response to be produced in the response layer.

c) A negative emotional node (e.g., Neg), which can be directly activated by the negative word input unit through an excitatory link, is added next to the cognitive node at the top level of attentional control (see Figure 1.7).

Figure 1.7

The architecture of Wyble, Sharma and Bowman's (2008) adaptive attentional control model.



Wyble et al. (2008) hypothesised that in the colour naming task, the colour-responding performance is slowed down by the presence of negative words because the cognitive control node is inhibited by the triggered negative node. This is due to the decrease in the activation flowing from the top-down cognitive control node to the colour naming task demand unit, which subsequently reduces the activation of colour processing pathways. Wyble and colleagues further explained that this withdrawal from the current ongoing task is not fast enough to affect the performance on the current trial where the negative word is displayed and therefore the delay occurs on the next trial.

To provide support for the hypothesis, the model was tested by two simulations to demonstrate the influence of negative words on the colour-word Stroop interference and the trial-by-trial effect of the emotional Stroop interference: (i) Tzelgov et al.'s (1992) effects of proportion manipulation on Stroop interference, and (ii) The slow effect of McKenna and Sharma (2004). Both results were replicated in the simulation. The followings are the details of the simulations.

In the first simulation, Wyble and colleagues used a design adapted from Tzelgov et al. (1992) by replacing neutral words with negative emotional words. In the simulation participants carried out three blocks of colour naming and each block contained different ratios of colour words to negative words: a) High proportion with 75% colour words and 25% negative words; b) Medium proportion with 50% colour words and 50% negative words; and c) Low proportion with 25% colour words and 75% negative words. The simulated results showed a pattern similar to the findings by Tzelgov et al. (1992) that among the three blocks, the amount of interference in the block with a high proportion of colour words was the smallest, whereas it was the largest in the block with a low proportion of colour words. In addition, there was an increase in the amount of interference in the low proportion block (25% colour words) where negative words represented 75% trials in comparison with the low proportion block in Tzelgov et al. (1992) where neutral words represented 75% trials, indicating that colour naming task can be disrupted by negative emotional stimuli. The data was simulated by the model and an explanation was provided to account for the results. That is, in the high proportion block (75% colour words), because of the frequent presence of incongruent trials, the colour naming task demand unit is regularly activated, thus the disruption by the negative words is small. By contrast, in the low proportion block (25% colour words), as the occurrence of negative trials becomes frequent, the active negative emotional node constantly inhibits the cognitive node, thereby decreasing the activation of the colour naming task demand unit. Accordingly, the interference to incongruent trials increases.

In the second simulation, the account of trial-by-trial effect in the model was tested using the data of McKenna and Sharma (2004), in which participants performed blocks of colour naming task mixing negative emotional and neutral words using a pseudorandom sequence method. Each pseudorandom sequence consisted of a negative word at the beginning of the sequence and six neutral words that follow the negative word. The results indicated a “slow effect” of emotional Stroop interference, which means that participants did not show a slowdown when responding to the negative trial but did demonstrate a delay on the following neutral trial and this delay diminished on the third trial. The model interprets the slow effect as that the negative emotional node triggered by the negative word input unit suppresses the cognitive node, thus reducing the activation allocated to the colour naming task demand unit. As a result, the colour naming processing is interrupted and response conflict is observed. However, this mechanism is not fast enough to influence the colour-responding to the ongoing negative trial but to the following neutral trial.

Chapter 2: Colour word Stroop Task and Multi-stage account model

The aforementioned connectionist models simply consider that the Stroop effect is due to informational/response conflict which was referred to as *single-stage accounts* in Risko, Schmidt and Besner (2006). The following studies will focus on *multiple-stage accounts* arguing that the Stroop effect is due to conflict from multiple components including informational and task conflicts (Risko et al., 2006).

Multiple-stage account model: Informational/Response Conflict and Task conflict

Goldfarb and Henik (2007)

MacLeod and MacDonald (2000) suggested that the brain imaging results are not consistent with the behavioural findings. That is, the brain imaging results showed that the degree of ACC activation is higher in both the incongruent and congruent conditions compared to the neutral condition, implying that even the congruent condition induces more conflict than the neutral condition does, whereas the behavioural findings illustrated that the reaction times (RTs) to the congruent condition are faster (i.e., facilitation effect) or much the same as the RTs to the neutral condition. Goldfarb and Henik (2007) attempted to provide behavioural evidence to support the brain imaging findings and proposed that it is because of the recruitment of the control mechanism, which can be referred to the task demand control (Botvinick et al., 2001) or the proactive control (Braver, 2012; De Pisapia & Braver, 2006), the interference due to the occurrence of task conflict is resolved, which as a result the reaction times to the congruent condition and the neutral condition do not differ from each other. Accordingly, if the degree of control is lowered, the role of task conflict should be disclosed by the slower reaction times for the congruent condition than the neutral condition.

To weaken the control mechanism, the design of Tzelgov et al. (1992) was adopted with a cueing method. In addition, non-colour words used in Tzelgov et al. (1992) were replaced by letter strings as neutral stimuli. Thus, when a neutral trial is presented, it does not activate word reading since a letter string does not have lexical meaning. In the first experiment, the proportion of each trial type was: 12.5% congruent, 12.5% incongruent and 75% neutral trials, in which half of the trials in each condition were cued and half were not cued. In the cued condition, when the cue ‘X’ was presented, it meant the forthcoming stimulus was a colour word; when the cue ‘O’ was shown, it meant the incipient stimulus was a letter string. In the uncued condition, ‘?’ was displayed prior to a stimulus.

As this 2 (cued, uncued) × 3 (congruent, incongruent, neutral) factorial design was aimed to reduce the control mechanism, it was predicted: (i) A reversed facilitation effect would be observed. That is, the RTs to the congruent trials would be longer than the RTs to the neutral trials in the uncued condition but not in the cued condition and (ii) The RTs to the congruent trials would be longer in the uncued condition where the control is alleviated than in the cued condition where the control is recruited. Both predictions were supported by the results that, first, in the uncued condition, the RTs to the congruent trials (942ms) were significantly slower than the RTs to the neutral trials (812ms), showing a reversed facilitation effect. Second, the RTs to congruent trials were significantly longer in the uncued condition (942ms) than the cued condition (834ms).

It could be argued that the reversed facilitation resulted from a difference in the proportion between congruent (12.5%) and neutral (75%) conditions rather than the effect of the task conflict due to the weakened control. Therefore, the second experiment was carried out. The design and procedure of the second experiment were identical to the first experiment. The only change was that non-colour words were selected as stimuli for the neutral condition instead of letter strings. Hence, in contrast to the first experiment in which the control mechanism was reduced because only 25% of trials were word stimuli, the control mechanism was predicted to be tightened in the second experiment since all the stimuli across the three conditions contained lexical meaning, which is strongly associated with and would trigger the performance of a goal-irrelevant word reading task (Monsell et al., 2001; Waszak, Hommel, & Allport, 2003).

It was predicted that the reversed facilitation effect observed in the first experiment would be diminished or even dissipated under the high proactive control state. The results showed that there was no significant difference in the RTs in the uncued condition between the congruent and neutral trials. Moreover, no significant difference was found in the RTs to the congruent trials between cued and uncued conditions. The results of the second experiment supported the prediction and suggested that the reversed facilitation effect was due to the effect of task conflict rather than the trial-type frequency effect.

Kalanthroff et al. (2013) and Entel and Tzelgov (2018)

Following the work of Goldfarb and Henik (2007), Kalanthroff et al. (2013) and Entel and Tzelgov (2018) attempted to examine whether the task conflict is independent of the informational conflict.

Kalanthroff et al. (2013) argued that the slower response to the congruent condition than the neutral condition (task conflict) revealed in Goldfarb and Henik (2007) could be due to an adaptive control process which is triggered to prevent participants from making mistakes when responding to the incongruent condition since the design was comprised of 12.5% congruent, 12.5% incongruent and 75% neutral trials. To explore whether the task conflict arises in the absence of informational conflict, Kalanthroff et al. (2013) replicated the design and the procedure of Goldfarb and Henik (2007). However, the incongruent condition was removed and only the congruent and neutral conditions were used – that is, 25% congruent and 75% neutral trials (letter strings). In addition, half the trials were cued to indicate whether an upcoming trial would be a congruent or a neutral stimulus.

In line with the results of Goldfarb and Henik (2007), in the uncued condition in which the proactive control was low, a reversed facilitation effect was observed, which suggested that a) Rather than the adaptive process that only arises when there exists an incongruent condition, the occurrence of the task conflict was due to a non-adaptive/compulsory process which is activated whenever a readable word (task-irrelevant) stimulus is presented, even though the information of a word stimulus is compatible with that of a colour (task-relevant) stimulus, and b) The effect of reversed facilitation took place with the absence of incongruent trials, suggesting that the appearance of task conflict is independent of the informational conflict.

On the other hand, to investigate whether the task conflict appears without the existence of the informational conflict, Entel and Tzelgov (2018) used a 3 Task conflict level (MC, MN, EP) × 2 Congruency (congruent, neutral) × 2 Block (first, second) mixed factorial design without the incongruent condition and manipulated the trial ratio of the congruent to neutral (a string of symbols e.g., ####) condition, which resulted in three conditions: a mostly congruent condition with 90% congruent and 10% neutral trials (MC), a mostly neutral condition with 10% congruent and 90% neutral trials (MN), and an equal proportion condition with 50% congruent and 50% neutral trials (EP). In the first experiment, participants were randomly assigned to one of the three conditions (MC, MN or EP) and instructed to perform a practice block followed by two blocks of the colour naming task. The results were inconsistent with the findings of Kalanthroff et al. (2013), showing no reversed facilitation effect. Instead, participants responded faster to the congruent condition than to the neutral condition across the three conditions. A large facilitation (123ms) especially was found in the MC condition, and a small facilitation was observed in the MN condition (the facilitation in the EP condition was no different from the MN condition).

The second experiment was conducted with the manipulation of the exposure to the incongruent condition. A 2 Task conflict level (MC, MN) × 2 Practice type (with, without incongruent trials) × 2 Congruency (congruent, neutral) × 4 Block (first, second, third, fourth) mixed factorial design was used, resulting in four conditions (see Table 2.1).

Table 2.1

The procedure of the second experiment in Entel and Tzelgov (2018)

Practice Phase	Colour Naming Task Phase			
1	1st	2nd	3rd	4th block
Without incongruent trials	MC	MC	MC	Contain incongruent trials
	MN	MN	MN	Contain incongruent trials
With incongruent trials	MC	MC	MC	Contain incongruent trials
	MN	MN	MN	Contain incongruent trials

That is, half of the participants carried out a practice block composed of congruent, incongruent and neutral conditions, whereas the other half of the participants performed a practice block without the incongruent condition. Moreover, following the practice block, there were four blocks instead of two blocks of the colour naming task. The first three blocks were identical, depending on which task conflict level condition (MC or MN) participants were assigned to. However, the fourth block presented to all the participants was composed of 9% congruent, 9% incongruent and 82% neutral trials. Therefore, participants were primed during the practice block and would expect the presence of an incongruent condition in the following test blocks, but the incongruent trials were not shown until the fourth block. The results revealed that, in the blocks of the MN condition, when there was no incongruent trial in the practice block, the facilitation effect was found across the first three blocks. Moreover, a reversed facilitation effect emerged in the fourth block with the presence of incongruent trials. Compared with it, intriguingly, when incongruent trials were included in the practice block, a reversed facilitation effect was observed in the first block. This reversed facilitation disappeared in the second and third block but arose again in the fourth block in which incongruent trials were presented. In contrast to Kalanthroff et al. (2013), the findings of Entel and Tzelgov (2018) suggested that the recruitment of task control requires the presence of informational conflict. That is, the task conflict is not independent of the informational conflict.

Kalanthroff and Henik (2014)

The task switching paradigm has been developed to investigate the cognitive mechanisms underlying task switching. The main focus in task switching studies is to account for the nature of switch costs (Kiesel et al., 2010). However, the task switching paradigm has also been used to explore the role of stimulus-induced task conflicts (Aarts et al., 2009; Steinhauser & Hübner, 2007, 2009). Following the work of Goldfarb and Henik (2007), Kalanthroff and Henik (2014) carried on an exploration of the reversed facilitation effect/task conflicts by using the task switching paradigm, because frequently switching task goals would weaken the proactive control to each task since no one task can be constantly activated, the competition between tasks escalates. (Aarts et al., 2009). Moreover, to further trigger the failure of proactive control, cue target interval (CTI) was manipulated. That is, the shorter the CTI, the less proactive control is recruited, resulting in higher task conflict. In the first experiment, participants had to perform colour naming and word reading tasks. Two colour words (red, green) were used as stimuli for congruent and incongruent conditions in both tasks. A four-letter string (XXXX) was selected as neutral stimuli for the colour naming task, whereas for the word reading task, words in the neutral condition were written in white ink. The CTI was varied across the three conditions – 0ms, 300ms and 1,500ms. Accordingly, a task cue (colour or word) would be presented simultaneously with a stimulus when the CTI was 0ms, or a task cue would be displayed prior to a stimulus with 300ms or 1,500ms CTI.

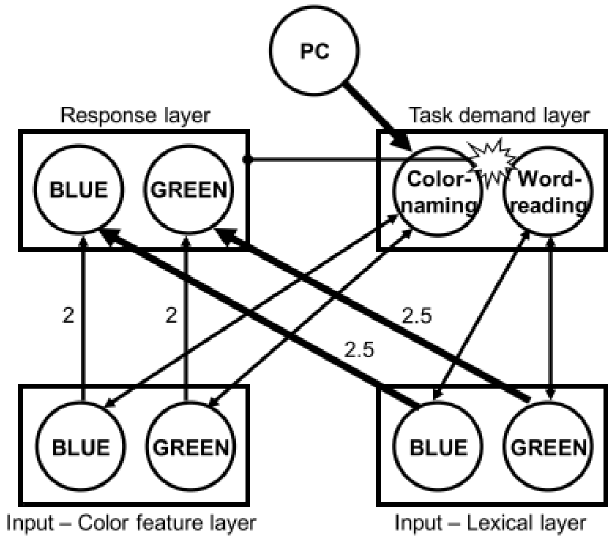
The design was 3 Congruency (congruent, incongruent, neutral) × 3 CTI (0, 300 and 1,500ms) × 2 Switching (switch, non-switch) x 2 Task (colour, word). It was predicted that the reversed facilitation effect would be probed and the effect would be greater at shorter CTI than longer CTI conditions. The results demonstrated that, for both colour naming and word reading tasks, there was a significant reversed facilitation (task conflict) at 0ms CTI and the amount of the reversed facilitation diminished as the CTI became longer. In addition, the interference (informational conflict) was significant and was the largest at 0ms CTI, which decreased when the CTI was longer. The same pattern for the results across the two tasks (colour naming and word reading) indicated that the recruitment of proactive control could be undermined in the task switching paradigm and it could be modulated through the variation of CTI.

The PC-TC Model of Kalanthroff et al. (2015)

Kalanthroff et al. (2015) created a model of proactive-control/task-conflict (PC-TC) to account for both the response conflict/informational conflict and task conflict of the Stroop colour naming task. The structure of the PC-TC model was based on the connectionist model of Botvinick et al. (2001). Moreover, the theory of dual mechanisms of control proposed by Braver (2012) and De Pisapia and Braver (2006) was incorporated into the PC-TC model in which the proactive control mechanism augments the task-relevant processing in a top-down and preparatory fashion, whereas the reactive control mechanism inhibits the task-irrelevant processing in a bottom-up and late-acting fashion. Accordingly, the PC-TC model is comprised of a response layer, a task demand layer, an input layer for colour information and an input layer for word information (see Figure 2.1).

Figure 2.1

The network of Kalanthroff et al.'s (2015) PC-TC model.



As in the connectionist model of Botvinick et al. (2001), the response units receive activation from the colour and word input units through the excitatory connections, and the connection weights between the word input layer and the response layer are higher than those between the colour input layer and the response layer due to the greater automaticity of word reading. In the single stage connectionist model, the task demand layer acts as top-down cognitive control providing extra activation to strengthen the task-relevant processing, and there is no account of task conflict. In comparison, in the PC-TC model, the task conflict is reflected by the competition between the colour task demand unit and the word task demand unit which inhibits the response layer via an inhibitory connection between the task demand layer and the response layer. The amount of task conflict is computed by the function of Hopfield energy. The task conflict can be mediated by top-down proactive control or by bottom-up reactive control, which occurs via the bidirectional connections between the task demand layer and the input layers. That is, for example, in the colour naming task, when the state of proactive control on the colour task demand unit is high, the word task demand unit is inhibited by the colour task demand unit, and colour processing is strengthened from top-down. Hence, the activations from the input layers to the task demand units can be regarded as negligible. Consequently, the competition within the task demand layer is low. However, when the state of proactive control on the colour task demand unit is low, as the activations flow from the input layers into the task demand units, the word task demand unit is activated and competes with the weakly activated colour task demand unit, resulting in the task conflict. The inhibition from the task conflict remains until the task conflict is alleviated by the reactive control.

The PC-TC model predicts that, a) When the PC is high, a classic Stroop effect will be observed. That is, the effects of interference (slower RTs to the incongruent than the non-word neutral condition) and facilitation (faster RTs to the congruent than the non-word neutral condition) and b) When the PC is low, there is an increase in the reaction times to both the congruent and incongruent conditions, which in turn results in the effects of interference and reversed facilitation (slower RTs to the congruent than the non-word neutral condition).

Apart from building the PC-TC model, Kalanthroff et al. (2015) investigated the impact of working memory load on the task conflict and the proactive control by using a 2

WM load (high, low) × 3 Congruency (congruent, incongruent, neutral) design that combines the *n*-back task with the Stroop task. With the manipulation of working memory (WM) load, participants had to perform two blocks in the experiment: one was composed of a *zero*-back task (low WM load) and a Stroop task; the other one was comprised of a *two*-back task (high WM load) and a Stroop task. In the *zero*-back task, participants had to match the letter presented at the current trial to a fixed target letter given for the whole block. In the *two*-back task, participants had to respond if the letter displayed at the current trial was matched to the letter that was shown two trials earlier. In each trial, an *n*-back task was presented before a Stroop task.

It was predicted that the degree of proactive control could be contingent on the amount of available WM resources. Accordingly, Stroop interference and facilitation would be observed under the condition of low WM load (*zero*-back task) since the high amount of available WM resources would result in high proactive control, which reduces the task conflict. On the other hand, stronger Stroop interference and a reversed facilitation effect would be probed under the condition of high working memory load, as the low amount of available WM resources would lead to low proactive control and high task conflict. The prediction was supported by the results of a significant two-way interaction between WM load and Congruency which illustrated the following:

a) When the WM load was low, an interference effect, slower RTs to the incongruent trials (754ms) than the neutral trials (720ms) ($t(16) = 2.169$, $p < .05$) and a facilitation effect, faster RTs to the congruent trials (699ms) than the neutral trials (720ms) ($t(16) = 2.8$, $p < .02$) were found and

b) When the WM load was high, a stronger interference effect, slower RTs to the incongruent trials (912ms) than the neutral trials (861ms)($t(16) = 4.861$, $p < .001$) and a reversed facilitation effect, longer RTs to the congruent trials (881ms) than the neutral trials (861ms) ($t(16) = 2.459$, $p < .03$) were observed.

Chapter 3: Non-colour word Stroop Task and Effects of Priming

Attentional bias towards non-colour neutral words

The Stroop paradigm has also been applied to examining implicit memory. One way this has been done is by using the study-test method to explore the effect of priming on the non-colour-word Stroop task.

In implicit memory tasks, the typical finding is that previously studied items can affect target responses: participants respond quicker to primed items than unprimed stimuli (i.e., the lexical decision task), or are more likely to produce the answer related to the previously primed stimuli (i.e., word completion task) (Mckoon & RatCliff, 1979; RatCliff & Mckoon, 1996). However, in the Stroop task, studies using the study-test procedure in which study and test vary on a trial-by-trial basis show that the priming effect significantly increases colour naming response latencies to the test items related to the primed studied items. In each trial, one or few study items (e.g., AUNT, UNCLE, COUSIN) are given, immediately followed by a colour naming test item, with a word printed in a specific colour (e.g., the word RELATIVE in green colour) and participants are required to name the colour. (Warren, 1972, 1974; Conrad, 1974). Nevertheless, studies also suggest that the priming effect can result in faster reaction times to the test items that are identical to the primed studied items (Burt, 1994, 1999, 2002).

MacLeod (1996) applied the study-test procedure using the block-by-block format method (in which all the study items are presented before all the test items). MacLeod mixed the studied and unstudied words in a test block, aiming to investigate whether this priming effect is strong enough to cross the interval between the study and test phases. Both the colour naming and word reading tasks were conducted with vocal responses during the test phase. The results of the reaction time showed that, for the colour naming task, there was no significant difference between the studied and unstudied words in the block (a null effect), while for the word reading task, there was a facilitation effect in which response times were faster for studied words than unstudied words. 'Process-specific' processing was given as an explanation to illustrate that the priming effects can only benefit the relevant word reading task but do not disrupt the irrelevant colour naming task. Probably because when participants saw the words during study, they were actually reading them silently in their minds.

Sharma (2018) argued that the 'process-specific' suggestion that MacLeod provided cannot explain the priming effects found in previous studies such as those of Warren, Conrad and Burt, that used the trial-by-trial presentation method. Alternatively, Sharma suggested it could be that task conflict caused the null effect within the mixed block as studied items may have slowed responses to unstudied items within the same block. Sharma (2018) replicated MacLeod's mixed block design and added a pure block composed of only unstudied words. The colour naming task was conducted with manual responses.

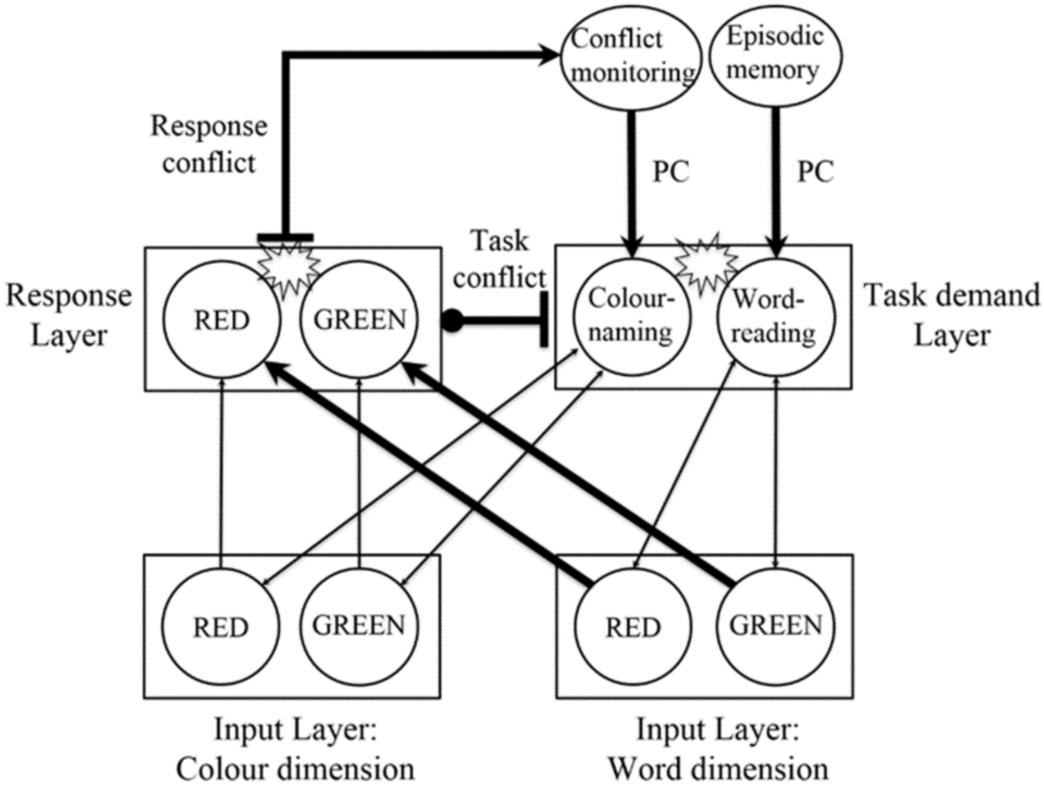
Based on the PC-TC model of Kalanthroff et al. (2015), the following was hypothesised:

a) According to the process-specific hypothesis of MacLeod (1996), as primed words do not interfere with colour naming, the null effect could result from the high state of PC to the colour naming task demand unit (response conflict account). Thus, given that the activations from the input layers to the task demand units can be considered negligible when the PC is high, the reaction times to the mixed block which contains studied words would be faster than the pure block which has only unstudied words. Furthermore, in terms of the trial-by-trial modulation effect (the impact of the previous trial on the subsequent trial), if the response conflict is produced by the primed studied words, a Gratton effect/sequential modulation effect would be found. That is, a faster response to a studied word preceded by a studied word compared to a studied word preceded by an unstudied word within the mixed block would be expected, or

b) To the contrary, Sharma (2018) suggested that the null effect could be due to the high state of PC to the word reading task demand unit (task conflict account) since the performance of word reading is triggered when a subject is instructed to memorise words during the study phase. In addition, during the test phase, when a primed word is presented, the word reading task demand unit could be activated by the episodic memory of studied stimuli (see Figure 3.1). Consequently, the response latencies to the mixed block which includes studied words would be slower than the pure block without studied words. Moreover, in terms of the trial-by-trial modulation effect, if the task conflict is induced by the primed studied words, a reversed sequential modulation effect would be observed. That is, a slowdown in response to a studied word preceded by a studied word compared to a studied word preceded by an unstudied word within the mixed block would be predicted.

Figure 3.1

Proactive-control/task-conflict (PC-TC) model. Adapted from Kalanthroff et al. (2015).



Note. The task demand units are regulated by proactive control through the conflict monitoring node. The episodic memory node was not a part of the original PC-TC model and has been added to make predictions for the task conflict account of the priming effect on the colour naming task in Sharma (2018).

Considering that, in the mixed block, there might be a shift from proactive control to reactive control or vice versa, the performance in the first half and the second half was investigated in the analysis. First, the analysis of 3 Study type (studied-mixed, unstudied-mixed, unstudied-pure) × 2 Block half (first half, second half) × 2 Block order (mixed-pure, pure-mixed) showed a significant main effect of study type and a significant two-way interaction between Study type and Block half. This revealed the following:

a) Within the mixed block, there was no significant difference in reaction time between the studied (699ms) and unstudied words (692ms) (p = .27), which replicated MacLeod's findings;

b) Between the blocks, the response latencies to the unstudied words mixed with the studied words (692ms) were significantly larger than the unstudied words (667ms) (p = .007) in the pure block, which supported the task conflict hypothesis;

c) Within the mixed block, in the first half, the reaction times to the studied words were no different from the unstudied words. However, in the second half, the reaction times to the studied words were significantly larger than the unstudied words (p = .048). Importantly, between the blocks, the studied-mixed words significantly took longer to respond to than the unstudied-pure words (p = .011), while there was no difference in the response latencies between the unstudied-mixed words and the unstudied-pure words in the second half (p = .26). The comparison between the first and the second half of the mixed block indicated the priming effect as well as the shift of the control mechanism from the proactive to the reactive; and

d) Block order did not have any influence on the results.

Second, the analysis of 2 Previous study type (studied, unstudied) × 2 Current study type (studied, unstudied) × 2 Block half (first half, second half) × 2 Block order (mixed-pure, pure-mixed) showed a significant, simple two-way interaction between the Previous study type and Current study type in the second half. This demonstrated that participants' speed was significantly slowed only when seeing the studied words preceded by the studied words, which is in line with the hypothesis of task conflict account.

In summary, Sharma (2018) replicated the findings of MacLeod (1996) and suggested that, in the block-by-block format non-colour word Stroop task, the priming effect can lead to colour interference that is due to task conflict. This is observable between blocks (RT for the mixed block > RT for the pure unstudied block) when PC to word reading is high; and within the mixed block (i.e., the second half) when RTs for CsCs trials are longer than for CCs trials when PC to word reading diminishes.

Attentional bias towards non-colour salient words

The Stroop paradigm has also been developed to investigate the effects of non-colour salient stimuli such as negative emotional/threat-related stimuli and addiction-related stimuli on attention, which are referred to as the emotional Stroop paradigm and the addiction Stroop paradigm, respectively.

The emotional Stroop paradigm has been used to explore attentional bias in anxiety and other emotional disorders such as depression, phobias, post-traumatic stress disorder, obsessive-compulsive disorder and panic disorder. The emotional Stroop task requires responding to threat-related and neutral word's ink colour while ignoring its meaning. The difference in colour naming response latency between threat-related and neutral words is referred to as the emotional Stroop effect. Findings suggest that both nonclinical individuals with high trait anxiety and clinically anxious individuals show attentional bias towards threat-related words, whereas such threat-related bias is not found in non-anxious individuals (Bar-Haim et al., 2007; Phaf & Kan, 2007; Yiend, 2010).

Regarding to the priming effects on the emotional Stroop task, Lundh and Czyzykow-Czarnocka (2001) reported that priming participants with a negative schema prior to the emotional Stroop task slowed down their colour-responding latencies to prime-relevant negative stimuli but not neutral stimuli; Segal, Gemar, Truchon and Guirguis (1995) and Segal and Gemar (1997) suggested that when responding to the prime-target pairs, depressed clinical patients showed greater colour naming interference to self-referent negative words primed by self-referent negative phrases compared to those primed by nonself-referent negative phrases. As for other works on priming effects on emotions, Janiszewski and Wyer's (2014) review illustrated that participants were faster to identify target's emotion type when it corresponded to prime's emotion type regardless of whether the stimuli were words, pictures or facial expressions, which demonstrated a congruency effect (Neumann & Lozo, 2012); participants became motivated to acquire attainable rewards after being primed with angry facial expressions compared to after being primed with neutral facial expressions (Veling, Ruys & Aarts, 2012).

In comparison with the emotional Stroop paradigm, the addiction Stroop paradigm has been established to examine attentional processing of addiction-related stimuli in addictive behaviours such as smoking, gambling, alcohol misuse and illicit drug abuse. The addiction Stroop task involves exposure to addiction-related stimuli (e.g., words or images) and neutral stimuli. General findings suggest that addictive substance abusers have attentional bias for addiction-related stimuli. That is, individuals with concerns related to addiction show longer reaction times to addiction-related Stroop stimuli compared to neutral stimuli (Cox, Fadardi & Pothos, 2006; Robbins & Ehrman, 2004). As for the priming effects on the addiction Stroop task, Stewart, Hall, Wilkie and Birch (2002) suggested that when primed by negative and positive, but not neutral words, participants who drink to alleviate negative emotions showed longer colour-responding to alcohol words than nonalcohol words; Field, Rush, Cole and Goudie (2007) found that smokers primed with the smoking cues (e.g., holding a lit cigarette) compared to the neutral cues (e.g., holding a pen) prior to the addiction Stroop task were slower to colour name smoking-related words than neutral control words. As for other studies on priming effects on addictions, it is suggested that priming addictive substance users with addiction-related cues that increase users' subjective craving on addictive substances would lead to an increase in their attentional bias for addiction-related stimuli (Feldtkeller, Weinstein, Cox and Nutt, 2001; Field & Cox, 2008; Weinstein & Cox, 2006; Metrik et al., 2016; for a review see O'Neil, Bachi & Bhattacharyya, 2020).

Summary

The primary aim of this thesis was to provide evidence of priming effects that can affect colour-responding to neutral words in the blocked format non-colour word Stroop task using the study-test method with native English speakers, which at first was designed by MacLeod (1996) and was developed by Sharma (2018). I aimed to develop this study-test procedure used by Sharma (2018) to further investigate whether task conflict plays a role in selective attention resulting from priming effects and if so, I asked whether the findings could be interpreted by the PC-TC model of Kalanthroff et al. (2015), exploring whether that task conflict involves a top-down proactive and/or a bottom-up reactive control mechanism.

In addition to the primary aim, the secondary interest was to extend the non-colour word Stroop task from Sharma (2018), using emotionally salient words, to investigate the effects of studied non-colour salient words on attentional bias in anxiety and addiction (e.g., negative emotional words and marijuana-related words, respectively), and to examine whether the attentional bias towards threat and addiction was due to task conflict or response conflict.

Section 2: The Role of Task Conflict in the Non-Colour Neutral Word Stroop Task

Chapter 4 – Experiment 1 to 3

Chapter 5 – Experiment 4 to 6

Chapter 4: The Effects of Working memory load and Priming on Task conflict

Abstract

This chapter attempted to replicate the findings by Sharma (2018) using different numbers of studied words to vary the load of working memory (WM). Three experiments were carried out to look into the effect of WM load reflected by the number of studied words on the amount of task conflict from proactive control (i.e., $RT_{mixed\ block} - RT_{pure\ block}$) and reactive control (i.e., the reversed sequential modulation effect). In comparison with the 20 studied words used in Sharma (2018), 10 studied words were used for the low WM load condition with two test blocks of 80 trials in Experiment 1 and 30 studied words were used for the high WM load condition with two test blocks of 240 trials in Experiment 2. The results revealed that the effect of proactive control arose in the low load condition but it disappeared in the high load condition, whereas the effect of reactive control did not occur in the low load condition but it took place in the high load condition. In Experiment 3, the number of test trials was equalised for the low and high load conditions with two test blocks of 80 trials. The results indicated the effects of proactive and reactive control. However, the finding suggested that the amount of task conflict from proactive control was not affected by the WM load although the data demonstrated a tendency that the larger the number of studied words, the higher the WM load, the lower the amount of task conflict from proactive control.

Introduction

Research using the study-test procedure with the trial-by-trial format suggest that colour-responding latencies can be slowed down by primed or primed-related stimuli in the non-colour word Stroop task (Warren, 1972, 1974; Conrad, 1974; MacLeod, 1991). For example, Warren (1974) had participants study three words from a single category (e.g., AUNT, UNCLE, COUSIN) which was immediately followed by a test trial that could be a related word (e.g., AUNT, RELATIVE), an unrelated word (e.g., DOG, ANIMAL) to the category of studied items, or a non-word control (e.g., XXXX). Participants were slower to colour name primed-related test trials compared to the unrelated and non-word test trials. In line with Warren (1974), Conrad (1974) reported the replication of this enhanced colour naming interference resulting from priming effects by having participants read a sentence (e.g., The toy costs a *nickel*.) before they colour named a test trial that was a related word (e.g., NICKEL, MONEY) or an unrelated word (e.g., CHAIR) to the sentence.

In an attempt to examine the effect of priming on selective attention using the block-by-block format non-colour word Stroop task, MacLeod (1996) suggested that priming does not have any effect on naming colours as there was no response latency difference between studied and unstudied words within the experimental block. In comparison to MacLeod's suggestion, Sharma (2018) proposed that the finding of no response latency difference between studied and unstudied words could be due to a strong effect of top-down proactive control. According to the PC-TC model of Kalanthroff et al. (2015), this could be a consequence of a strong proactive control to the colour naming task demand unit that would engender a general speed up to both studied and unstudied words within the experimental block if studied non-colour words generate response conflict as incongruent colour words do. Or, this could be a result of a strong proactive control to the word reading task demand unit which would lead to a general slowdown regardless of whether words are studied or unstudied if studied non-colour words produce task conflict. By comparing MacLeod's experimental block (mixed block) comprising of studied and unstudied words with a baseline block (pure block) that consisted of only unstudied words, Sharma (2018) reported that the null effect was in fact due to the general slowdown, supporting the prediction from the PC-TC model that the effect of priming could trigger task conflict resulting from the top-down proactive control to the word reading task demand unit. In addition to the finding of task conflict from proactive control, Sharma also reported the observation of a shift in attentional control from top-down to bottom-up in the second half of the mixed block, illustrating longer response latencies to studied words than unstudied words. Moreover, by further looking into the trial-by-trial effect in the second half of the mixed block, Sharma found that the responses were longer to studied words when preceded by studied words compared to when preceded by unstudied words, showing a reversed pattern of the sequential modulation effect. To conclude, the findings by Sharma (2018) revealed that priming can interfere with colour-responding in the non-colour word Stroop task not only with the trial-by-trial format but also with the block-by-block format, and the findings were in line with the task conflict predictions from the PC-TC model of Kalanthroff et al. (2015).

Experiment 1 – 10 studied items

Introduction

Studies of the interactions between working memory (WM) and selective attention have suggested that WM has a key role to play in the control of selective attention where it involves in the maintenance of information and processes of top-down attentional control to focus limited cognitive resources on relevant information for ongoing cognitive task goals (Downing, 2000; de Fockert, Rees, Frith & Lavie, 2001; Soto, Heinke, Humphreys & Blanco, 2005; Soto, Hodsoll, Rotshtein & Humphreys, 2008). Brain imaging findings suggest that WM and selective attention share a common neural structure (i.e., prefrontal cortex) for top-down attentional control (Gazzaley & Nobre, 2012). Studies of WM capacity demonstrate that performance on the colour-word Stroop task is better for individuals with high-WM-capacity, showing smaller Stroop interference compared to those with low-WM-capacity (Kane & Engel, 2003; Kane, Conway, Hambrick & Engel, 2007; Meier & Kane, 2013). Studies of WM load illustrate that in Stroop-like tasks high load on WM reduces top-down attentional control which leads to increased interference by task-irrelevant stimuli compared to low load on WM (de Fockert et al., 2001; Lavie, Hirst, De Fockert & Viding, 2004; Lavie & de Fockert, 2005; Pratt, Willoughby & Swick, 2011).

Kalanthroff et al. (2015) provided evidence that WM load can modulate the state of proactive control, thereby affecting performance on the Stroop colour naming task and accounted for the interference that is due to task conflict within the PC-TC model. In the current study, I manipulate the level of proactive control through a change in WM load by varying the number of studied words that need to be maintained in WM, aiming to investigate whether the manipulation has any impact on the magnitude of task conflict due to priming in the subsequent test block.

The aims of Experiment 1 were to replicate Sharma (2018) with a methodological difference. The first aim was to provide further evidence for the role of task conflict in the non-colour word Stroop task. The second aim was to investigate whether reducing the number of words shown in the study block would have any impact on the magnitude of colour naming interference due to priming in the subsequent test block. Experiment 1 used 10 studied words compared to the 20 studied words used by Sharma.

It was hypothesised that first a general slowdown would be observed in a block of studied and unstudied words (mixed block) compared to a block of only unstudied words (pure block), which would be an indicator of task conflict resulting from the top-down proactive control to the word reading task according to the PC-TC model. Second, the smaller set of studied words (compared to Sharma) might result in a stronger proactive control from episodic memory due to less words that need to be held in working memory. In addition, if the level of proactive control remains high throughout the mixed block, a reversed sequential modulation in the mixed block, an indicator of task conflict from bottom-up reactive control, would not be observed.

Method

Participants

Sixty native English-speaking students from the University of Kent took part in this study for one course credit. The sample comprised of 47 female and 13 male students aged 18-34 with a mean age of 19.82 (SD = 3.03). Ethical approval was given by the School of Psychology Ethics committee at the University of Kent.

Design

A single factor design was employed with Study type (unstudied-pure, unstudied-mixed, studied-mixed) as the within-subject factor. The dependent variable was the mean correct response latency to respond to the ink colours the words were printed in.

Apparatus and materials

The experiment program was written in E-Prime 2.0 and presented on a 21-inch Dell® widescreen monitor. Reaction times and manual responses were recorded throughout the whole experiment. The presentation, randomisation of the trials and the assignment of the word lists were controlled by E-Prime 2.0 using a Latin square design.

One hundred fifty neutral words were selected from the English Lexicon Project (Balota et al., 2007) and were separated into three sets of 50 words (Word sets were counterbalanced, i.e., each of the three word sets was randomly assigned across participants.). In each set, 50 words were split into five lists of 10 words (see Table 4.1.1). Each word list included an equal number of 4, 5, 6, 7 and 8 letter words, which were matched for word frequency (average Log frequency HAL of 11.42), which was at the midrange for the collection of words (Range 0–17) (Balota et al., 2007).

Table 4.1.1

Word lists used in Experiment 1

1st Word set				
A	B	C	D	E
body	easy	head	club	near
deal	text	wall	face	main
based	class	phone	issue	voice
often	basic	hours	price	large
search	office	series	future	effect
record	driver	matter	couple	happen
science	command	numbers	include	project
package	machine	auction	anybody	library
together	children	interest	consider	standard
sequence	language	response	hardware	position
2nd Word set				
A	B	C	D	E
past	type	move	tape	area
hear	sell	less	page	upon
cover	image	south	heard	print
small	times	learn	north	among
become	normal	market	states	posted
result	united	format	across	making
section	account	usually	outside	advance
country	company	general	running	current
location	magazine	specific	security	evidence
national	complete	thinking	shipping	previous
3rd Word set				
A	B	C	D	E
note	told	room	open	care
road	sort	mind	view	disk
trade	space	clear	paper	taken
month	radio	level	guess	house
design	groups	member	resume	amount
street	screen	report	client	return
similar	minimum	various	contact	product
release	college	process	society	history
business	original	required	organism	everyone
messages	comments	articles	programs	opinions

Procedure

When participants arrived at the lab, each of them was provided with an information sheet and a consent form. After signing the consent form, the participant was instructed to sit in front of a computer monitor and was asked to follow the instructions displayed on the screen throughout the experiment. There were four parts in the experiment which began with Study phase, Practice phase, Colour naming test phase and ended with Recognition phase, which took around 10 minutes to complete. See Table 4.1.2 (below) for the procedure, the number of trials used in each phase, and an example of word lists assigned to each phase.

Table 4.1.2
The procedure of Experiment 1

Phase	**Study**	**Practice**	**Colour naming Test**		**Recognition**
Block type			Mixed	Pure	
Stimulus type	Studied word	Letter string	Studied word & Unstudied word	Unstudied word	Studied word & Unstudied word
Trial number	10	60	80	80	20
Word list	A		A+B	C+D	A+E

Study phase

A list of 10 words was presented for participants to study and they were instructed to memorise the words as best as they can. To strengthen participants' working memory performance, following each word, a five-point Likert scale was presented (1 = 0%, 2 = 25%, 3 = 50%, 4 = 75% and 5 = 100%) in which participants were asked to grade how strong they felt the word associated with themselves.

There were 10 trials in total. In each trial, a word was displayed for 1,500ms in black print at the centre of the screen on a white background, followed by an 800ms blank page. Then, the five-point Likert scale was shown and would remain on the screen until a response was made prior to the start of the next trial.

Practice phase

Prior to the experimental trials, participants were familiarised with the colour and key association by completing practice trials consisting of letter strings. Five letter strings (e.g., ppp, uuuu, ttttt, eeee, and aaaaaaa) were used and each of them was printed in each of four colours (e.g., red, green, blue, and yellow), resulting in 20 trials. This process was then repeated three times, thereby producing 60 trials in total. An instruction page was displayed before the practice trials began where participants were instructed to place their index and middle fingers from each hand on top of four colour corresponding keys (z = red, x = green, n = blue, m = yellow) on a QWERTY keyboard, and they were asked to ignore the letter string and respond to the ink colour as quickly and as accurately as possible. Each trial began with a black fixation cross at the centre of the screen for 1,000ms, followed by a coloured letter string which would last until a response was given before the next trial started.

Colour naming test phase

The general instructions and settings for the experimental trials were identical to the practice trials. There were two blocks in the experimental phase – mixed and pure. The mixed block contained a mixture of the list of 10 studied words that had been seen in the study phase and a list of 10 unstudied words, whereas the pure block consisted of a list of 10 unstudied words and another list of 10 unstudied words. 20 words in each of the two blocks were printed in each of four colours for 80 trials, resulting in 160 trials in total for the colour naming test phase. As soon as the first block was completed, the same introduction page was presented and participants were instructed to carry on with the second block by pressing the space bar.

Each word was presented in a random order in each block and the order of the two blocks was counterbalanced across participants.

Recognition phase

Following the test phase was the recognition phase which was a more explicit memory test to examine whether participants remembered the words they had studied in the study phase. There were 20 trials in total which were composed of the list of 10 studied words and a list of 10 unstudied words (different from those unstudied words which appeared in the colour naming test phase). Participants were requested to make a choice as to whether they had seen the word in the study phase by pressing one of four corresponding keys (1 = Seen this word before – high confidence; 2 = Seen this word before – but not sure; 3 = Not seen this word before – high confidence; 4 = Not seen this word before – but not sure). Each trial began with a 1,000ms fixation cross at the centre of the screen, followed by a word presented above the four response options, which would stay on the screen until a response was given.

The five lists of 10 words assigned to study, test and recognition phases were counterbalanced using a Latin square design across participants.

After the participants had finished the recognition phase, they were thanked for their participation and were provided with a debrief sheet, and given the chance to ask any questions.

Results

Data preparation

One participant's data (No. 31) was removed from the analysis due to long reaction times (above 2.5 standard deviation). The error rate of the remaining 59 subjects was 3.4%. Prior to the analysis of the mean correct response latencies, the first trial of each block and trials with a RT less than 200ms and larger than 3,000ms, which was 1.5% of the trials, were excluded.

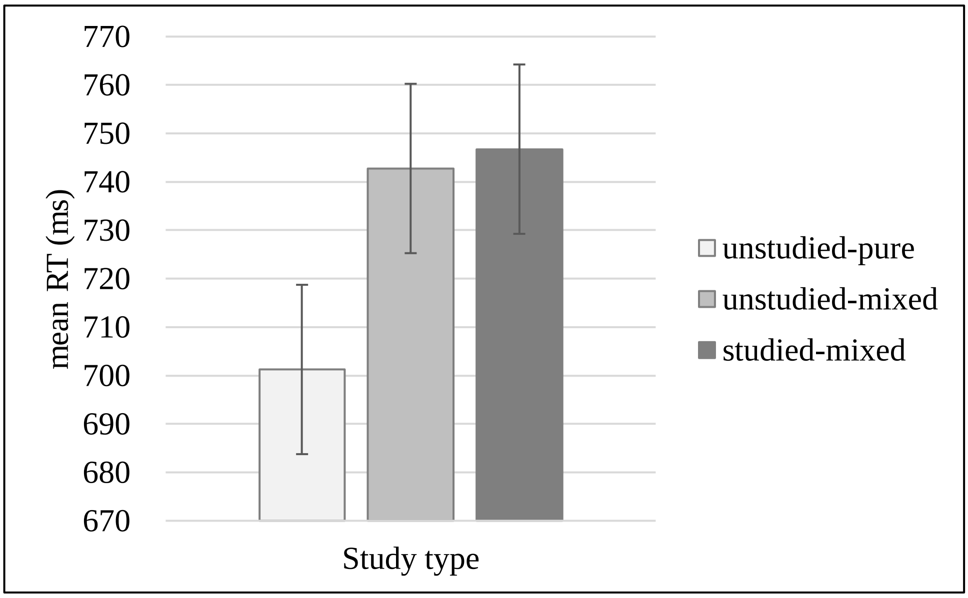
Analysis of response latencies

The first analysis was executed on the mean correct reaction times, using a single factor analysis of variance (ANOVA), with Study type (unstudied-pure, unstudied-mixed, studied-mixed) as the within-subject factor. Greenhouse-Geisser corrected values were reported when the sphericity assumption was violated.

The analysis revealed a significant main effect of Study type, $F(1.64, 94.82) = 8.15$, MSe = 5623.96, $p = .001$, $\eta p^2 = .123$. Within the mixed block, the paired sample t-test (corrected for Bonferroni) showed that there was no significant difference between the studied (M = 746.75ms, SE = 18.83) and unstudied (M = 742.76ms, SE = 20.31) words, $t(58) = .43$, $p > .1$. On the other hand, between the mixed and pure blocks, the unstudied-pure words (M = 701.25ms, SE = 14.51) were significantly shorter than the studied-mixed words (M = 746.75ms, SE = 18.83), $t(58) = 3.54$, $p = .002$, and the unstudied-mixed words (M = 742.76ms, SE = 20.31), $t(58) = 2.84$, $p = .019$ (see Figure 4.1.1). These findings suggest that there was a general slowdown in the mixed block compared to the pure block. In other words, studied words have a tendency to slow colour-responding latencies for the block with studied words. I further explored the data by Block half, but did not find any effect of Block half.

Figure 4.1.1

Mean correct reation times for each Study type.



Note. Error bars represent the 95% confidence interval adjusted for the within-subject design (Masson & Loftus, 2003). Pure, block of only unstudied words; Mixed, block of studied and unstudied words.

In the following two analyses, I aimed to find the effect of reactive control indicated by a slowdown to studied words that are preceded by other studied words relative to studied words preceded by unstudied words – the reversed sequential modulation effect. In general, there are two ways to look into the effect. The first way is to carry out a 2-way factorial ANOVA with Previous study type (unstudied word, studied word) and Current study type (unstudied word, studied word) as within-subject factors, which forms two lines defined by the latencies of four conditions with CCs, CsCs, and CC, CsC, investigating whether the amount of the priming effect in the current trials (i.e., $RT_{studied\ words} - RT_{unstudied\ words}$) would be larger when the previous trials are studied words compared to unstudied words. The second way is to focus on the contrast between the response latencies of the two conditions – CCs and CsCs by carrying out a planned comparison test, examining whether the latencies of CsCs would be slower than that of CCs. Note that the labels C and Cs were used in Chapter 4 to represent an unstudied neutral word and a studied neutral word, respectively. This was to avoid the confusion of the labels N and Ns used in Experiment 7 in Chapter 6 to represent an unstudied negative word and a studied negative word, respectively.

Analysis of the trial-by-trial effect within the mixed block (ANOVA)

To explore whether there was a shift in attentional control between proactive control and reactive control, the second analysis was conducted using a 2-way factorial ANOVA with Previous study type (unstudied, studied) and Current study type (unstudied, studied) as within-subject factors.

This analysis showed null effects, indicating that there was no stimulus-driven reactive control. The 2-way interaction between Previous study type and Current study type was not significant, $F(1, 58) = .04$, MSe = 14095.72, $p = .843$, $\eta p^2 = .001$ (trial CCs, M = 739.00ms, SE = 19.73; trial CsCs, M = 756.07ms, SE = 20.69; trial CC, M = 734.95ms, SE = 19.11; trial CsC, M = 749.23ms, SE = 23.62). None of the main effects were significant (all *p*'s > 0.1). I further looked into the data by Block half, however, the result revealed null effects.

Analysis of the trial-by-trial effect within the mixed block (Planned comparison for trial CCs vs. trial CsCs)

To check whether there was a shift in attentional control where reactive control took over after proactive control decreased, I carried out a planned comparison within the mixed block. I looked for the reversed sequential modulation effect asking whether studied words take longer to respond to when preceded by studied words compared to when preceded by unstudied words. That is, I compared the RTs to trial CCs with trial CsCs. The results demonstrated that there was no significant reversed sequential modulation effect, $t(58) = 1.23$, $p = .223$, showing no evidence for reactive control. I further explored Block half, but I did not find any reversed sequential modulation effect.

Analysis of Recognition phase

The data of recognition phase were transformed to d-prime, C-bias (criterion bias), hit and false alarm rates using methods from signal detection theory (Macmillan, N. A., & Creelman, 2005). In this analysis, d-prime is a measure of participants' sensitivity with respect to distinguishing between studied and unstudied words. The larger the value of d-prime, the higher the sensitivity. The value of d-prime is 0 when the hit rate is equal to the false alarm rate, which suggests chance performance (i.e., guessing) where participants have no sensitivity and thus are not able to differentiate between studied and unstudied words. The value of d-prime is above 0 when the hit rate is larger than the false alarm rate, demonstrating that participants are able to discriminate between studied and unstudied words. The value of d-prime close to 3 reflects near-perfect performance. In studies that attempt to avoid the floor effect (i.e., chance performance) and the ceiling effect (i.e., perfect performance), the typical range of d-prime's value lies between 0.5 (Hit rate = 60%; False alarm rate = 40%) and 2.5 (Hit rate = 90%; False alarm rate = 10%) (Macmillan, N. A., & Creelman, 2005). With regard to C-bias, it indicates whether there is a tendency for participants to deem word stimuli to be studied or unstudied. The value of C-bias is 0 when there is no difference between the false alarm and miss rates, reflecting that participants have no tendency to judge word stimuli to be studied or unstudied; the value of C-bias is negative when the false alarm rate is larger than the miss rate, indicating that participants tend to regard word stimuli as studied; the value of C-bias is positive when the false alarm rate is smaller than the miss rate, suggesting that participants are biased to consider word stimuli as unstudied (Macmillan, N. A., & Creelman, 2005).

The results disclosed the sensitivity that was above 0.5, demonstrating that participants explicitly remembered studied words well and were able to discriminate them from unstudied words. The value of bias was negative, implicating that participants tended to consider words that presented in the recognition phase as those shown in the study phase (d-prime: M = 1.03, SE = 0.03; C-bias: M = - 0.09, SE = 0.02; Hit rate: 72.80%; False alarm rate: 33.90%).

Discussion

The results illustrated three main findings. First, in the mixed block, the response latencies to unstudied and studied words did not differ from each other, showing a null effect. Second, both the unstudied words and studied words in the mixed block took longer to respond to than unstudied words in the pure block. Third, within the mixed block there was no reversed sequential modulation effect. That is, a studied word preceded by a studied word did not take longer to respond to compared to a studied word preceded by an unstudied word.

In line with the finding by Sharma (2018), firstly I found the null effect in the mixed block. By comparing the mixed block with the pure block, the evidence further revealed that the null effect was due to priming effects from studied words, resulting in a general slowdown that is indicative of task conflict triggered by proactive control. Within the PC-TC model, this could be due to a high state of proactive control represented by the episodic memory node to the word reading task demand unit (see Figure 3.1), which resulted in the competition between the word reading and colour naming task demand units. As a consequence, the inhibition from the task demand layer to the response layer was sustained that colour-responding to all of the stimuli presented in the mixed block were slowed down regardless of the study type.

On the other hand, compared with the finding of a reversed sequential modulation in the second half of the mixed block by Sharma (2018), within the mixed block I did not find any reversed sequential modulation effect, the indicator of task conflict driven by reactive control. This demonstrated that there was no shift of attentional control from proactive control to reactive control, which could be a result of the strong proactive control to word reading that last throughout the whole mixed block. I suggest that this may be due to using the smaller set of studied words that might have increased the saliency of each studied word because the number of words that needed to be held in working memory was small, thereby resulting in the stronger proactive control from episodic memory than that in Sharma (2018) (10 studied words in this study compared to 20 studied words in Sharma).

Experiment 2 – 30 studied items

Introduction

The aims of Experiment 2 were identical to Experiment 1. A larger set of 30 studied words (high WM load) was used in Experiment 2 in comparison with Experiment 1 where 10 studied words were used (load WM load).

I hypothesised that first, if the proactive control to the word reading task from priming is involved, there would be a general slowdown, a null effect, in the mixed block as it was found in Experiment 1. However, the amount of this slowdown would be smaller compared to Experiment 1 as the effect of proactive control to word reading would be reduced due to using the larger set of studied words. Second, I expected there to be a shift in attentional control from proactive control to reactive control and the sign of reactive control – a reversed sequential modulation effect would be observed in the mixed block. Third, I predicted that the recognition memory performance would decline compared to Experiment 1 due to the larger set of studied words to be memorised.

Method

The general methodology (design, apparatus and materials, and procedure) was similar to that in Experiment 1 in all respects except the following changes:

Participants

Sixty native English-speaking students from the University of Kent who had not participated in Experiment 1 took part in this study for two course credits. The sample comprised of 55 female and 5 male students aged 18-28. With a mean age of 19.08 (SD = 1.67). Ethical approval was given by the School of Psychology Ethics committee at the University of Kent.

Materials

The 150 words used in Experiment 2 were exactly the same as those used in Experiment 1. These 150 words were divided into five lists of 30 words (see Table 4.2.1).

Table 4.2.1

Word lists used in Experiment 2

Word lists				
A	B	C	D	E
body	easy	head	club	near
deal	text	wall	face	main
past	type	move	tape	area
hear	sell	less	page	upon
note	told	room	open	care
road	sort	mind	view	disk
based	class	phone	issue	voice
often	basic	hours	price	large
cover	image	south	heard	print
small	times	learn	north	among
trade	space	clear	paper	taken
month	radio	level	guess	house
search	office	series	future	effect
record	driver	matter	couple	happen
become	normal	market	states	posted
result	united	format	across	making
design	groups	member	resume	amount
street	screen	report	client	return
science	command	numbers	include	project
package	machine	auction	anybody	library
section	account	usually	outside	advance
country	company	general	running	current
similar	minimum	various	contact	product
release	college	process	society	history
together	children	interest	consider	standard
sequence	language	response	hardware	position
location	magazine	specific	security	evidence
national	complete	thinking	shipping	previous
business	original	required	organism	everyone
messages	comments	articles	programs	opinions

Procedure

The five lists of 30 words were assigned to blocks in Study, Colour naming test and Recognition phases and were counterbalanced across participants. In the colour naming test phase, 60 words in each of the two blocks were printed in each of four colours for 240 trials, resulting in 480 trials in total for the colour naming test phase, which was different from Experiment 1 where there were 160 trials in the test phase. The experiment took about 30 minutes to complete. The Table 4.2.2 (below) shows the procedure, the number of trials used in each phase, and an example of word lists assigned to each phase. Note that the number of trials in the test phase was thrice the number of Experiment 1.

Table 4.2.2
The procedure of Experiment 2

Phase	**Study**	**Practice**	**Colour naming Test**		**Recognition**
Block type			Mixed	Pure	
Stimulus type	Studied word	Letter string	Studied word & Unstudied word	Unstudied word	Studied word & Unstudied word
Trial number	30	60	240	240	60
Word list	A		A+B	C+D	A+E

Results

Data preparation

Two participant's data (No. 15, 20) were excluded from the analysis due to long response latencies (above 2.5 standard deviation). The error rate of the remaining 58 subjects was 3.7%. Prior to the analysis of the mean correct response latencies, the first trial of each block and trials with a RT less than 200ms and larger than 3,000ms, which was 0.7% of the trials, were removed.

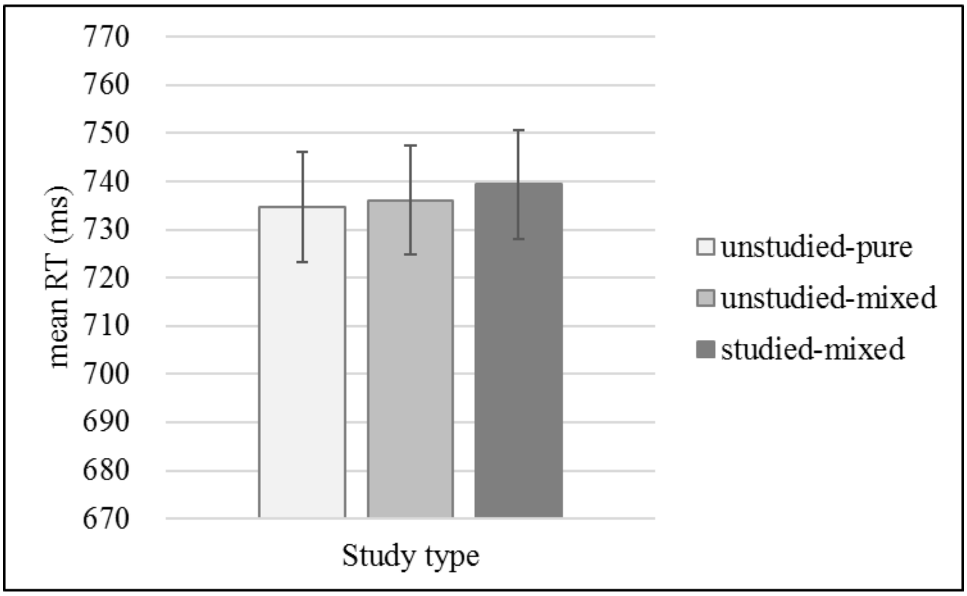
Analysis of response latencies

The first analysis was conducted on the mean correct reaction times, using a single factor analysis of variance (ANOVA), with Study type (unstudied-pure, unstudied-mixed, studied-mixed) as the within-subject factor. Greenhouse-Geisser corrected values were reported when the sphericity assumption was violated.

The analysis revealed a null effect. A main effect of Study type was not significant, $F(1.55, 88.11) = .17$, MSe = 2475.79, $p = .785$, $\eta p^2 = .003$ (unstudied-pure, M = 734.73ms, SE = 15.78; unstudied-mixed, M = 736.09ms, SE = 14.86; studied-mixed, M = 739.38ms, SE = 15.46) (see Figure 4.2.1). I further looked into the data by Block half, but the result only showed a null effect.

Figure 4.2.1

Mean correct reation times for each Study type.



Note. Error bars represent the 95% confidence interval adjusted for the within-subject design (Masson & Loftus, 2003). Pure, block of only unstudied words; Mixed, block of studied and unstudied words.

Analysis of the trial-by-trial effect within the mixed block (ANOVA)

Although there was no sign of proactive control, I looked into the mixed block to check if there was any indication of task conflict driven by reactive control. The second analysis was carried out using a 2-way factorial ANOVA with Previous study type (unstudied, studied) and Current study type (unstudied, studied) as within-subject factors.

This analysis only revealed a significant main effect of Previous study type, $F(1, 57) = 4.52$, MSe = 1682.72, $p = .038$, $\eta p^2 = .073$. Bonferroni corrected t-test suggested that it took longer to respond to when previous trials were studied words (M = 743.51ms, SE = 15.07) than unstudied words (M = 732.06ms, SE = 15.27), $t(57) = 2.13$, $p = .038$, indicating a strong reactive control effect. The 2-way Previous × Current was not significant, $F(1, 57) = 1.04$, MSe = 2384.08, $p = .312$, $\eta p^2 = .018$, revealing no reversed sequential modulation effect. I further checked the data by Block half, however, there was no effect of Block half.

Analysis of the trial-by-trial effect within the mixed block (Planned comparison for trial CCs vs. trial CsCs)

To look for the reserved sequential modulation effect as evidence for task conflict from bottom-up reactive control, a planned comparison within the mixed block was conducted. I asked whether studied words take longer to respond to when preceded by studied words compared to when preceded by unstudied words. That is, I compared the RTs to trial CCs with trial CsCs. The results showed that there was no significant reversed sequential modulation effect, $t(57) = .567$, $p = .573$, suggesting that reactive control was not involved. Further looking into Block half, no significant reversed sequential modulation effect was found.

Analysis of Recognition phase

The data of recognition phase were converted to d-prime, C-bias, hit and false alarm rates using methods from signal detection theory (Macmillan, N. A., & Creelman, 2005). The results indicated that participants in the explicit recognition memory task could remember studied words and distinguish them from unstudied words although there were 30 words to hold in working memory. However, note that in the more implicit Stroop colour naming task, the finding of no priming effects implied that participants implicitly did not remember the studied words while responding to colours. Moreover, the negative value of bias illustrated that participants had tendencies to judge words presented in the recognition phase as those shown in the study phase. (d-prime: M = 0.93, SE = 0.03; C-bias: M = - 0.06, SE = 0.01; Hit rate: 69.75%; False alarm rate: 34.39%). Furthermore, the independent t-test showed that the discrimination performance (d-prime) was better in Experiment 1 (M = 1.03, SE = 0.03) than Experiment 2 (M = 0.93, SE = 0.03), $p = .018$.

Discussion

Experiment 1 and 2 were carried out to explore the effects of WM load and priming on task conflict, using 10 studied words as the low WM load condition in Experiment 1 and using 30 studied words as the high WM load condition in Experiment 2. The result of recognition memory was as expected: participants in Experiment 1 had better performance than those in Experiment 2, which is in accordance with evidence that due to the limited WM resources, WM performance deteriorates as the amount of information that needs to be stored in WM increases (Bays & Husain, 2008; Cowan, 2010; Adam, Vogel & Awh, 2017).

In Experiment 1, I expected to observe a strong top-down proactive control but no bottom-up reactive control from priming in the mixed block due to the low load on WM. This prediction was supported by the finding of the slowdown in the mixed block compared to the pure block. Moreover, there was no sign of the bottom-up reactive control which could be due to the strong proactive control that remained throughout the mixed block.

On the other hand, in Experiment 2, a relatively weak top-down proactive control and a bottom-up reactive control were predicted due to the high load on WM. Accordingly, I expected to see a smaller amount of task conflict from proactive control as well as a reversed sequential modulation effect. However, to my surprise, the results of Experiment 2 showed null priming effects not only within the mixed block but also between the mixed and pure blocks. The null proactive control was reflected by the observation that the response latencies to the mixed block did not differ from that to the pure block. I suggest that these null priming effects could be due to the large number of trials used in each of the two test blocks (240 in Experiment 2 compared to 80 in Experiment 1 and 160 in Sharma) that might have resulted in the practice and fatigue effects (Boksem & Tops, 2008). Moreover, the response latencies for the colour naming task in the low WM load condition and the high WM load condition are in fact not able to be compared since the unequal number of trials might be a confound. In addition, for the low load condition it took 10 minutes to complete the experiment whereas it took 30 minutes to finish the experiment for the high load condition. To overcome this problem, the number of trials in Test phase needs to be equalised for both the low and high WM load conditions.

As for task conflict from reactive control, although I did not observe any reversed sequential modulation effect within the mixed block, the finding of the main effect of Previous study type suggested a reactive control effect in which studied words compared to unstudied words on the previous trials slowed down colour-responding on the current trials. So, in comparison with Sharma (2018) where the reactive control showed its effect on studied trials preceded by studied trials (CsCs trials) but not unstudied trials preceded by studied trials (CsC trials), I found the reactive control effect that led to a slowdown on both of the CsCs and CsC trials compared to the CCs and CC trials (i.e., main effect of Previous study type), indicating a strong task conflict from reactive control.

Experiment 3 – 10 studied items versus 30 studied items

Introduction

In Experiment 2, contrary to my predictions, priming effects did not produce the task conflict from proactive control. The rationale of Experiment 3 was first to keep the number of studied words in the high WM load condition identical to Experiment 2 while reducing the number of trials in the test blocks to avoid the practice and fatigue effects that could potentially lead to null priming effects; and second to make a comparison of the low and high WM load conditions with an equal number of trials in the test blocks for both of the conditions.

For the colour naming task, I expected there to be effects of task conflict from proactive control (i.e., $RT_{mixed\ block} - RT_{pure\ block}$) for both the low and high WM load conditions, and the magnitude of task conflict would be larger for the low load condition than the high load condition. In terms of task conflict from reactive control (i.e., a reversed sequential modulation effect), for the low load condition, I predicted a replication of the finding in Experiment 1 where there was no reversed sequential modulation effect. For the high load condition, I expected to see a reversed sequential modulation effect if the effect of proactive control for the high load condition is smaller than that for the low load condition. However, if the level of proactive control for the high load condition does not differ from that for the low load condition, I hypothesised that the reversed sequential modulation effect would not appear.

Method

Participants

Eighty native English-speaking students from the University of Kent who had not taken part in Experiment 1 nor Experiment 2 participated in this study for one course credit. Participants were randomly assigned to two WM load conditions – half for the low load condition and the other half for the high load condition. The sample comprised of 73 female and 7 male students aged 18-24. With a mean age of 18.66 (SD = 0.95). Ethical approval was provided by the School of Psychology Ethics committee at the University of Kent.

Design

A 3 × 2 mixed factorial design was employed with Study type (unstudied-pure, unstudied-mixed, studied-mixed) as the within-subject factor and Working memory load condition (low, high) as the between-subject factor. The dependent variable was the mean correct response latency to respond to the ink colours the words were printed in.

Apparatus and Material

In Experiment 3, PsychoPy 1.83 was used to build the program instead of E-Prime 2.0, which was used in Experiment 1 and 2. The experiment was presented on a 21-inch Dell® widescreen monitor. Reaction times and manual responses were recorded throughout the whole experiment. The presentation, randomisation of the trials, selection of words to each word list and the assignment of the word lists to each test block were controlled by PsychoPy 1.83.

In contrast to the words used in Experiment 1 and 2, where the lengths of word were 4, 5, 6, 7 and 8 letters, I simplified the design in Experiment 3 to use 4-letter words only. This was to avoid the PsychoPy program selecting unequal number of words with various lengths to each of the five word lists. Prior to doing this, I checked whether there was any word length effect on task conflict from proactive control (the difference in RT between the mixed and pure blocks) using the data of Experiment 1 since there was no proactive control effect found in Experiment 2. Using a single factor analysis of variance (ANOVA), with Word length (4, 5, 6, 7, 8) as the within-subject factor. The result showed a null effect, $F(3.39, 199.75) = 0.53$, MSe = 12482.35, $p = .687$, $\eta p^2 = .009$. Bonferroni corrected t-tests indicated that there was no effect of word length on the amount of task conflict from proactive control.

Ninety four-letter neutral words were chosen from the English Lexicon Project (Balota et al., 2007). For the low load condition, 50 out of 90 words were selected and split into five lists of 10 words. For the high load condition, on the other hand, all of the 90 words were used which were divided into nine lists of 10 words (see Table 4.3.1). Each word list was matched for word frequency (average Log frequency HAL of 9.42 and 9.49 for the low and high load conditions, respectively), which was in the midrange of the dataset (Range 0–17) (Balota et al., 2007).

Table 4.3.1

Word lists used in Experiment 3

Word list for the low load condition

A	B	C	D	E
dual	vast	grab	scan	solo
coat	lift	slot	ears	wing
inch	boat	swap	odds	push
tall	auto	myth	busy	rely
clue	seat	wage	desk	neck
lane	drum	roll	gate	ease
tube	pray	loop	fate	flag
wash	chat	farm	hint	bent
peak	bare	tone	asks	duty
rack	folk	dawn	maps	urge

Word list for the high load condition

A	B	C	D	E	F	G	H	I
coat	peak	disc	crew	asks	wage	loop	rely	hint
rain	ease	thin	dual	bent	pour	suit	wing	rack
boat	seek	grew	push	wash	tube	bond	drum	acts
lens	solo	neck	flow	gear	bowl	task	wave	tone
urge	icon	tiny	nose	scan	rise	duty	ears	core
flag	rank	seat	dawn	pray	farm	seed	myth	wake
tall	roll	folk	font	lift	gate	fate	inch	odds
clue	dive	lane	spot	swap	slot	laid	busy	vast
desk	drew	bird	maps	grab	bare	pays	auto	blow
dice	visa	sake	chat	fork	bass	fund	puts	tail

Procedure

In the current experiment, there were two WM load conditions – low and high load. The procedure for the low load condition was identical to Experiment 1, whereas the procedure for the high load condition differed from that for Experiment 2. That is, compared with the high load condition in Experiment 2 where all of 30 studied words were shown in the test phase, the high load condition in Experiment 3 only had 10 out of 30 studied words presented in the test blocks. Accordingly, there was a difference between the low and high load conditions in the number of lists that were assigned to blocks in Study, Colour naming test and Recognition phases. That is, compared to the low load condition where five lists of 10 words were used, nine lists of 10 words were used in the high load condition. The experiment took around 10 minutes and no more than 15 minutes to complete for the low and high load conditions, respectively. The Table 4.3.2 (below) shows the procedure, the number of trials used in each phase, and an example of word lists assigned to each phase for the low load condition (upper) and the high load condition (lower). Note that the number of trials in the colour naming test phase for both conditions was identical.

Table 4.3.2

The procedure of Experiment 3 – the low and high load conditions

Low load					
Phase	**Study**	**Practice**	**Colour naming Test**		**Recognition**
Block type			Mixed	Pure	
Stimulus type	Studied word	Letter string	Studied word & Unstudied word	Unstudied word	Studied word & Unstudied word
Trial number	10	60	80	80	20
Word list	A		A+B	C+D	A+E

High load						
Phase	**Study**	**Practice**	**Colour naming Test**		**Recognition**	
Block type			Mixed	Pure	1st	2nd
Stimulus type	Studied word	Letter string	Studied word & Unstudied word	Unstudied word	Studied word & Unstudied word	
Trial number	30	60	80	80	20	40
Word list	A_1+A_2+A_3		A_1+B	C+D	A_1+E	A_2+A_3+ F+G

Results

Data preparation

Two participant's data, one from the low load condition (No. 32) and the other from the high load condition (No. 74), were excluded from the analysis due to long response latencies (above 2.5 standard deviation in their corresponding condition). The error rate of the remaining 58 subjects was 3.1%. Prior to the analysis of the mean correct response latencies, the first trial of each block and trials with a RT less than 200ms and larger than 3,000ms, which was 1.4% of the trials, were removed.

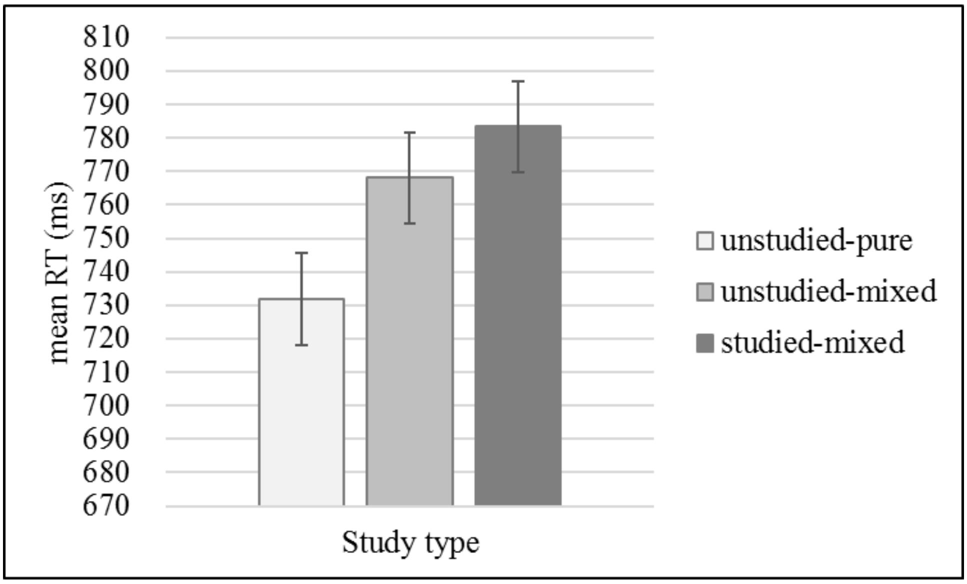
Analysis of response latencies

To examine whether priming words resulted in task conflict from top-down proactive control and whether the WM load had any effect on the level of proactive control, the first analysis was executed on the mean correct reaction times, using a 3 × 2 two-way mixed analysis of variance (ANOVA), with Study type (unstudied-pure, unstudied-mixed, studied-mixed) as the within-subject factor and WM load condition (low, high) as the between-subject factor. Greenhouse-Geisser correction was applied when the assumption of sphericity was violated.

The results disclosed a significant main effect of Study type, $F(1.56, 118.77) = 14.73$, MSe = 4745.29, $p < .001$, $\eta p^2 = .162$. Within the mixed block, the paired sample t-test (corrected for Bonferroni) showed that there was no significant difference between the studied (M = 783.41ms, SE = 17.70) and unstudied (M = 768.01ms, SE = 17.50) words, $t(77) = 2.24$, $p = .084$. On the other hand, between the mixed and pure blocks, the unstudied-pure words (M = 731.87ms, SE = 14.55) were significantly shorter than the studied-mixed words (M = 783.41ms, SE = 17.70), $t(77) = 4.48$, $p < .001$, and the unstudied-mixed words (M = 768.01ms, SE = 17.50), $t(77) = 3.53$, $p = .002$, indicating that there was a top-down proactive control. The main effect of WM load condition was not significant, $F(1, 76) = 1.47$, MSe = 57396.03, $p = .229$, $\eta p^2 = .019$. The interaction between Study type and WM load condition was not significant, $F(1.56, 118.77) = .754$, MSe = 4745.29, $p = .443$, $\eta p^2 = .010$, indicating that the manipulation of WM load condition had no influence on the proactive control effect (see Figure 4.3.1 for whole).

Figure 4.3.1

Mean correct reation times for each Study type.

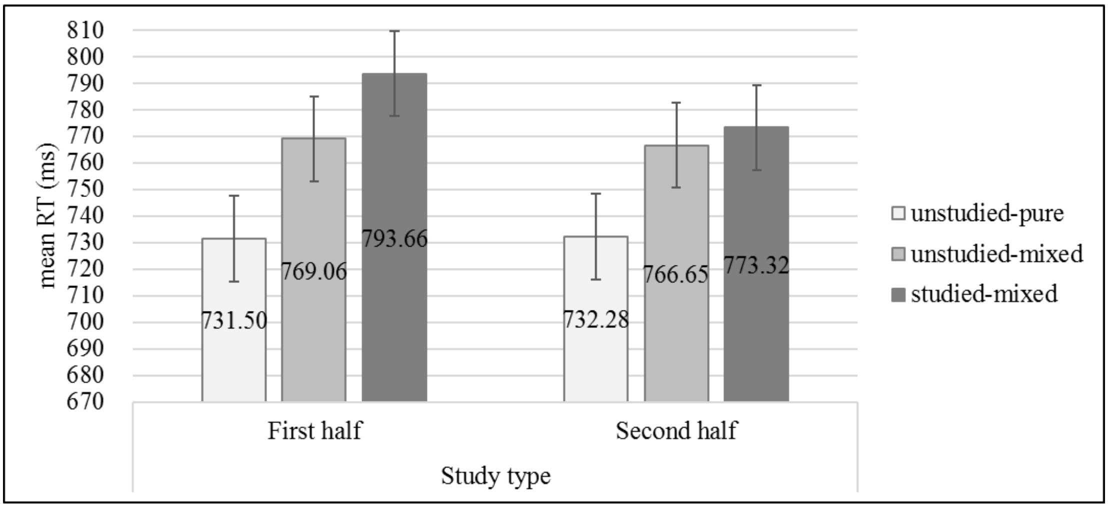


Note. Error bars represent the 95% confidence interval adjusted for the within-subject design (Masson & Loftus, 2003). Pure, block of only unstudied words; Mixed, block of studied and unstudied words.

I further looked into Block half to see whether there was a shift in control within the mixed block by contrasting the response latencies to studied words with unstudied words in the first and second halves of the mixed block. the paired sample t-tests illustrated that within the mixed block, studied words took longer to respond to than unstudied words in the first half of the block (p = .013) but they did not differ from each other in the second half of the block (p = .537), indicating a tendency for a reactive control effect occurring in the first half of the block and a proactive control effect arising in the second half of the block. Moreover, between the mixed and pure blocks, both of the studied and unstudied words in the first half of the mixed block were longer than the unstudied words in the first half of the pure block (p < .001 and p = .007 for studied and unstudied words, respectively), and both the studied and unstudied words in the second half of the mixed block were slower than the unstudied words in the second half of the pure block (p = .001 and p = .012, respectively) (see Figure 4.3.2).

Figure 4.3.2

Mean correct reation times for each Study type within the first and second half of the mixed block.

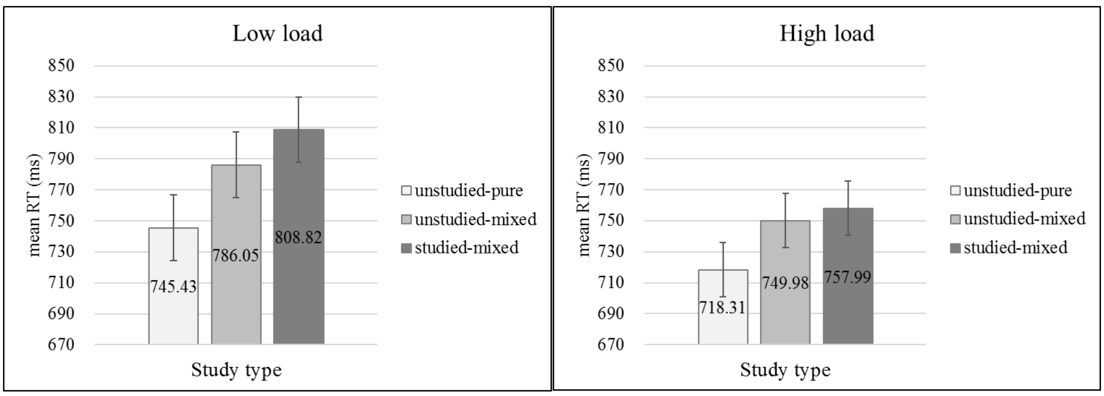


Note. Error bars represent the 95% confidence interval adjusted for the within-subject design (Masson & Loftus, 2003). Pure, block of only unstudied words; Mixed, block of studied and unstudied words.

To answer my question on whether the effect of proactive control was stronger in the low load condition than the high load condition, I checked if the mixed block took longer to respond to than the pure block for the low and high load conditions separately prior to conducting the independent t-test. The results demonstrated that for the low load condition, the RTs were greater to the mixed block (M = 797.43ms, SE = 27.28) than the pure block (M = 745.43ms, SE = 22.51), $t(38) = 3.23$, $p = .003$); the pattern for the high load condition was similar to the low load condition that the mixed block (M = 753.98ms, SE = 21.15) were longer than the pure block (M = 718.31ms, SE = 18.44), $t(38) = 2.74$, $p = .009$). However, the independent t-test indicated that the effect of proactive control in the low load condition did not differ from that in the high load condition, $t(76) = .788$, $p = .433$, suggesting that there was no difference in the magnitude of priming effects regardless of whether there were 10 or 30 words presented during the study phase even though from the bar chart, it seems that generally the colour-responding was slower in the low load condition than in the high load condition (see Figure 4.3.3 for the RTs to the low and high load conditions and Figure 4.3.4 for the difference in the magnitude of task conflict from proactive control between the low and high load conditions).

Figure 4.3.3

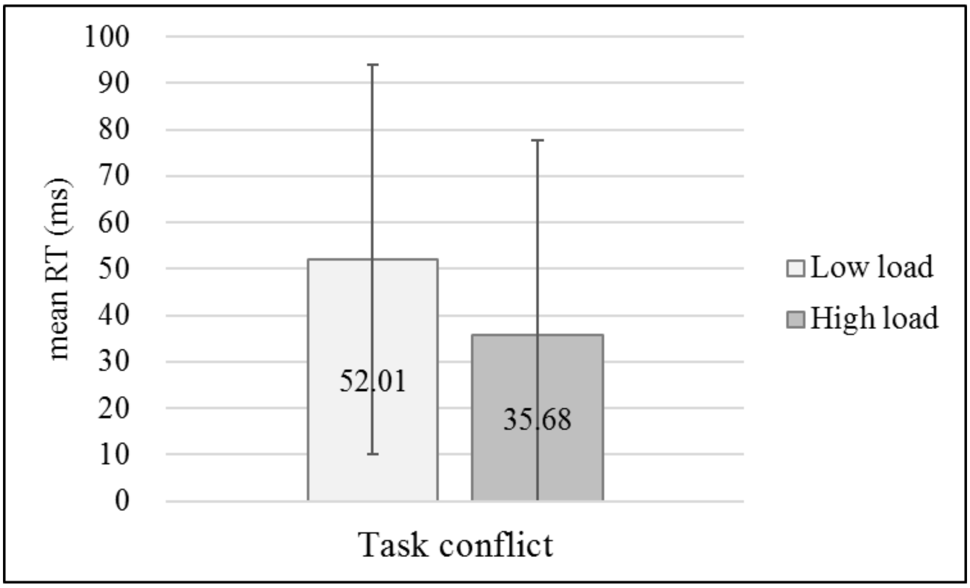
Mean correct reation times for the low and high WM load condition in each Study type.



Note. Error bars represent the 95% confidence interval adjusted for the within-subject design, calculated separately for the low and high WM load conditions (Masson & Loftus, 2003). Pure, block of only unstudied words; Mixed, block of studied and unstudied words.

Figure 4.3.4

Comparing the low load with the high load condition in terms of the amount of task conflict from proactive control (the RT difference between the mixed and pure blocks). Independent t-test indicated that the difference was not significant.



Note. Error bars represent the 95% confidence interval for the difference between two independent means (Pfister & Janczyk, 2013).

Analysis of the trial-by-trial effect within the mixed block (ANOVA)

To look for evidence for the bottom-up reactive control driven by studied words within the mixed block, a 2 × 2 two-way mixed analysis of variance (ANOVA) was conducted with Previous study type (unstudied, studied), Current study type (unstudied, studied) as within-subject factors. WM load condition was not included as the between-subject factor in the ANOVA since the magnitude of task conflict from proactive control for the low and high load conditions did not differ from each other and by doing so the increase in power might help us to find the effect of reactive control. Greenhouse-Geisser corrected values were reported when the sphericity assumption was violated.

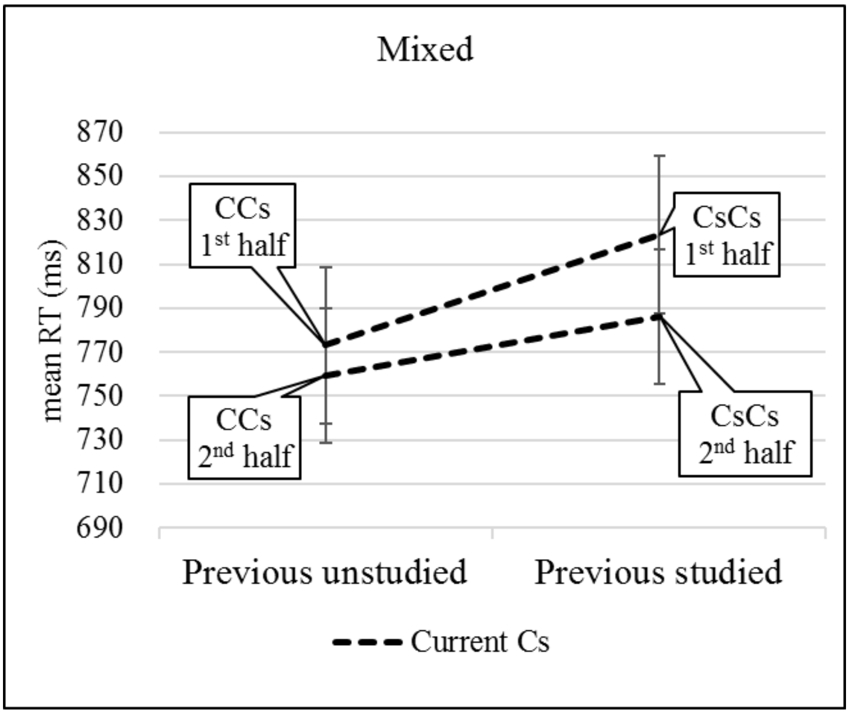
The analysis revealed two significant main effects: Previous study type, $F(1, 77) = 19.66$, MSe = 4960.57, $p < .001$, $\eta p^2 = .203$ and Current study type, $F(1, 77) = 5.28$, MSe = 3734.15, $p = .024$, $\eta p^2 = .064$. Bonferroni corrected t-test indicated that for both previous and current trials, colour responding was significantly longer for studied words (M = 794.28ms, SE = 18.44 and M = 784.55ms, SE = 17.91 for previous and current trials, respectively) than unstudied words (M = 758.92ms, SE = 17.18 and M = 768.65ms, SE = 17.51 for previous and current trials, respectively), $t(77) = 4.43$, $p < .001$, and $t(77) = 2.30$, $p = .024$ for previous and current trials, respectively. However, as for my main focus, the 2-way interaction between Previous study type and Current study type, $F(1, 77) = .000$, MSe = 4728.50, $p = .982$, $\eta p^2 = .000$ was not significant, suggesting that the latency difference between trial CCs and trial CsCs was similar to that between trial CC and trial CsC. I further investigated the data by Block half, but the result suggested no effect of Block half.

Analysis of the trial-by-trial effect within the mixed block (Planned comparison for trial CCs vs. trial CsCs)

To examine whether priming effects led to task conflict from bottom-up reactive control, a planned comparison within the mixed block was carried out excluding the WM load condition. I were interested in whether studied words take longer to respond to when preceded by studied words compared to when preceded by unstudied words. That is, I compared the RTs to trial CCs (766.96ms) with trial CsCs (802.15ms). The results revealed a significant reversed sequential modulation effect, $t(77) = 3.25$, $p = .002$, indicating the involvement of reactive control. I also checked Block half and found that the reversed sequential modulation effect appeared in the first half, trial CCs (773.05ms) vs. trial CsCs (823.40ms), $t(77) = 2.81$, $p = .006$, but it diminished in the second half, trial CCs (759.42ms) vs. trial CsCs (786.21ms), $t(77) = 1.74$, $p = .086$ (see Figure 4.3.5).

Figure 4.3.5

Showing the reversed sequential modulation effect (trial CCs vs. trial CsCs) that appeared in the first half of the mixed block but diminished in the second half of the mixed block.



Note. Error bars represent the 95% confidence interval for the difference between two paired means, computed separately for the effects in the first half and second half of the mixed block (Pfister & Janczyk, 2013). C, neutral word; s, word is studied.

Analysis of Recognition phase

As the analysis in Experiment 1 and 2, The data of recognition phase were converted to d-prime, C-bias, hit and false alarm rates. For the low load condition, the results revealed the sensitivity that was above 0.5, suggesting that participants in the explicit recognition memory task remembered studied words well and were able to distinguish them from unstudied words. The negative value of bias implicated that participants were inclined to consider words shown in the recognition phase as those studied in the study phase (d-prime: M = 1.20, SE = 0.03; C-bias: M = - 0.02, SE = 0.01; Hit rate: 73.21%; False alarm rate: 28.33%). On the other hand, for the high load condition, the results also disclosed the sensitivity that was above 0.5 and the negative value of bias (d-prime: M = 1.06, SE = 0.03; C-bias: M = - 0.02, SE = 0.01; Hit rate: 70.91%; False alarm rate: 30.82%). The independent t-test suggested that the memory performance was significantly better for the low load condition than the high load condition in terms of d-prime, $t(76) = 3.59$, $p = .001$, Hit rates, $t(76) = 2.89$, $p = .05$ and False alarm rate, $t(76) = 2.37$, $p = .020$, but not C-bias, $t(76) = .144$, $p = .886$.

Discussion

The current experiment set out firstly to improve the design of the high WM load condition by reducing the trial number of each test block to control for the potential practice and fatigue effects that resulted in null effects in Experiment 2; secondly, to explore the effect of WM load on task conflict using the design that both the low and high load conditions had an equal number of trials in the test phase.

Episodic recognition memory

The memory results were as predicted: participants in the low load condition showed higher level of discrimination, higher hit rates and lower false alarm rates compared to participants in the high load condition.

Priming effects

First, the main findings were the evidence for task conflict from proactive control. I replicated the findings of Experiment 1 and Sharma (2018) where response latencies were larger to the mixed block than the pure block, and the unstudied words in the mixed block took longer to respond to than the unstudied words in the pure block. This is an interesting finding since I did not find any priming effect in Experiment 2 where participants had to study 30 words in the study phase, but in the current experiment there was a strong priming effect on the top-down attentional control to the contrary. I suggest that this was due to the reduced number of trials in the test blocks, which controlled for the practice and fatigue effects. In the PC-TC model, the longer colour-responding in the mixed block than the pure block could result from the strong proactive activation of the word reading task demand unit due to the priming effect. That is, priming words in the study phase resulted in a high state of proactive control to the word reading task demand unit. As a result, the two task demand units – the goal-irrelevant word reading task and the goal-relevant colour naming task – competed with each other, causing task conflict. This task conflict from proactive control then slowed colour-responding to any word on trials regardless of whether the word was studied or unstudied.

In addition to the findings of proactive control, I also found the effect of reactive control within the mixed block where studied words took longer to respond to than unstudied words in the first half block, showing the attentional bias towards studied words. This finding was not observed in Experiment 1 in which the latencies of studied words did not differ from that of unstudied words throughout the mixed block. Moreover, this finding illustrated an opposite pattern of the observation by Sharma (2018) where studied words showed longer response latencies than unstudied words in the second half, indicating that the reactive control emerged when the proactive control arising in the first half diminished. I considered that this could be due to the difference between the different participant groups. In PC-TC model, our finding of the attentional bias towards studied words in the first half could be considered as a result of weak proactive control in the first half, allowing studied words to produce longer responses than unstudied words in a bottom-up reactive mechanism. Whereas the general slowdown in the second half could be indicated by the increased level of proactive control to word reading, slowing down any presented word stimuli.

Second, I expected to see that the manipulation of varying WM load would differentiate the amount of task conflict from proactive control between the low and high load conditions. However, this prediction was not supported by the result. The main effect of

Study type was not influenced by WM load. Further independent t-test also suggested that there was no difference in the amount of task conflict between the two WM load conditions. This indicates that compared to the 10-studied-word low load condition, requiring participants to memorise 30 words was insufficient to increase WM load to a level that can reduce the state of proactive control to word reading. It could be argued that the WM load manipulation (10 versus 30) was ineffective because the numbers of studied words in both the low and high load conditions exceed the typical limit of WM capacity, for example, three to four items (Adam, Vogel & Awh, 2017; Luck & Vogel, 1997; Vogel, Woodman & Luck, 2001; Zhang & Luck, 2008), four items (for reviews see Cowan, 2001, 2005; Saults & Cowan, 2007; Sperling, 1960), or seven items (Miller, 1956, 1994; Pascual-Leone, 2001). However, the findings of the limit (i.e., 3, 4 or 7 items) were derived from the conditions where a number of items were presented simultaneously at once on a memory trial prior to a following test trial, and variables that help to strengthen WM performance were controlled for, thereby strategies such as chunking, grouping or rehearsal, or the use of sensory information about how a stimulus is looked, smelled, sounded or felt were prevented. Under these conditions, the measured WM capacity is a central storage which can be referred to the focus of attention in the theoretical framework of Cowan (1988, 1995, 1999), or the episodic buffer in the framework of Baddeley (2000, 2001) and Baddeley, Allen & Hitch (2011) (see Cowan, 2001, 2005; Baddeley, 2007; Logie, Camos & Cowan, 2020, for reviews). By contrast, in Chapter 4's design, only one word was presented at a time on each trial in the study phase. Moreover, following the appearance of each word, a five-point Likert scale was provided for participants to evaluate how strong they felt the displayed word related to themselves. The Likert scale remained on the screen until a response was given. In this way, participants were allowed to rehearse the word and/or to use sensory information to form associations between the studied word and existing semantic networks in long-term memory, thus enriching the memory representations of the studied word in WM (Craik & Tulving, 1975; Leshikar, Dulas & Duarte, 2015; Serbun, Shih & Gutchess, 2011). As a result, the WM capacity in this design can go beyond the typical limit. I did not measure how many words participants could remember, however, the recognition data did suggest that participants from both conditions were able to distinguish studied words from unstudied words and the performance was better for the 10-word condition than the 30-word condition. Accordingly, I considered that the ineffective manipulation of WM load was not due to that the numbers of studied words (i.e., 10, 30) in both conditions were greater than the typical limit of WM (i.e., 3, 4, 7). Future work is needed for testing the manipulation of the high WM load.

Third, in contrary to my prediction in which I expected to replicate the finding of Experiment 1 where there was no task conflict driven by reactive control in terms of the trial-by-trial effect, I observed longer colour-responding to studied words preceded by studied words than studied words preceded by unstudied words (i.e. the reversed sequential modulation effect) using the planned comparison test, indicating an effect of task conflict from reactive control. Although the finding of the reversed sequential modulation effect provided evidence of task conflict from reactive control, the effect seemed to be unstable since I did not observe it with the same design in Experiment 1. Moreover, further looking into the effect by Block half revealed a stronger reactive control effect in the first half than the second half, which differed from the finding by Sharma (2018) where the effect of reactive control did not occur in the first half under the strong proactive control, but emerged in the second half from the diminished proactive control.

Conclusion

The findings from Experiment 1, 2 and 3 provided further evidence in support of using the study-test method to reveal the role of task conflict in the non-colour neutral word Stroop task. First, the effect of proactive control indicated by larger response latencies to the block with studied words than the block without studied words was observed for both the low (10 studied words) and high (30 studied words) WM load conditions in Experiment 1 and 3, supporting my hypothesis based on the PC-TC model in which task conflict can be triggered by the priming effect that activates a high state of proactive control (episodic memory node) to the goal-irrelevant word reading task demand unit, which competes with the ongoing goal-relevant colour naming task demand unit. Second, in contrary to the findings of task conflict from proactive control that were consistent between Experiment 1 and 3, the observation of task conflict from reactive control was not consistent between Experiment 1 and 3 given that the design and the procedure for the two experiments were identical. The result of Experiment 1 demonstrated that there was no effect of task conflict from reactive control in the mixed block, suggesting that the effect of proactive control might have persisted throughout the block. Whereas in Experiment 3, the observation of longer responses to studied words than unstudied words in the first half of the mixed block, and the trial-by-trial effect where longer colour-responding to studied words shown after studied words than studied words presented after unstudied words indicated a strong reactive control in the first half of the mixed block. Third, according to the finding of Experiment 1 and 3, the dissipated effect of proactive control in Experiment 2 was a result of the long length of test blocks rather than the large set of words that were studied in the study phase and held in working memory through the whole experiment. I reasoned that the priming effects could spread over the large number of the repeated test trials, and also it could be diluted through practice and time course.

Chapter 5: The Effects of Proportion of Rectangle versus Word and Priming on Task conflict

Abstract

This chapter aimed to extend the works of Goldfarb and Henik (2007) and Entel et al. (2015) where the proportion of non-word control stimuli were manipulated to lower down the level of proactive control to the colour naming task to unveil the existence of task conflict. Three experiments were conducted to inspect the effects of proportion of illegible rectangle stimuli versus legible non-colour neutral words (75/25, 75% of rectangle trials and 25% of word trials, and 25/75, 25% of rectangle trials and 75% of word trials) and priming on the amount of task conflict from proactive control (i.e., $RT_{word} - RT_{rectangle}$) and reactive control (i.e., the reversed sequential modulation effect). First, a larger amount of task conflict from proactive control in the 75/25 block relative to the 25/75 block was continually observed across the three experiments. However, contrary to my predictions from the PC-TC model where I expected there to be no response latency difference for rectangle stimuli between the two blocks since rectangle stimuli do not generate conflict, and responses to word stimuli would be faster in the 25/75 block compared to the 75/25 block as a result of stronger proactive control to the colour naming task due to the higher number of word trials in the 25/75 block, there was no latency difference for word stimuli between the two blocks, while responses to rectangle stimuli were faster in the 75/25 block than the 25/75 block. Second,

the performance of participants who were presented studied words during the colour naming test was not different from that of those who were shown unstudied words during the colour naming test in Experiment 5 and 6, showing a null priming effect. Third, no reversed sequential modulation effect was observed throughout the three experiments. The finding suggested that my proportion manipulation did not result in an adaptation for the proactive control to colour naming which could be due to the insensitivity of neutral word stimuli to the proportion manipulation in the non-colour word Stroop task.

Introduction

Logan and Zbrodoff (1979) and Logan (1980) conducted a word task in which participants were required to identify the spatial-word stimuli (i.e., ABOVE, BELOW) which could appear either above or below a fixation point, forming congruent and incongruent trials. It was reported that manipulating the relative proportion of incongruent spatial-word stimuli resulted in faster responses to incongruent stimuli when incongruent stimuli were shown relatively more frequent compared to congruent stimuli and vice versa. Following the works by Logan and his colleague, Tzelgov et al. (1992) investigated the effect of proportion of colour-word incongruent and congruent stimuli relative to neutral stimuli on the informational/response conflict, and reported that the amount of conflict decreased when the proportion of colour-word incongruent stimuli increased. The results suggested that the informational/response conflict can be modulated by the expectation for the occurrence of incongruent stimuli. This expectation was later interpreted as the recruitment of top-down proactive control to colour naming in the conflict monitoring model of Botvinick et al. (2001) and the dual mechanism of control model of De Pisapia and Braver (2006) and Braver (2012). However, the account of expectation-driven top-down attentional control has been challenged by the contingency learning account whereby the attentional control is considered to be driven by items or stimuli rather than expectation (Jacoby, Lindsay & Hessels, 2003; Blais, Robidoux, Risko & Besner, 2007; Schmidt, Crump, Cheesman & Besner, 2007; Bugg, Jacoby & Toth, 2008; Schmidt & Besner, 2008).

The manipulation of proportion was used to examine not only the informational/response conflict but also the task conflict. Goldfarb and Henik (2007) applied Tzelgov and his colleagues' approach to explore the role of task conflict in the colour word Stroop task, using a high proportion of non-word neutrals (letter strings) relative to colour words. In addition, to weaken the state of proactive control to the relevant information (i.e., ink colour), a cueing method was applied whereby a cue appeared prior to a trial indicating whether the upcoming trial was a neutral or a colour-word stimulus. As a result, a reversed facilitation effect was observed in the non-cued condition where RTs were longer to congruent than non-word neutral stimuli, reflecting the role of task conflict. In line with Goldfarb and Henik (2007), Kalanthroff et al. (2013) also found the reversed facilitation effect by applying Goldfarb and Henik's method with only congruent and neutral trials (incongruent trials were excluded).

Entel, Tzelgov, Bereby-Meyer and Shahar (2015) adapted the proportion manipulation of previous studies and further varied the ratio of congruent to incongruent trial, employing a 3 Stimulus type (congruent, incongruent, neutral) × 3 Colour word versus non-word neutral proportion (80/20, 50/50, 20/80) × 3 congruent-to-incongruent trial ratio (80/20, 50/50, 20/80) mixed factorial design. By doing so, Entel and colleagues proposed that task conflict and informational conflict can be measured independently with an orthogonal comparison method. It was assumed that task conflict could be estimated through varying the proportion of colour words versus illegible non-word neutrals (string of symbols i.e., #### or square patches). That is, task conflict can be obtained by contrasting the RTs to colour words, which can activate the goal-irrelevant word reading task, with unreadable non-word neutrals, which do not induce the action of reading words. Whereas informational conflict could be gauged by contrasting the RTs to congruent with incongruent trials via altering the ratio of congruent to incongruent colour-word stimuli.

The results showed that for the informational conflict, the findings by Tzelgov et al. (1992) was replicated by the manipulation of colour word/neutral proportion, and the findings by Logan (1980) was replicated by the manipulation of congruent-to-incongruent ratio. For the task conflict, in line with the findings by Goldfarb and Henik (2007) and Kalanthroff et al. (2013), the effect of reversed facilitation was observed, which was modulated by the proportion of neutral stimuli. Entel and colleagues suggested that firstly, compared to the letter strings used by Goldfarb and Henik that might have triggered the recruitment of proactive control to colour naming since a letter contains a lexical component and thus is readable, the non-readable string of symbols or square patches used in their experiments may be better neutral stimuli to investigate the role of task conflict because a symbol or a square does not activate the word reading action. However, Entel et al. (2015) did not include letter strings in their design, it is therefore not clear what the difference would be between the effects of legible and illegible neutrals on task conflict. Second, the emergence of task conflict was accompanied by the high proportion of incongruent trials when the amount of informational conflict was high. Accordingly, Entel and his colleagues suggested that task conflict is not independent of informational conflict, which is inconsistent with the findings by Kalanthroff et al. (2013) where the reversed facilitation effect was found without exposure to incongruent stimuli.

In Kalanthroff et al.'s (2015) PC-TC model (see Figure 2.1), the results of Goldfarb and Henik (2007) and Entel et al. (2015) can be interpreted as follows:

a) In the block where 75% of the trials were words and 25% of the trials were non-words, the recruitment of PC to colour naming was triggered due to the frequent appearance of word stimuli that induce the word reading action, which led to a high state of PC on the colour naming task demand unit. When the PC was high, the activations flowed from input units to task demand units became non-significant, resulting in no task conflict since there was no competition between the two task demand units. As a result, there was no inhibition to the response layer and response latencies to words speeded up, resulting in no difference between congruent word and non-word stimuli. On the other hand,

b) In the block that was comprised of 75% non-word trials and 25% word trials, since most of the trials were non-word that do not activate the word reading task demand unit, the recruitment of PC to ink colour was not needed and remained inactive, thereby leading to a low state of PC on the colour naming task demand unit. When the PC was low, the activations of word input units became influential that were able to activate the word reading task demand unit, leading to the competition between the two task demand units. As a result, the rise of task conflict inhibited a response to be produced at the response layer, thus slowing down the colour-responding to congruent word stimuli compared to non-word stimuli.

Experiment 4 – Within-subject design

Introduction

Goldfarb and Henik (2007) were the first to provide behavioural evidence for the existence of task conflict in the colour-word Stroop task. In their design, colour words and control stimuli (i.e., XXXX) were mixed in a block. To lower down the PC to colour naming that suppresses task conflict, the proportion of control stimuli versus colour words was manipulated to 75%/25%, while the ratio of incongruent-to-congruent colour words was set to one to one constantly. Entel et al. (2015) developed Goldfarb and Henik's (2007) work by adapting their design and further manipulated the proportion of unreadable control stimuli (i.e., #### or square) relative to colour-word stimuli as well as the ratio of incongruent-to-congruent colour words in a block and task conflict was observed.

This study aimed to extend the works of Goldfarb and Henik (2007) and Entel et al. (2015) to the non-colour word Stroop task. I tested the priming effects on task conflict and examined the sensitivity of task conflict to the proportion of control stimuli by manipulating the proportion of non-readable control stimuli relative to neutral non-colour word stimuli. In my study, studied and unstudied neutral non-colour words were used as word stimuli, and coloured rectangle patches (Shichel & Tzelgov, 2018) were used as control stimuli. I manipulated the proportion of rectangles in comparison with words while holding the ratio of studied-to-unstudied words constant (i.e., 1:1). Task conflict is defined as the response latency difference between rectangle and word stimuli.

The following were hypothesised:

a) In line with Goldfarb and Henik (2007), I expected to observe a larger amount of task conflict in the block where there are more rectangles than words (75/25, 75% of rectangle trials and 25% of word trials), which would lead to a lower level of PC on colour naming since the frequent appearance of coloured rectangles do not evoke the word reading action. In addition, in line with Sharma (2018) and my findings of Experiment 1 and 3, there would be a general slowdown to word stimuli due to the top-down PC on word reading triggered by studied words. That is, colour-responding to studied and unstudied words would be no different from each other in the block.

b) By contrast, the magnitude of task conflict would be smaller in the block that consists of a minority of rectangles compared to words (25/75, 25% of rectangle trials and 75% of word trials). This is because of the frequent presence of words that would activate the action of reading words, which is task-irrelevant. As a result, the recruitment of PC on colour naming would be triggered to direct attention to the colour dimension rather than the word dimension.

c) Moreover, I also expected to see a general slowdown resulting from priming effects. However, the amount of this general slowdown was expected to be smaller in the 25/75 block compared to the 75/25 block due to the recruitment of PC on the colour naming task that could weaken the PC on the word reading task triggered by priming effects. In other word, the word stimuli in the 25/75 block would be faster than those in the 75/25 block.

d) If there is any reactive control effect arising in any of the two blocks, I expected to find the effect of reversed sequential modulation where studied words take longer to respond to when preceded by studied words than when preceded by unstudied words (i.e., trial CsCs vs. trial CCs).

Method

Participants

Sixty students from the University of Kent, who were native speakers of English, took part in this study for two course credits. The sample comprised of 56 female and 4 male students aged 18-39. With a mean age of 19.65 (SD = 3.53). Ethical approval was given by the School of Psychology Ethics committee at the University of Kent.

Design

Two independent variables were manipulated within participants. One was Rectangle/Word proportion (R/W proportion), the proportion of rectangles relative to neutral words, with two levels (75/25, 25/75), and the other was Stimulus type (rectangle, studied word, unstudied word). The dependent variable was the mean correct RTs to ink colour. Note that in both the two test blocks, the ratio of studied-to-unstudied words was fixed at 1:1 while the proportion of rectangles in comparison with words was varied at 75%:25% or 25%:75%.

Apparatus and materials

The experiment program was built on Psychopy 1.83.04 and presented on a 21-inch Dell® widescreen monitor. Reaction times and manual responses were recorded through the entire experiment. The presentation, randomisation of the trials, the generation and assignment of the word lists were controlled by Psychopy 1.83.04.

For the word stimuli, 30 four-letter neutral words were selected from the 150 neutral words used in Experiment 2 (See Table 5.4.1). Word frequency was matched and the average Log frequency HAL was 11.49, which was at the midrange for the collection of words (Range 0–17) (Balota et al., 2007). For the non-word stimuli, a rectangle patch which covered the width and length of a four-letter word was used.

Table 5.4.1
Word lists used in Experiment 4

A	B	C
area	less	room
body	main	sell
care	mind	sort
club	move	tape
deal	near	text
disk	note	told
easy	open	type
face	page	upon
head	past	view
hear	road	wall

Procedure

Upon participants' arrival at the lab, they received an information sheet and a consent form to sign. After signing the consent form, they were instructed to sit in front of a computer screen and asked to read through and follow instructions displayed on the screen across the experiment. The experiment consisted of three parts: Study phase, Colour naming test phase and Recognition phase. See below Table 5.4.2 for the procedure, the number of trials used in each phase, and an example of word lists assigned to each phase.

Table 5.4.2
The procedure of Experiment 4

Phase	**Study**	**Practice**	**Colour naming Test**		**Recognition**
Block type			75/25	25/75	
Stimulus type	Studied word	Rectangle	Rectangle + Studied word + Unstudied word	Rectangle + Studied word + Unstudied word	Studied word & Unstudied word
Trial number	10	60	320	320	20
Word list	A		A+B	A+B	A+C

Study phase

At the beginning of the experiment, three lists of 10 words were generated randomly from the 30-word pool. During the study phase, a list of 10 words was presented one at a time and participants were required to memorise the words as best as they can. To enhance participants' working memory performance, a five-point Likert scale (1 = 0%, 2 = 25%, 3 = 50%, 4 = 75% and 5 = 100%) was provided following each word where participants were asked to assess how strong they felt the word connected with themselves. In general, the setups were identical to Study phase in Experiment 1 (See Method in Experiment 1).

Practice phase

Practice trials were given to make participants familiar with the colour and key association prior to experimental trials. A rectangle patch that covered the size of a four-letter word was used as the stimulus and was printed in each of four colours (red, green, blue, yellow) for 4 trials. The process was repeated 15 times, thereby resulting in 60 trials in total. Before engaging in the practice trials, an instruction page was presented to instruct participants to put both their index and middle fingers from each hand on the top of each of four colour corresponding keys (z = red, x = green, n = blue, m = yellow) on a QWERTY keyboard, and to ask them to respond to ink colour a rectangle patch was printed in as quickly and as accurately as possible. Each trial started with a black fixation cross at the centre of the screen for 1,000ms, followed by a coloured rectangle patch which would last until a response was given before the next trial began.

Colour naming test phase

The general instructions and settings for the experimental trials were identical to the practice trials. Three stimuli were used for the experimental trials – the list of 10 studied words that was shown in the study phase, a list of 10 unstudied words, and a rectangle patch. There were two blocks containing 320 trials in each block – 75/25 block and 25/75 block. In the 75/25 block, 75% of trials were represented by rectangle patches and the remaining 25% were split between studied and unstudied words, whereas in the 25/75 block, 75% of trials were split between studied and unstudied words and the remaining 25% were represented by rectangle patches. Each of the stimuli was printed in each of four colours. As a result, in the 75/25 block there were 240 rectangle patches, 40 studied words and 40 unstudied words. By contrast, in the 25/75 block there were 120 studied words, 120 unstudied words and 80 rectangle patches.

Recognition phase

The recognition phase contained the list of 10 studied words and a list of 10 unstudied words. 20 words were presented one at a time to investigate participants' memory performance in Study phase. The settings for the recognition phase were identical to that for the experiments of Chapter 4.

Results

Data preparation

Two data (No. 21) were omitted from the analysis because one did not follow the instructions and the other (No. 38) had long average response latencies that were above 2.5 standard deviation. The error rate of the remaining 58 participants was 2.90%. Prior to the analysis of the mean correct response latencies, the first trial of each block, and trials with a RT less than 200ms and larger than 3,000ms, which was 0.62% of the whole trials, were excluded.

Analysis of response latencies

To explore whether priming words led to the task conflict from proactive control and to check whether the manipulation of R/W proportion affected the magnitude of task conflict from proactive control, the analysis was carried out on the mean correct response latencies, using a 2 × 3 two-way factorial analysis of variance (ANOVA), with R/W proportion (75/25, 25/75) and Stimulus type (rectangle, studied word, unstudied word) as within-subject factors.

Greenhouse-Geisser corrected values were reported when the assumption of Sphericity was violated.

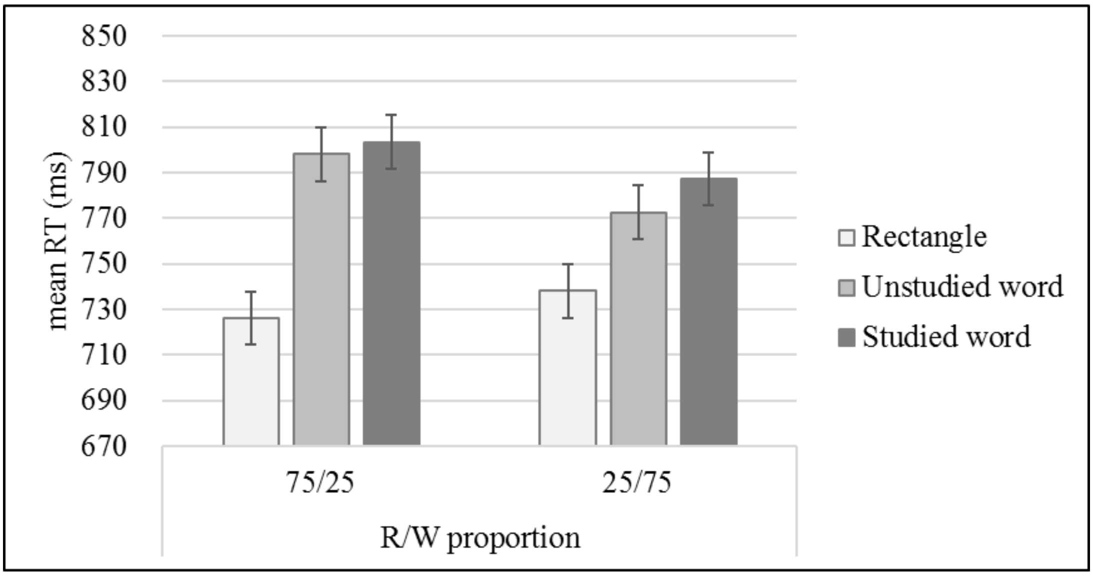
The results revealed a significant main effect for Stimulus type, $F(2, 114) = 62.19$, MSe = 2155.83, $p < .001$, $\eta p^2 = .522$, but not for R/W proportion, $F(1, 57) = .577$, MSe = 14711.49, $p = .451$, $\eta p^2 = .010$. The two-way interaction between R/W proportion and Stimulus type was significant, $F(1.75, 99.68) = 5.45$, MSe = 2303.27, $p = .008$, $\eta p^2 = .087$. The paired sample t-test results indicated the following:

a) In the 75/25 block in which R/W proportion was 75/25, the rectangles (M = 726.12ms, SE = 15.04) took shorter to respond to than both the studied words (M = 803.40ms, SE = 20.31), $t(57) = 7.25$, $p < .001$, and the unstudied words (M = 798.04ms, SE = 20.76), .$t(57) = 6.43$, $p < .001$. As for words, the studied words (M = 803.40ms, SE = 20.31) did not differ from the unstudied words (M = 798.04ms, SE = 20.76), $t(57) = .599$, $p = .552$. This general slowdown replicates my previous findings in Experiment 1 and 3;

b) On the other hand, in the 25/75 block where R/W proportion was 25/75, the rectangles (M = 738.06ms, SE = 15.04) were faster than the studied words (M = 787.26ms, SE = 18.02), $t(57) = 7.11$, $p < .001$ and the unstudied words (M = 772.61, SE = 16.75), $t(57) = 5.60$, $p < .001$. The studied words (M = 787.26ms, SE = 18.02) significantly took longer to respond to compared to the unstudied words (M = 772.61, SE = 16.75), $t(57) = 2.84$, $p = .006$ (see Figure 5.4.1).

Figure 5.4.1

Mean correct reation times as a function of R/W proportion and Stimulus type.

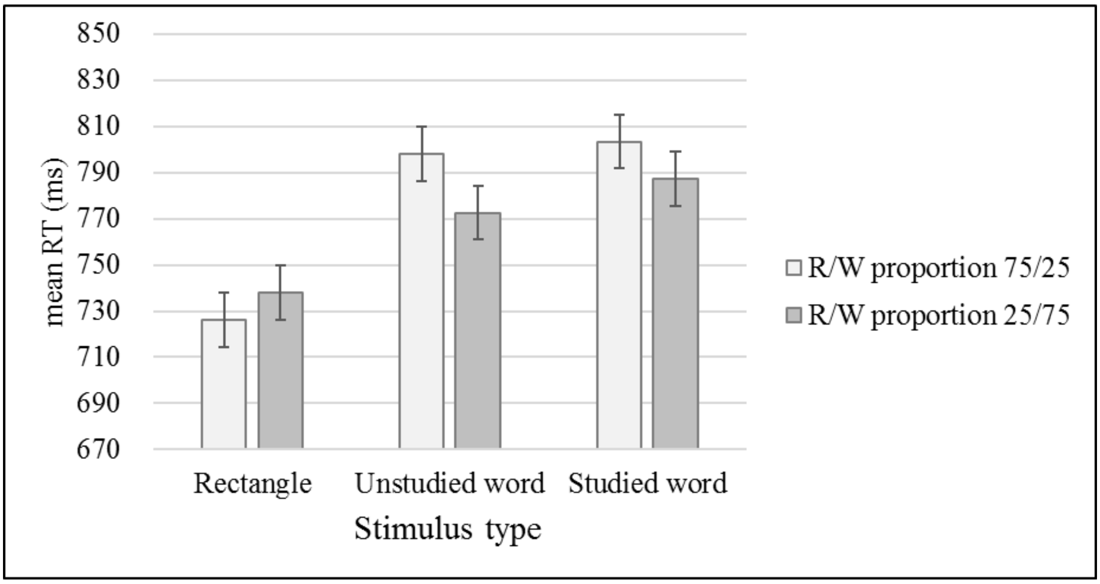


Note. Error bars represent the 95% confidence interval adjusted for the within-subject design (Masson & Loftus, 2003). 75/25, the 75/25 block containing 75% of rectangle trials and 25% of word trials; 25/75, the 25/75 block consisting of 25% of rectangle trials and 75% of word trials.

To look into what caused the interaction, I checked the comparisons of each stimulus type between the two blocks. However, the results showed that none of the differences were significant even though the colour-responding seemed to be faster for rectangles in the 75/25 block than the 25/75 block, and the reaction times for both studied and unstudied words seemed to be slower in the 75/25 block than the 25/75 block, all *p*'s > 0.1 (see Figure 5.4.2).

Figure 5.4.2

Comparing the latencies of each stimulus type between the 75/25 and 25/75 blocks.

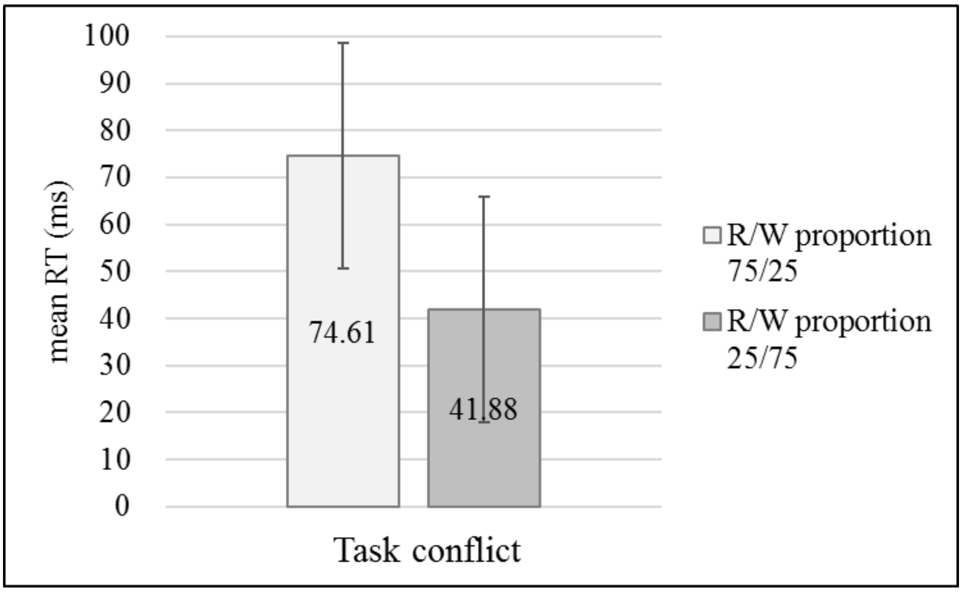


Note. Error bars represent the 95% confidence interval adjusted for the within-subject design (Masson & Loftus, 2003).

To answer my main question, further analysis of this interaction involved a planned comparison to contrast the amount of task conflict from proactive control observed in R/W proportion 75/25 and 25/75. That is, to compare the difference in RT between rectangle and word stimuli in the two blocks. The results indicated that the amount of task conflict in the 75/25 block (M = 74.61ms, SE = 9.97) was greater than that in the 25/75 block (M = 41.88ms, SE = 6.03), $F(1, 57) = 7.49$, MSe = 4148.96, $p = .008$, $\eta p^2 = .116$ (see Figure 5.4.3).

Figure 5.4.3

Comparing the amount of task conflict (the RT difference between the rectangle and word stimuli) between R/W proportion 75/25 and R/W proportion 25/75. Bonferroni corrected t-test indicated that the difference was significant.



Note. Error bars represent the 95% confidence interval for the difference between two paired means (Pfister & Janczyk, 2013).

Analysis of the trial-by-trial effect within the 75/25 and 25/75 blocks (ANOVA)

A 3 × 3 two-way factorial analysis of variance (ANOVA) was carried out for the 75/25 block and the 25/75 block separately with Previous Stimulus type (rectangle, studied word, unstudied word), Current Stimulus type (rectangle, studied word, unstudied word) as within-subject factors. Greenhouse-Geisser corrected values were reported when the sphericity assumption was violated.

The results demonstrated that for the 75/25 block, there was only a main effect of Current Stimulus type, $F(2, 112) = 10.29$, MSe = 17681.39, $p < .001$, $\eta p^2 = .155$, showing that in the current trials both studied (M = 797.27ms, SE = 20.47) and unstudied (M = 790.59ms, SE = 23.00) word stimuli, took longer to respond to than rectangle stimuli (M = 737.74ms, SE = 15.92). The main effect of Previous Stimulus type, $F(2, 112) = 0.43$, MSe = 16610.40, $p = .654$, $\eta p^2 = .008$, and the interaction between Previous and Current Stimulus type, $F(2.42, 135.66) = 0.95$, MSe = 24737.17, $p = .405$, $\eta p^2 = .017$, were not significant.

For the 25/75 block, the results revealed a significant main effect of Previous Stimulus type, $F(2, 114) = 9.93$, MSe = 3083.36, $p < .001$, $\eta p^2 = .148$, indicating that colour-responding was longer when studied words (M = 772.37ms, SE = 17.91) or unstudied words (M = 771.93ms, SE = 16.63) were presented in the previous trials compared to rectangle stimuli (M = 749.18ms, SE = 15.68). A main effect of Current Stimulus type was also significant, $F(1.77, 100.63) = 37.15$, MSe = 3302.55, $p < .001$, $\eta p^2 = .395$, illustrating that when presented in the current trials, studied words (M = 785.48ms, SE = 17.88) showed longer RTs than unstudied words (M = 771.10ms, SE = 16.39) and rectangle stimuli (M = 736.91ms, SE = 15.89). The 2-way interaction between Previous and Current Stimulus type was not significant, $F(3.35, 190.93) = 0.45$, MSe = 4023.77, $p = .739$, $\eta p^2 = .008$.

Analysis of the trial-by-trial effect within the 75/25 and 25/75 blocks (Planned comparison for trial CCs vs. trial CsCs)

I conducted planned comparisons to check whether there was task conflict from reactive control reflected by the reversed sequential modulation effect in which response latencies to studied words would be longer when preceded by studied words compared to unstudied words (i.e., trial CCs vs. trial CsCs). The results revealed no reversed sequential modulation effect in the 75/25 block, $t(57) = 0.31$, $p = .756$, nor in the 25/75 block, $t(57) = 0.70$, $p = .490$, suggesting no effect of task conflict from reactive control in the two blocks.

Analysis of Recognition phase

The data of recognition phase were converted to d-prime, C-bias, hit and false alarm rates applying methods of signal detection theory (Macmillan, N. A., & Creelman, 2005). This revealed the sensitivity that was above 0.5, demonstrating that participants explicitly remembered studied words well and were able to differentiate them from unstudied words. The value of bias was close to 0, implicating that participants did not have a tendency to deem a word a studied word or an unstudied word when they were not sure (d-prime: M = 1.12, SE = 0.03; C-bias: M = - 0.0019, SE = 0.01; Hit rate: 71.12%; False alarm rate: 29.05%).

Discussion

This experiment aimed to test whether manipulating the proportion of non-readable control stimuli versus readable words led to a change in the magnitude of task conflict.

Episodic recognition memory

The memory results indicated that participants committed to memorising words at the study phase and were able to distinguish those studied from those not studied at the recognition phase.

Priming effects

The results illustrated two findings. First, the magnitude of task conflict from proactive control, defined as the response latency difference between rectangle and word stimuli, was larger in the 75/25 block than the 25/75 block. Second, in the 75/25 block, there was no response latency difference between studied and unstudied words, which replicated the findings of a general slowdown by Sharma (2018) and my Experiment 1 and 3. Whereas in the 25/75 block, studied words took longer to respond to than unstudied words.

First, the finding in which a larger amount of task conflict in the 75/25 block than the 25/75 block was observed indicated that the magnitude of task conflict was modulated by the proportion of rectangle versus word stimuli in a block. Within the PC-TC model, this could be due to that the proactive activation of the word reading task demand unit triggered by studied words was restrained by the high state of PC to the colour naming task demand unit because of the frequent appearance of word stimuli in the 25/75 block. Whereas in the 75/25 block, the state of PC to the colour naming task demand unit was low since the majority of trials were rectangle stimuli and thereby the proactive activation of the word reading task demand unit remained strong. However, the results did not clearly indicate what caused the 2-way R/W proportion × Stimulus type interaction. That is, whether the change in the magnitude of task conflict was caused by word or rectangle stimuli is unclear. I expected that the interaction would be a result of the stronger PC to colour naming that leads to faster RTs for word stimuli in the 25/75 block than the 75/25 block while there was no response latency difference for rectangle stimuli between the two blocks. But my results showed that even though there seemed to be a decrease in RT for word stimuli in the 25/75 block in comparison with those in the 75/25 block, it did not reach statistical significance. Moreover, although rectangle remained unaffected statistically, there appeared to be an increase in RT for rectangle stimuli in the 25/75 block compared to those in the 75/25 block. As a result, I consider that the interaction was due to the decrease in RT for word stimuli and also the increase in RT for rectangle although none of them reached significance.

Given that both word and rectangle stimuli seemed to be dependent on the R/W proportion, albeit the effects were not strong enough to reach the significance, it could be argued that this finding was due to the frequency effect rather than the change in the state of

PC by which the more participants saw a stimulus type the more they became habituated to that stimulus type and thereby they became faster to react to the stimulus type. Whereas, the less a stimulus type was shown, the more novel it became and thereby it took longer to respond to. However, Goldfarb and Henik (2007) provided evidence showing that their finding of the reversed facilitation effect (i.e., task conflict, longer RTs to congruent trials than letter string trials) vanished when the non-word control stimuli were replaced by the non-colour word stimuli in their second experiment, suggesting that when there were more words, the PC to colour naming was recruited to direct attention to the task-relevant information, i.e., ink colour, resulting in no response latency difference between congruent trials and non-colour word trials. Whereas when there were more non-words, the state of PC to colour naming was weakened, leading to longer RTs to congruent trials than non-word trials that unveiled the role of task conflict. If it had been caused by the effect of frequency, the colour-responding for congruent trials would have remained unchanged before and after the non-word control stimuli were replaced by the non-colour word stimuli since there was no change in proportion for congruent trials. Furthermore, in line with Goldfarb and Henik (2007), Entel et al. (2015) also reported that congruent trials took longer to respond to than control trials (i.e. the reversed facilitation effect) in one block where control stimuli were non-word squares, whereas shorter RTs to congruent trials compared to control trials (i.e., the facilitation effect) were observed and the reversed facilitation effect disappeared in the other block in which animal words were used as control stimuli. If the findings had been a result of the frequency effect, the colour-responding to congruent trials would have remained the same across the two blocks since the proportions of congruent stimuli were identical in the two blocks. Accordingly, although it is not possible for my study to examine the assumption of the frequency effect by replacing non-word neutrals with non-colour words since non-colour word stimuli were already used in my design, with the evidence provided by Goldfarb and Henik (2007) and Entel et al. (2015), I suggest that it is unlikely that my finding of the change in the amount of task conflict was caused by the frequency effect.

Second, the results of the 75/25 block replicated the findings of Experiment 1 and 3 in Chapter 4 which showed that when studied and unstudied were mixed together in a block, the response latencies for studied words were not different from those for unstudied words – a general slowdown. Moreover, I examined whether there was any effect of task conflict from reactive control indicated by the reversed sequential modulation effect in the 75/25 block by conducting a 2-way ANOVA and planned comparisons, but I did not find any reversed sequential modulation effect (i.e., greater RTs to trial CsCs compared to trial CCs). The result of ANOVA only demonstrated a main effect of Current Stimulus type, showing that word (both studied and unstudied) stimuli took longer to respond to than rectangle stimuli. On the other hand, in the 25/75 block, studied words produced longer response latencies than unstudied words did. This attentional bias could be due to the reactive control that was driven by studied words as evidenced by Sharma (2018) who demonstrated that in the first half of the mixed block there was no response time difference between studied and unstudied words since the high state of proactive control to word reading slowed down both studied and unstudied word stimuli. Whereas in the second half of the mixed block after the top-down proactive control diminished, the bottom-up reactive control emerged, which led to the attentional bias towards studied words. Moreover, when looking into the trial-by-trial effect, this attentional bias was accompanied by a reversed sequential modulation effect in which a slowdown in colour-responding occurred when responses were made to two consecutively presented studied words. To test this assumption, I looked into the first half and the second half of the 25/75 block and compared its pattern with the pattern reported by Sharma (2018). However, I found that studied words took longer than unstudied in the first half but there was no latency difference between studied and unstudied words in the second half, which showed an opposite pattern of the observation by Sharma (2018). In addition, I carried out a 3×3 two-way ANOVA with Previous Stimulus type (rectangle, studied words, unstudied words) and Current Stimulus type (rectangle, studied words, unstudied words) as within-subject factors to check whether there was any reversed sequential modulation effect occurring with the attentional bias towards studied words in the first half of the 25/75 block. However, I did not find any interaction effect between Previous and Current Stimulus type, indicating that there was no reversed sequential modulation effect. Further, planned comparison tests also indicated that there was no reversed sequential modulation effect. To this extent, I cannot be sure what caused this attentional bias towards studied words in the 25/75 block.

Third, since I applied the within-subject design mixing studied words, unstudied words and rectangles in a block, I were not able to differentiate whether the task conflict I observed was produced by studied words or unstudied words. To tackle this problem, I adopted a between-subject design in the following experiment with one group who conducted the Stroop colour naming task consisting of only studied word stimuli, and the other group who performed the task comprising of only unstudied word stimuli.

Experiment 5 – Between-subject design

Introduction

The purpose of Experiment 5 was to replicate the finding of Experiment 4 in which the amount of task conflict from proactive control was larger in the 75/25 block than the 25/75 block. In contrast to Experiment 4, I employed a between-subject method to inspect whether the task conflict found in Experiment 4 was due to priming effects in addition to lexical effects (i.e., studied words) or a result of lexical effects (i.e., unstudied words). That is, participants were divided into two groups – a studied block group and an unstudied block group. Both of the two groups carried out Study phase in the first part of the experiment. However, during Colour naming test phase, the studied block group only saw studied words, whereas the unstudied block group only saw unstudied words that had not been presented in the study phase. After completing the Stroop colour naming task, both the two groups conducted Recognition phase.

The following were hypothesised:

a) In line with Experiment 4, the magnitude of task conflict from proactive control would be larger in the 75/25 block than the 25/75 block for both of the two groups due to word stimuli that would be faster to respond to in the 25/75 block than the 75/25 block resulting from the recruitment of PC to colour naming task, and rectangle stimuli that would remain the same in colour-responding across the two blocks since rectangles do no induce conflict and thus they would not be affected by PC.

b) In line with Sharma (2018) and my previous findings of Experiment 1 and 3 in which colour-responding latencies were generally longer in a block with studied words than in another block without studied words due to priming effects, I expected to observe longer RTs to word stimuli for the studied block group compared to those for the unstudied block group. In addition, I predicted that rectangle stimuli would not be affected by priming effects, thereby showing a similar RTs in both of the two groups. In other words, the response latency difference between word and rectangle stimuli (i.e., task conflict from proactive control) in both of the 75/25 and 25/75 blocks would be smaller for the unstudied block group compared to the studied block group.

c) As it was predicted in Experiment 4, if task conflict from reactive control emerges in any of the two blocks, I expected there to be a reversed sequential modulation effect for the studied block group where studied words show greater response times when preceded by studied words compared to rectangles (i.e., trial CsCs vs. trial RCs).

Method

The general methodology (apparatus and materials, and procedure) was similar to that in Experiment 4 in all respects except the following changes.

Participants

Eighty native English-speaking students from the University of Kent, who had not taken part in Experiment 4, participated in this study for two course credits. Participants were randomly assigned to two groups – half for the studied block group and half for the unstudied block group. The sample comprised of 66 female and 14 male students aged 18-34. With a mean age of 19.50 (SD = 2.39). Ethical approval was provided by the School of Psychology Ethics committee at the University of Kent.

Design

A 2 × 2 × 2 mixed factorial design was employed with R/W proportion (75/25, 25/75) and Stimulus type (rectangle, word) as within-subject factors. Study block group (studied block, unstudied block) was the between-subject factor. The dependent variable was the mean correct RTs to ink colour.

Procedure

Study phase

All of the settings were identical to Experiment 4. Note that although participants were divided into the studied block group and the unstudied block group, both groups studied 10 words in this phase.

Colour naming test phase

In the test phase, 10 studied words from the study phase were presented only to the studied block group, but not to the unstudied group. For the unstudied block group, a new list of 10 unstudied words were shown to participants. As a result, compared to Experiment 4, the number of trials represented by studied and unstudied words in each block were changed for both groups. That is, in the block where R/W proportion was 75/25, in contrast to Experiment 4 where the remaining 25% of trials were split between studied and unstudied words, the remaining 25% of trials in the current experiment were represented by either studied words or unstudied words depending on the study group to which participants were assigned, resulting in 240 rectangle patches and 80 words. Whereas when R/W proportion was 25/75, 75% of trials were represented by studied words in the studied block group, or by unstudied words in the unstudied block group, leading to 80 rectangle patches and 240 words.

Results

Data preparation

Three data were excluded from the analysis because two (No. 3 & 29) did not follow the instructions and one (No. 47) had long average response latencies above 2.5 standard deviation. The error rate of the remaining 77 participants was 3.20%. Prior to the analysis of the mean correct response latencies, the first trial of each block, and trials with a RT less than 200ms and larger than 3,000ms were removed, which was 0.59% of the whole trials.

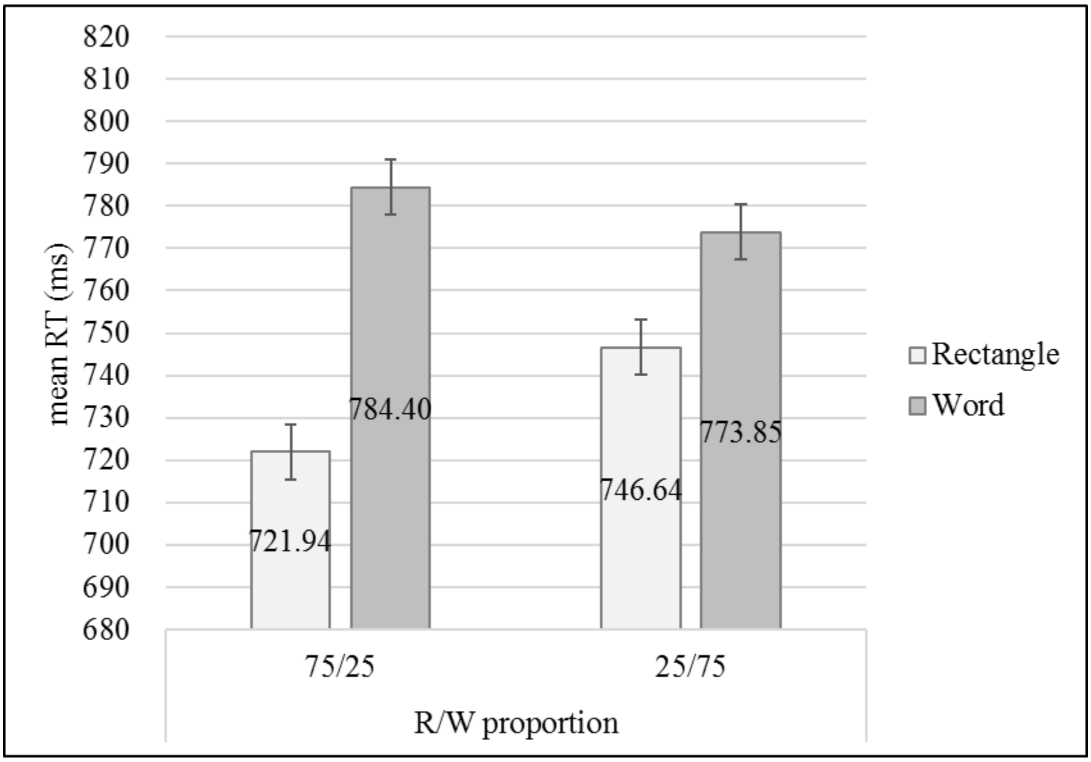
Analysis of response latencies

To explore whether the task conflict due to priming effects differed from the task conflict due to lexical effects, and whether the magnitude of task conflict from proactive control was influenced by the manipulation of R/W proportion, the mean correct response latencies were analysed using a 2 × 2 × 2 three-way mixed factorial analysis of variance (ANOVA), with R/W proportion (75/25, 25/75) and Stimulus type (rectangle, word) as within-subject factors, and Study block group (studied block, unstudied block) as the between-subject factor. Greenhouse-Geisser corrected values were reported when the assumption of Sphericity was violated.

The analysis disclosed a significant main effect of Stimulus type, $F(1, 75) = 131.98$, MSe = 1172.54, $p < .001$, $\eta p^2 = .638$, indicating that within each of the two blocks, word stimuli (M = 779.12ms, SE = 13.07) took longer to respond to than rectangle stimuli (M = 734.29ms, SE = 12.18). This main effect was qualified by an interaction with R/W proportion, $F(1, 75) = 29.65$, MSe = 806.91, $p < .001$, $\eta p^2 = .283$, demonstrating that the difference between word and rectangle stimuli (i.e., task conflict) was significantly larger in the 75/25 block (M = 62.41ms, SE = 5.18) than in the 25/75 block (M = 27.18ms, SE = 4.91) (see Figure 5.5.1 and 5.5.2). The 3-way R/W proportion × Stimulus type × Study block group interaction was not significant, $F(1, 75) = .097$, MSe = 806.91, $p = .757$, $\eta p^2 = .001$, indicating that the magnitude of task conflict from proactive control was not affected by the between-subject factor – Study block group (see Figure 5.5.3). I checked into the data by Block half to examine whether response latencies for word stimuli in the first half of each of the two blocks were longer in the studied block group relative to the unstudied block group, however, there was no difference in colour-responding for word stimuli between the two groups.

Figure 5.5.1

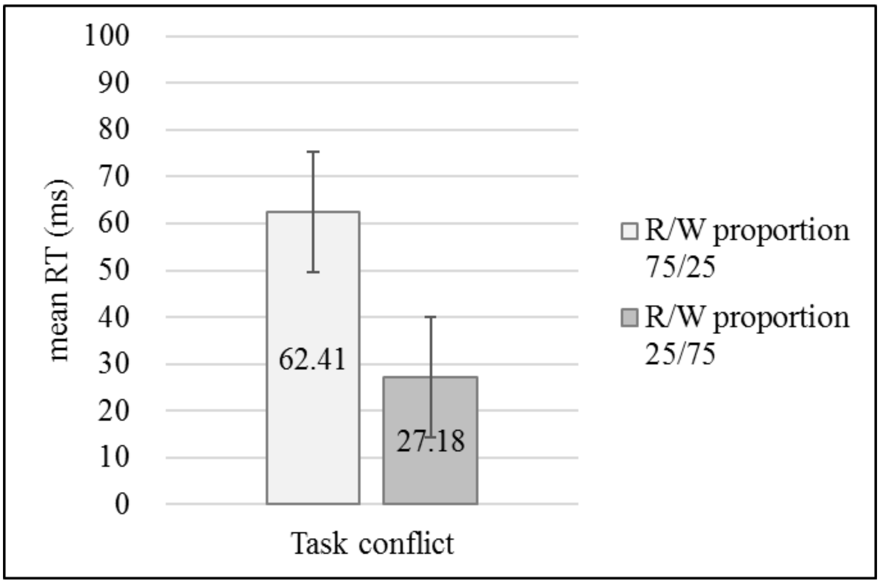
Mean correct reation times as a function of R/W proportion and Stimulus type, reflecting the impact of R/W proportion on the magnitude of task conflict.



Note. Error bars represent the 95% confidence interval adjusted for the within-subject design (Masson & Loftus, 2003). 75/25, the 75/25 block containing 75% of rectangle trials and 25% of word trials; 25/75, the 25/75 block consisting of 25% of rectangle trials and 75% of word trials.

Figure 5.5.2

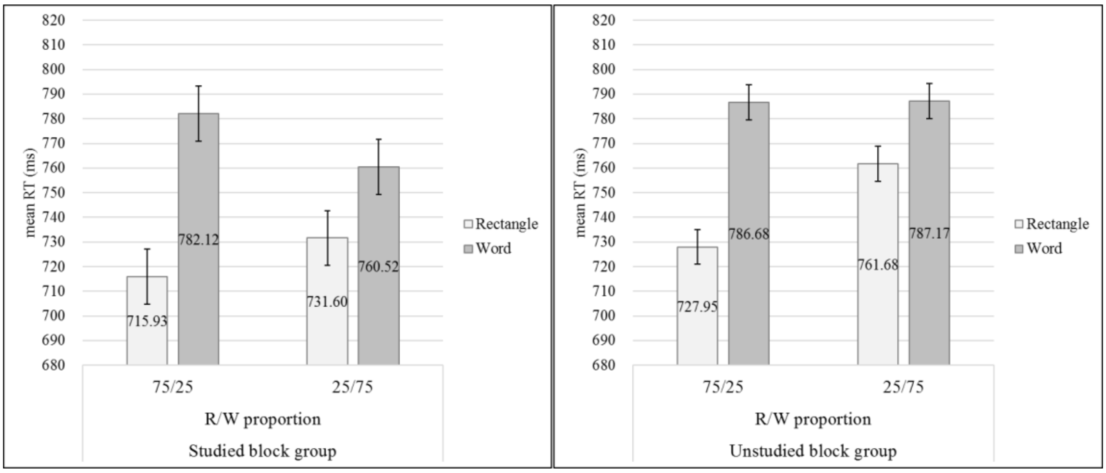
Comparing the amount of task conflict (the RT difference between the rectangle and word stimuli) between R/W proportion 75/25 and R/W proportion 25/75. Bonferroni corrected t-test indicated that the difference was significant.



Note. Error bars represent the 95% confidence interval for the difference between two paired means (Pfister & Janczyk, 2013).

Figure 5.5.3

The 2-way interaction between R/W proportion and Stimulus type was not qualified by Study block group.



Note. Error bars represent the 95% confidence interval adjusted for the within-subject design, calculated separately for the studied block (left panel) and unstudied block groups (right panel) (Masson & Loftus, 2003).

I looked into the 2-way R/W proportion × Stimulus type interaction to find out what caused the effect by comparing the response latency for each level of Stimulus type (i.e., rectangle and word) between the two blocks. The paired sample t-test results demonstrated that the response latencies for rectangle stimuli were significantly longer in the 25/75 block (M = 746.84ms, SE = 12.88) than the 75/25 block (M = 722.02ms, SE = 12.81), $t(76) = 2.99$, $p = .004$, whereas the colour-responding for word stimuli in the two blocks did not differ from each other (the 75/25 block, M = 784.43ms, SE = 13.50; the 25/75 block, M =

774.02ms, SE = 13.82), $t(76) = 1.25$, $p = .214$, indicating that the interaction was a result of the increase in RT for rectangles in the 25/75 block compared to the 75/25 block.

No other main or interaction effects were significant: Main effects of R/W proportion, $F(1, 75) = .862$, MSe = 4472.53, $p = .356$, $\eta p^2 = .011$, Study block group, $F(1, 75) = .539$, MSe = 47971.01, $p = .465$, $\eta p^2 = .007$. The 2-way interaction between R/W proportion and Study block group, $F(1, 75) = 1.74$, MSe = 4472.53, $p = .192$, $\eta p^2 = .023$. The 2-way Stimulus type × Study block group interaction, $F(1, 75) = .486$, MSe = 1172.54, $p = .488$, $\eta p^2 = .006$.

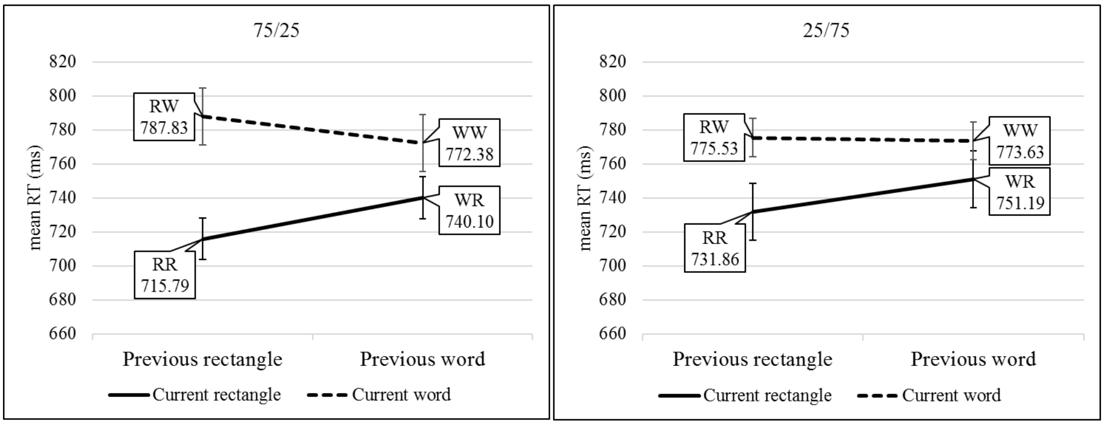
Analysis of the trial-by-trial effect within the 75/25 and 25/75 blocks (ANOVA)

I further examined whether there was any trial-by-trial effect indicating the influence of task conflict from reactive control within each block. I did not include Study block group in the analysis since the previous analysis of proactive control illustrated that there was no interaction by Study block group and in this way, it might increase power to help to reveal a reactive control effect. A 2 × 2 two-way factorial analysis of variance (ANOVA) was conducted for the 75/25 block and the 25/75 block separately with Previous Stimulus type (rectangle, word), Current Stimulus type (rectangle, word) as within-subject factors. Greenhouse-Geisser corrected values were reported when the sphericity assumption was violated.

The analysis revealed that in both of the two blocks, there was a significant main effect of Current Stimulus type, $F(1, 76) = 86.63$, MSe = 2418.30, $p < .001$, $\eta p^2 = .533$ for the 75/25 block and $F(1, 76) = 31.01$, MSe = 2714.41, $p < .001$, $\eta p^2 = .290$ for the 25/75 block, demonstrating that it took longer to respond to when the current trial was a word than a rectangle. In addition, the main effect of Current Stimulus type was qualified by an interaction for both the two blocks, $F(1, 76) = 11.91$, MSe = 2555.06, $p = .001$, $\eta p^2 = .135$ for the 75/25 block and $F(1, 76) = 4.59$, MSe = 1892.07, $p = .035$, $\eta p^2 = .057$ for the 25/75 block. Post-hoc tests revealed that the 2-way interactions were the results of faster response latencies for rectangle trials preceded by rectangle trials compared to rectangle trials preceded by word trials in both the 75/25 block ($p < .001$) and the 25/75 block ($p = .024$), suggesting a sequential modulation effect. Whereas the colour-responding for word stimuli presented after word stimuli did not differ from that for word stimuli presented after rectangle stimuli in the 75/25 block ($p = .070$), nor in the 25/75 block ($p = .736$), implying no task conflict from reactive control due to the reversed sequential modulation effect (see Figure 5.5.4).

Figure 5.5.4

The 2-way interaction between Previous Stimulus type and Current Stimulus type (left panel for block 75/25 and right panel for block 25/75) that was caused by sequential modulation effects in which rectangles took faster to respond to when preceded by rectangles relative to when preceded by words. No reversed sequential modulation effect was observed.



Note. Error bars represent the 95% confidence interval for the difference between two paired means, computed separately for trial RW vs. trial WW and for trial RR vs. trial WR (Pfister & Janczyk, 2013). R, rectangle; W, word.

Analysis of the trial-by-trial effect within the 75/25 and 25/75 blocks (Planned comparison for trial RW vs. trial WW)

I examined whether any effect of reversed sequential modulation occurred in the two blocks by carrying out planned comparisons. The results demonstrated that there was no reversed sequential modulation effect in the 75/25 block, $t(76) = 1.84$, $p = .070$, nor in the 25/75 block, $t(76) = 0.34$, $p = .736$, implying there was no task conflict from reactive control.

Analysis of Recognition phase

The data of recognition phase were converted to d-prime, C-bias, hit and false alarm rates applying methods of signal detection theory (Macmillan, N. A., & Creelman, 2005). For the studied block group, the results revealed the sensitivity that was above 0.5, demonstrating that participants explicitly remembered the words they had seen in the study phase and were able to discriminate between studied and unstudied words. The value of bias that was close to 0 suggested that participants did not have a bias towards studied or unstudied words when they were unsure about whether the presented word was studied or not (d-prime: M = 1.20, SE = 0.03; C-bias: M = - 0.0036, SE = 0.02; Hit rate: 72.50%; False alarm rate: 27.76%). For the unstudied block group, the results showed the sensitivity that was above 0.5, indicating that participants explicitly remembered studied words well and were able to recognise them in the recognition phase. The bias that had a negative value implicated that when participants were unsure of whether a word was seen or unseen in the study phase, they had a tendency to answer that they had seen the word (d-prime: M = 1.03, SE = 0.04; C-bias: M = - 0.03, SE = 0.02; Hit rate: 70.51%; False alarm rate: 31.79%). Further analysis using independent t-tests to compare the performance between the two groups showed that the level of discrimination was higher in the studied block group (M = 1.20, SE = 0.03) than the unstudied block group (M = 1.03, SE = 0.04), $t(75) = 3.36$, $p = .001$, and the studied block group had a lower false alarm rate (27.76%) compared to the unstudied block group (31.79%), $t(75) = 2.77$, $p = .007$. The hit rate and C-bias did not differ between the two groups(all *p*'s > 0.1).

Discussion

Experiment 5 was set off to replicate the finding of Experiment 4 and distinguish the task conflict caused by studied words from the task conflict resulting from unstudied words using the between-subject design with the studied block group and the unstudied block group.

Episodic recognition memory

The memory results illustrated that both of the groups were capable of differentiate studied words from unstudied words and the performance was better for the studied block group than for the unstudied block group.

Priming effects

The main finding was the significant 2-way interaction between R/W proportion and Stimulus type, which replicated Experiment 4's result, showing that the amount of task conflict from proactive control was larger in the 75/25 block than in the 25/75 block. However, this 2-way interaction was not influenced by the manipulation of Study block group, suggesting that it did not make any difference whether the words presented in the colour naming task were studied or unstudied. When I further investigated the 2-way interaction, in contrast to Experiment 4 where it was uncertain what resulted in the 2-way interaction since neither the change in RT for rectangle nor for word stimuli between the two blocks was significant, I found that rectangle stimuli showed longer response latencies in the 25/75 block compared to the 75/25 block, whereas there was no difference for word stimuli between the two blocks.

Firstly, contrary to my prediction, there was no difference between the studied block group and the unstudied block group in which studied words did not take longer to respond to than unstudied words in any of the two blocks, indicating that there was no priming effect from studied words. Further exploratory analysis of Block half illustrated no difference in response latency for words in the first half of each block between the studied and unstudied block groups. One explanation might be that using a large number of trials (320 trials) in a block could have eliminated the priming effect based on the findings of Chapter 4. In both Experiment 2 and 3 in Chapter 4, participants studied 30 words in the study phase. During the colour naming test phase, those from Experiment 2 conducted two blocks of 240 trials, which led to the null priming effect where the response latencies for studied and unstudied words in the mixed block did not differ from those for unstudied words in the pure block. Moreover, the analysis of Block half also suggested the null priming effect. On the other hand, those from Experiment 3 carrying out two blocks of 80 trials did demonstrate the priming effect where the mixed block contained studied words were longer to respond to than the pure block without studied words. In the subsequent Experiment 6, I reduced the number of trials in each test block to half (160 trials) to test whether the null priming effect was caused by the trial number.

Second, the PC-TC model suggests that when the proactive activation to the colour naming task demand unit is strong, the word reading task demand unit would be inhibited and thereby there would be no competition between the colour naming and word reading tasks. Moreover, when the top-down proactive control is strong, the influence of the bottom-up activations from input units to task demand units can be ignored. Accordingly, I expected to see word stimuli speed up in the 25/75 block where PC to colour naming would be employed since there were more words compared to the 75/25 block. However, this prediction was not supported by my result as word stimuli were not faster in the 25/75 block relative to the 75/25 block, suggesting that there was no difference in the state of PC to the colour naming task demand unit between the two blocks.

As for rectangle stimuli, in contrast to my hypothesis in which I expected the response latencies for rectangle stimuli to remain the same over the two blocks, there was an increase in RT in the 25/75 block compared to the 75/25 block. This could be due to the effect of sequential modulation in the 75/25 block where rectangle trials were faster when preceded by another rectangle trials than when preceded by word trials. However, the same pattern of the sequential modulation effect was also observed in the 25/75 block, suggesting that the sequential modulation effect cannot explain why rectangle slowed down in the 25/75 block.

Or, the change in response latency for rectangles could be caused by the frequency effect. Because rectangle stimuli were presented less frequently in the 25/75 block, they might have become more novel and thus being slower to respond to compared to those which were shown more frequently in the 75/25 block. But, as it was discussed in Experiment 4's discussion section, I consider that it is unlikely for the frequency effect to account for my results as evidenced by the findings of Goldfarb and Henik (2007) and Entel et al. (2015).

Experiment 6 – Between-subject design with Half number of trials

Introduction

The aim of Experiment 6 was to investigate whether the null priming effect found in Experiment 5 was a consequence of the large number of trials in each test block. To do so, the number of trials in a test block was decreased by half (160 trials in the current experiment compared to 320 trials in Experiment 5).

Method

Apart from the participants and the trial number, all other methods were identical to Experiment 5.

Participants

Eighty native English-speaking students from the University of Kent, who had not participated in both Experiment 4 and 5, took part in this study for one course credit. Participants were randomly assigned to two groups – half for the studied block group and half for the unstudied block group. The sample comprised of 73 female and 7 male students aged 18-44. With a mean age of 19.50 (SD = 3.04). Ethical approval was provided by the School of Psychology Ethics committee at the University of Kent.

Procedure

Colour naming test phase

In the test phase, in comparison with Experiment 5 where there were 320 trials in each test block, there were 160 trials in each of the two test blocks in Experiment 6. The 75/25 block where R/W proportion was 75/25 comprised 120 rectangle patches and 40 words, whereas the 25/75 block in which R/W proportion was 25/75 contained 40 rectangle patches and 120 words.

Results

Data preparation

One data (No. 56) was removed from the analysis because the participant did not follow the instructions. The error rate of the remaining 79 participants was 3.20%. Prior to the analysis of the mean correct response latencies, the first trial of each block, and trials with a RT less than 200ms and larger than 3,000ms were removed, which was 0.94% of the whole trials.

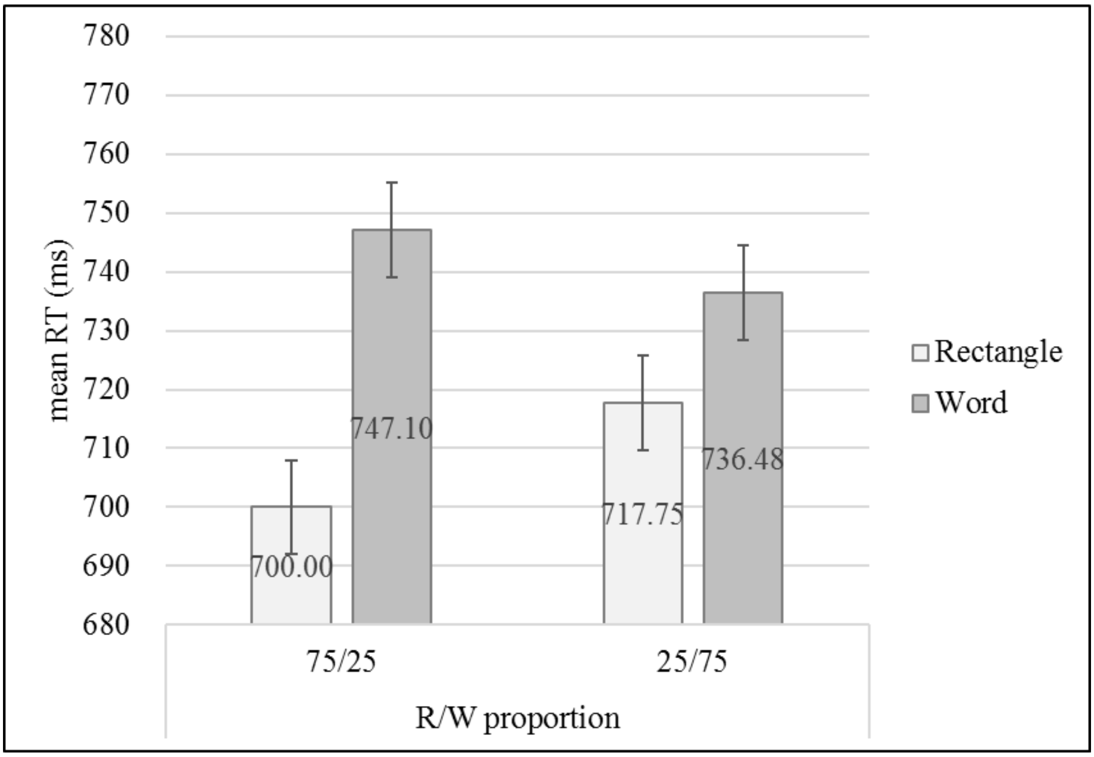
Analysis of response latencies

Identical to Experiment 5, the analysis was carried out on mean correct response latencies using a 2 × 2 × 2 three-way mixed factorial analysis of variance (ANOVA), with R/W proportion (75/25, 25/75) and Stimulus type (rectangle, word) as within-subject factors, and Study block group (studied block, unstudied block) as the between-subject factor. Greenhouse-Geisser corrected values were reported when the Sphericity assumption was violated.

The results were consistent with the findings of Experiment 5, showing a significant main effect of Stimulus type, $F(1, 77) = 39.36$, MSe = 2174.61, $p < .001$, $\eta p^2 = .338$, illustrating that within each of the two blocks, response latencies were longer for word stimuli (M = 741.79ms, SE = 12.78) than rectangle stimuli (M = 708.88ms, SE = 13.19). Moreover, there was a 2-way interaction between R/W proportion and Stimulus type, $F(1, 77) = 12.36$, MSe = 1285.55, $p = .001$, $\eta p^2 = .138$, illustrating that the amount of task conflict from proactive control was larger in the 75/25 block (M = 47.13ms, SE = 6.05) than the 25/75 block (M = 18.83ms, SE = 7.12), which was due to an increase in RT for rectangle stimuli in the 25/75 block (M = 717.75ms, SE = 14.30) compared to the 75/25 block (M = 700.00ms, SE = 13.20), $t(78) = 2.21$, $p = .030$. There was no difference in RT for word stimuli between the 75/25 block (M = 747.10ms, SE = 13.24) and the 25/75 block (M = 736.48ms, SE = 13.52), $t(78) = 1.35$, $p = .181$(see Figure 5.6.1 and 5.6.2). Moreover, as it was found in Experiment 5, the 3-way R/W proportion × Stimulus type × Study group interaction was still not significant, $F(1, 77) = .376$, MSe = 1285.55, $p = .542$, $\eta p^2 = .005$, demonstrating that the amount of task conflict did not differ between Study block groups (see Figure 5.6.3).

Figure 5.6.1

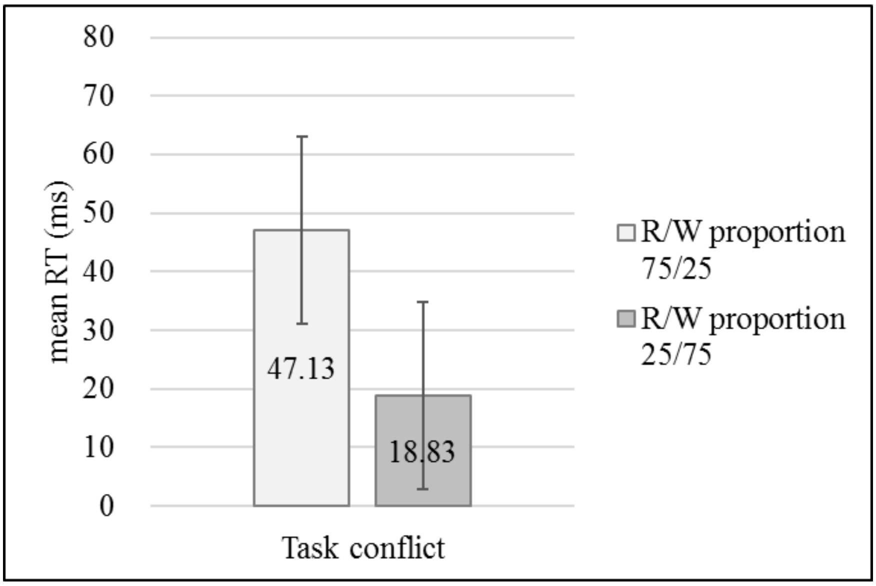
Mean correct reation times as a function of R/W proportion and Stimulus type, reflecting the impact of R/W proportion on the magnitude of task conflict.



Note. Error bars represent the 95% confidence interval adjusted for the within-subject design (Masson & Loftus, 2003). 75/25, the 75/25 block containing 75% of rectangle trials and 25% of word trials; 25/75, the 25/75 block consisting of 25% of rectangle trials and 75% of word trials.

Figure 5.6.2

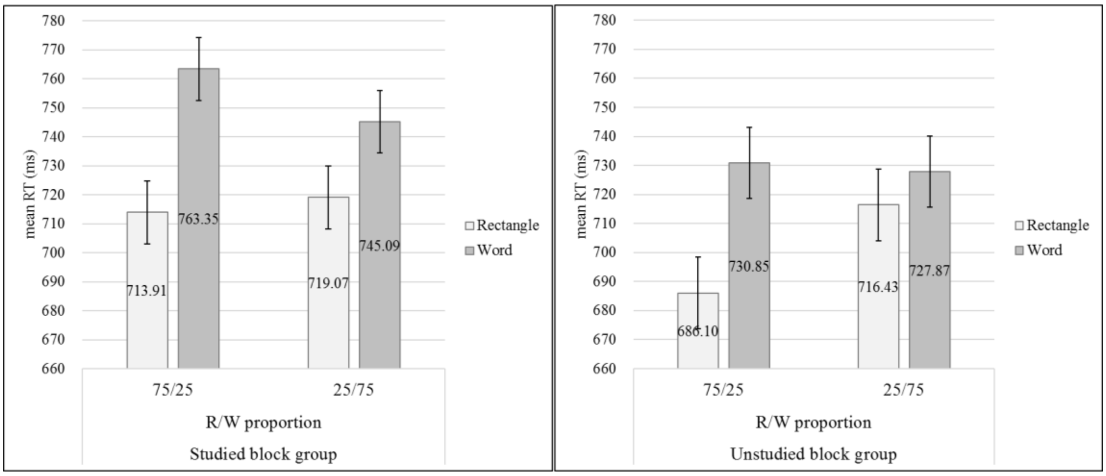
Comparing the amount of task conflict (the RT difference between the rectangle and word stimuli) between R/W proportion 75/25 and R/W proportion 25/75. Bonferroni corrected t-test indicated that the difference was significant.



Note. Error bars represent the 95% confidence interval for the difference between two paired means (Pfister & Janczyk, 2013).

Figure 5.6.3

The 2-way interaction between R/W proportion and Stimulus type was not qualified by Study block group.



Note. Error bars represent the 95% confidence interval adjusted for the within-subject design, calculated separately for the studied block (left panel) and unstudied block groups (right panel) (Masson & Loftus, 2003).

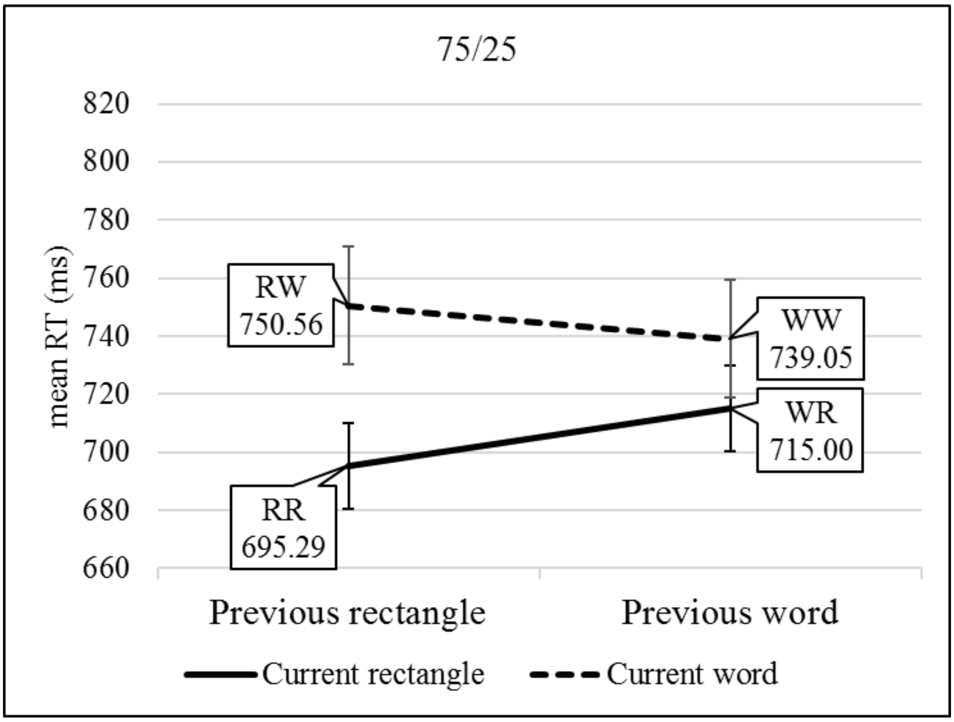
Analysis of the trial-by-trial effect within the 75/25 and 25/75 blocks (ANOVA)

I further examined whether there was an effect of task conflict from reactive control within each block. A 2 × 2 two-way factorial analysis of variance (ANOVA) was conducted for the 75/25 block and the 25/75 block individually with Previous Stimulus type (rectangle, word), Current Stimulus type (rectangle, word) as within-subject factors. Greenhouse-Geisser corrected values were reported when the sphericity assumption was violated.

The analysis disclosed a significant main effect of Current Stimulus type for both of the blocks, $F(1, 78) = 33.36$, MSe = 3724.42, $p < .001$, $\eta p^2 = .300$ for the 75/25 block, and $F(1, 78) = 4.70$, MSe = 5831.72, $p = .033$, $\eta p^2 = .057$ for the 25/75 block, suggesting a reactive control effect in which word stimuli took longer to respond to than rectangle stimuli in the current trials. However, the 2-way interaction between Previous Stimulus type and Current Stimulus type was only significant in the 75/25 block, $F(1, 78) = 5.71$, MSe = 3369.59, $p = .019$, $\eta p^2 = .068$, but not in the 25/75 block, $F(1, 78) = .041$, MSe = 4497.37, $p = .839$, $\eta p^2 = .001$. Post hoc-tests revealed that it was the sequential modulation effect that led to the 2-way interaction in the 75/25 block in which rectangle trials were faster to respond to when preceded by rectangle trials compared to when preceded by word trials (RR vs. WR, $p = .010$), which indicated a reactive control effect of word stimuli from the previous trials. On the other hand, word trials following word trials were not different from word trials following rectangle trials (RW vs. WW, $p = .263$), showing no reversed sequential modulation effect (see Figure 5.6.4).

Figure 5.6.4

The 2-way interaction between Previous Stimulus type and Current Stimulus type for the 75/25 block, showing a sequential modulation effect in which rectangles show faster response latencies when preceded by rectangles compared to when preceded by words.



Note. Error bars represent the 95% confidence interval for the difference between two paired means, computed separately for trial RW vs. trial WW and for trial RR vs. trial WR (Pfister & Janczyk, 2013). R, rectangle; W, word.

Moreover, since sequential modulation effects were found in both of the 75/25 and 25/75 blocks in Experiment 5, I further explored whether there was also a sequential modulation effect in the 25/75 block by contrasting the response latencies to trial RR and trial

WR. The result revealed that the comparison was not significant, $t(78) = 0.10$, $p = .918$, indicating that there was no sequential modulation effect in the 25/75 block.

Analysis of the trial-by-trial effect within the 75/25 and 25/75 blocks (Planned comparison for trial RW vs. trial WW)

I conducted planned comparisons to check whether word stimuli were longer when preceded by word stimuli relative to rectangle stimuli, showing the reversed sequential modulation effect in the 75/25 block and/or in the 25/75 block. However, neither in the 75/25 block, $t(78) = 1.13$, $p = .263$, nor in the 25/75 block, $t(78) = 0.64$, $p = .525$, did the reversed sequential modulation effect emerge.

Analysis of Recognition phase

The data of recognition phase were converted to d-prime, C-bias, hit and false alarm rates applying methods of signal detection theory (Macmillan, N. A., & Creelman, 2005). For the studied block group, the results revealed the sensitivity that was above 0.5, demonstrating that participants were able to distinguish words they had seen in the study phase from those they had not seen in the study phase. The negative value of bias suggested that participants showed a tendency to consider a word as the studied word when they were uncertain (d-prime: M = 1.15, SE = 0.03; C-bias: M = - 0.03, SE = 0.02; Hit rate: 72.63%; False alarm rate: 29.38%). For the unstudied block group, the results also showed the sensitivity that was above 0.5 and the bias that had a negative value (d-prime: M = 1.03, SE = 0.05; C-bias: M = -0.03, SE = 0.01; Hit rate: 70.64%; False alarm rate: 31.79%). I conducted independent t-tests to compare the performance between the two groups. The results illustrated that the level of discrimination was higher in the studied block group (M = 1.15, SE = 0.03) than the unstudied block group (M = 1.03, SE = 0.05), $t(77) = 2.22$, $p = .030$, and the hit rate was higher for the studied block group (72.63%) than the unstudied block group (70.64%), $t(66.52) = 2.05$, $p = .044$. The false rate and C-bias were not significantly different between the two groups(all *p*'s > 0.1).

Discussion

The memory results were similar to Experiment 5, showing that both of the groups were able to identify studied and unstudied words well and the performance was better for the studied block group than the unstudied block group.

Priming effects

In the current experiment, the trial number was lessened by half in each test block compared to Experiment 5. I replicated the finding of Experiment 5 that the magnitude of task conflict from proactive control was greater in the 75/25 block than the 25/75 block. However, the manipulation of trial number did not result in any difference between the studied and unstudied block groups although word stimuli seemed to be faster in the unstudied block group than the studied block group, indicating that there might be other factors causing the null priming effect apart from the trial number. One possible factor could be due to the 10 unstudied word the unstudied block group saw during the test phase. That is, since there were only 10 words repeatedly presenting in the test blocks, it could possibly result in a priming effect, slowing down unstudied words. If this was the case, I asked whether the pattern of colour-responding for word stimuli in the unstudied block group was the same as that in the studied block group where word stimuli in the first half or the first quarter of the 75/25 block were faster than those in the second half or the rest of the three quarters of the 75/25 blocks, respectively. We looked into Block half and Block quarter, but this assumption was not supported by the results. Therefore, it remains unclear what caused the null effect between the studied and unstudied block groups. Or, it could possibly be argued that when there were only word stimuli in the design (i.e., Sharma (2018) and Experiment 1 and 3 in Chapter 4), studied words could stand out from unstudied words in terms of the salience. Whereas in the design where word stimuli were intermixed with rectangle stimuli (e.g., Experiment 5 and 6 in Chapter 5), word stimuli, regardless of whether the words were studied or unstudied, stood out from rectangle stimuli due to lexical effects. As a result, the difference in salience between studied words and rectangles might not be different from that between unstudied words and rectangles. Therefore, when comparing studied words with unstudied words, studied words no longer have higher salience than unstudied words.

In line with Experiment 5, the result of the current experiment demonstrated that the latencies of word stimuli remained unchanged across the two blocks, suggesting that the state of PC to colour naming did not change across the two blocks, which did not support my hypothesis from the PC-TC model where I expected to see word stimuli speed up in the 25/75 block compared to the 75/25 block. Whereas the rectangle stimuli were faster to respond to in the 75/25 block than the 25/75 block. The analysis of the trial-by-trial effect suggested that faster rectangle stimuli in the 75/25 block than the 25/75 block could be due to the sequential modulation effect that was only observed in the 75/25 block, but I cannot be sure because this finding was not consistent with Experiment 5 where the sequential modulation effect was found in both the 75/25 and 25/75 blocks. As previously discussed in Experiment 4 and 5, despite that the response latency difference for rectangle stimuli between the two blocks could be a consequence of the frequency effect, I suggest that my result was due to the effect of task conflict based on the findings of Goldfarb and Henik (2007) and Entel et al. (2015).

Conclusion

The findings provided evidence that the magnitude of task conflict from proactive control could be modulated by the proportion of illegible rectangle stimuli relative to legible word stimuli in the non-colour word Stroop task. However, predictions from the PC-TC model were not supported by the results. First, through Experiment 4, 5 & 6, it was consistently observed that the amount of task conflict from proactive control was greater in the 75/25 block where there were more rectangle stimuli relative to word stimuli than the 25/75 block where rectangle stimuli were the minority compared to word stimuli. Across the three experiments, there was no difference in RT for word stimuli between the two blocks, showing that the proportion manipulation could have failed or might not be enough to affect the recruitment of proactive control to colour naming, and/or suggesting the insensitivity of word stimuli to the proportion manipulation, which was contrary to my prediction where I expected to see faster responses to word stimuli in the 25/75 block than the 75/25 block that indicates a strengthened top-down proactive control to colour naming in response to the increased proportion of word stimuli. On the other hand, faster responses to rectangle stimuli in the 75/25 block than the 25/75 block were observed in both Experiment 5 and 6, indicating that rectangle stimuli were sensitive to the proportion manipulation. However, this was opposite to my hypothesis where I expected the colour-responding for rectangle stimuli to remain the same across the two blocks since rectangles do not produce conflict and thus they would not be affected by the proactive control. Second, both in Experiment 5 and 6, participants from the studied block group showed a similar pattern to those from the unstudied block group, suggesting a null priming effect, which was inconsistent with the findings of task conflict from proactive control in Sharma (2018) and Experiment 1 and 3 in

Chapter 4 where blocks with studied words showed longer colour-responding than blocks without studied words.

Section 3: The Role of Task Conflict in the Non-Colour Salient Word Stroop Task

Chapter 6 – Experiment 7 and 8

Chapter 6: The Effects of Emotional Salience and Priming on Task conflict

Experiment 7 was published in the journal Frontiers in Psychology in August 2019 and was also presented in an Experimental Psychology Society poster presentation in April 2019 in Manchester.

Abstract

This chapter set out to generalise the findings of task conflict from using studied neutral words to using studied salient words – negative emotional words for Experiment 7 and marijuana-related words for Experiment 8. Participants were divided into two groups with high and low trait anxiety in Experiment 7 and with marijuana users and non-users in Experiment 8. I asked whether the two groups in each experiment responded to studied salient words in different patterns. In addition to the pure block with only unstudied neutral words (i.e., the [C] block) and the mixed block with studied neutral words (i.e., the [CsC] block) that were applied in Chapter 4's design, two more blocks were added into the design – a block of unstudied neutral words and unstudied salient words (i.e., the [NC] block and the [MC] block for Experiment 7 and 8, respectively), and a block of unstudied neutral words and studied salient words (i.e., the [NsC] block and the [MsC] block for Experiment 7 and 8, respectively). Experiment 7's results for the low anxiety group showed no emotional Stroop effect, but did demonstrate the slowdown in response latencies to the [CsC] and [NsC] blocks compared to the baseline [C] block. In contrast, the high anxiety group showed (a) An

emotional Stroop effect but only for studied negative words in the [NsC] block, and (b) A reversed sequential modulation effect in which studied negative words slowed down the colour-responding of studied negative words on the next trial. Experiment 8's results for the non-users exhibited no addition Stroop effect, but did illustrate the slowdown to the average response times of the [MC], [CsC] and [MsC] blocks compared to the baseline [C] block. On the contrary, users showed (a) Strong addiction Stroop effects for both studied and unstudied marijuana-related words in the [MC] and [MsC] blocks, and (b) Marginally significant reversed sequential modulation effects where two consecutively presented marijuana-related words, regardless of whether the words were studied or unstudied, slowed down the responses. I considered how these findings can be incorporated into the PC-TC model and suggested the interacting role of trait anxiety/addiction, episodic memory, and emotional/incentive salience driving selective attention that is based on task conflict.

Experiment 7 – Studied Negative words

Introduction

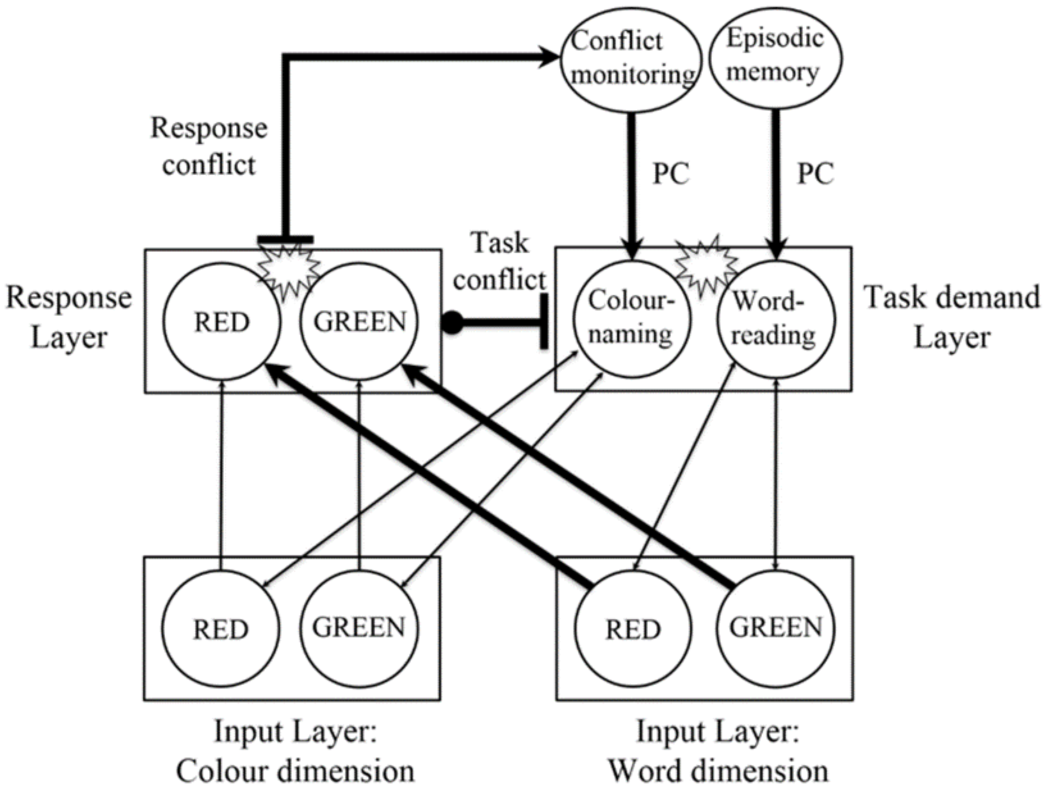
The Stroop task is often used to investigate executive control processes. In particular, to examine the ability to selectively attend to relevant and ignore irrelevant information (Stroop, 1935). The most common form of the task is one in which a word is printed in an ink colour with the focus to report the ink colour and ignore the word. Typically, with colour words the word and ink colour can be congruent (e.g., word RED printed in red) or incongruent (e.g., word GREEN printed in red) with the difference in reaction time (RT) used to measure the Stroop effect. A neutral control (e.g., XXXX printed in red) can also be used to separate the Stroop effect into interference (difference between incongruent and neutral trials) and facilitation (difference between congruent and neutral trials) effects (MacLeod, 1991).

The Stroop task is thought to result from two types of conflict, informational conflict and task conflict. Informational conflict is thought to be dependent on the congruency between the word and ink colour, with conflict arising when the meaning of the word and the ink colour contradict each other (Klein, 1964; though see Shichel & Tzelgov, 2018 for further decomposition of informational conflict). Task conflict occurs between two potentially competing tasks. This can occur when certain stimuli become associated with certain tasks. For example, words tend to activate reading processes which results in competition between the task of reading and responding to the ink colour (MacLeod & MacDonald, 2000; Goldfarb & Henik, 2007; Kalanthroff, Goldfarb, & Henik, 2013; Kalanthroff, Goldfarb, Usher, & Henik, 2013, Entel & Tzelgov, 2018; Sharma, 2018).

Connectionist models have been used to develop theoretical accounts of the Stroop effect (Cohen, Dunbar, & McClelland, 1990; Botvinick, Braver, Barch, Carter, & Cohen, 2001). Central to these models is the flow of information from an input layer (colour and word input units) to an output layer (colour and word response units). In addition, a task demand layer (colour naming and word reading units) is included to bias information flow based on task goals (e.g., instructions to focus on colour naming) between the input and output layers. In such models informational conflict results from competition between the output units (referred to as response conflict). Although early models relied on information flow in a bottom-up fashion, later models also allowed for a proactive top-down control mechanism (Botvinick et al., 2001; Braver, 2012; De Pisapia & Braver, 2006) to help maintain focus on the task goal. One source of evidence to support a proactive mechanism of control is the sequential modulation effect (aka the Gratton effect) in which incongruent trials are responded to faster when their previous trials are also incongruent than when they are congruent (Gratton, Coles, & Donchin, 1992; Kerns et al., 2004). It is thought that the attentional system monitors the degree of response conflict (a conflict monitoring node) and uses this to proactively increase the activation to the task goal of colour naming to help reduce interference from words on subsequent trials (Botvinick et al., 2001). It is thought that the anterior cingulate cortex (ACC) is involved in the conflict monitoring mechanism (Botvinick et al., 2001). A more recent model, the Proactive-control/task conflict (PC-TC) model (Kalanthroff et al., 2015, 2018), inherits the response conflict mechanism from earlier models but in addition includes a mechanism for task conflict. Kalanthrofff et al., (2015, 2018) suggested that task conflict arises from the inhibitory connection between the task demand layer and the output layer (implemented by raising the response threshold for all the units in the output layer) where the level of inhibition is determined by the level of competition between the task demand (colour naming and word reading units) units (see Figure 6.7.1).

Figure 6.7.1

Proactive-control/task-conflict (PC-TC) model. Adapted from Kalanthroff, Avnit, Henik, Davelaar, and Usher (2015).



Note. The task demand units are modulated by proactive control through the conflict monitoring node. The episodic memory node was not part of the PC-TC model and has been added to explain the current findings and those of Sharma (2018).

Support for the PC-TC model comes from several sources. First, the reversed facilitation effect in which congruent words take longer to respond to than non-words under low PC (for a review see Kalanthroff et al., 2018). Here it is thought that the word reading task demand unit is activated by the congruent word in a bottom-up fashion to produce greater task conflict with colour naming, compared to a non-word. Second, Sharma (2018) also provided evidence for the influence of task conflict using the non-colour word Stroop task. Sharma used a priming procedure in which participants learned neutral words during a study phase (see also MacLeod, 1996). A subsequent testing session included two types of blocks. A block of unstudied words and a mixed block of studied and unstudied words. In both testing blocks the task was to ignore the words and respond to the ink colour. Primed words resulted in slower responses to all studied and unstudied words in the mixed block compared to the unstudied block. Sharma suggested that the PC-TC model could explain this finding by assuming an episodic memory unit that holds the contextual details of the study event and activates the word reading task demand unit, which can result in task conflict (see Figure 6.7.1). In addition, Sharma showed that in the second half of the mixed block, when presumably PC diminishes, there was a reversed sequential modulation effect in which studied words had longer latencies when preceded by studied words compared to when preceded by unstudied words (for a similar finding with studied nonwords see Dumay, Sharma, Kellen & Abdelrahim, 2018). This is consistent with a task conflict explanation that is due to reactive control from studied words.

Although much of the research using the Stroop task has focused on using colour words, there is considerable evidence that non-colour words can also slow down response latencies (Klein, 1964; Sharma & McKenna, 1998; Burt, 2002). One of the most common non-colour word versions of the Stroop task is one in which negative emotional words are compared to neutral words, often labelled the emotional Stroop task (Williams, Mathews & MacLeod, 1996; McKenna & Sharma, 2004; Algom, Chajut, & Lev, 2004; Dalgleish, 2005). The emotional Stroop task has been widely used to investigate attentional bias in anxiety and other emotional disorders such as depression, phobias, post-traumatic stress disorder, obsessive-compulsive disorder and panic disorder. The difference in response latency between negative emotional and neutral words is referred to as the emotional Stroop effect. Findings suggest that both non-clinical individuals with high trait anxiety and clinically anxious individuals show attentional bias towards threat-related words, whereas such threat-related bias is not found in non-anxious individuals (Bar-Haim et al., 2007; Phaf & Kan, 2007; Yiend, 2010).

Following the connectionist model of Cohen et al. (1990), previous models to explain the emotional Stroop effect have tacitly assumed that emotional interference occurs at the output layer due to response conflict. Williams et al., (1996) hypothesised that input units which represent negative emotional words could have higher resting activation levels (implemented by regulating the gain parameter). Consequently, the greater activation throughout the negative emotional word processing pathway results in greater competition with colour response units in the output layer. Matthews and Harley (1996) hypothesised that attentional bias is contingent on the allocation of voluntary attention to threat stimuli. Adapting from Cohen et al.'s (1990) model, they introduced a threat monitoring unit in the task demand layer (to simulate trait like effects) as well as an emotion word unit in the input layer. When a threatening word is presented the active threat monitoring task demand unit would sensitise the threat emotional word processing pathway which would result in greater response conflict in the output layer. An alternative model for negative emotional interference was provided by Wyble, Sharma and Bowman (2008) who suggested that negative words affected the balance of control proactively. This was implemented by a mutual inhibition between the conflict monitoring unit and the negative emotional unit in their adaptive attentional control layer and supports the conclusion that negative emotional words reduce proactive control to the task goal of colour naming. This approach is also consistent with other more general models that make similar predictions such as the Dual Competition Model (Pessoa, 2009) and the attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007) which suggest that high level of threat or the anxiety of an individual can lead to a shift in the attentional control system from top-down (goal-oriented) to bottom-up (stimulus-driven), prioritising attentional resources to the processing of the threat-related stimuli.

Since the role of task conflict has not been considered in connectionist models of the emotional Stroop effect, here we consider how this might be implemented. In the PC-TC model this can occur in a number of ways but one way might be by greater activation of the word reading task demand unit. The word reading task demand unit can be activated in two ways, either in a bottom-up reactive fashion (e.g., by activation from negative word input units) or in a top-down proactive control mechanism (e.g., by a threat monitoring task demand unit in high anxious individuals or more generally by priming from negative schemas) that enables the word reading task demand unit to compete with the colour naming task demand unit. Evidence for both mechanisms was provided by Sharma (2018) when comparing trials within and between blocks. Between blocks proactive control was evidenced as a general slowdown, in particular the neutral words in the block containing studied words were slower than those in a block without studied words. On the other hand, within a block of studied and unstudied words, an indication of reactive control came from a reversed sequential modulation effect in which studied words were slower to respond to when preceded by another studied word than an unstudied word.

The main aim of our research was to use the priming procedure developed by Sharma (2018) to investigate further evidence for the role of task conflict in the non-colour word

Stroop task. In our experiment participants study both negative and neutral words during an initial study phase, which is followed by a test phase comprising four blocks with different word categories: (1) a block of unstudied neutral words [C]; (2) a block of unstudied negative and neutral words, [NC]; (3) a mixed block of studied and unstudied neutral words, [CsC] and (4) a mixed block of studied negative and unstudied neutral words, [NsC]. This leads to seven word categories, which are represented by the following labels: (note that letters within square brackets refer to the type of block and letters outside the square brackets refer to the type of word) [C]-C, [NC]-C, [NC]-N, [CsC]-C, [CsC]-Cs, [NsC]-C, [NsC]-Ns. As previous research highlights differential results for high and low anxiety with negative emotional stimuli, we also investigate the role of trait anxiety (Kalanthroff, Henik, Derakshan, & Usher 2016).

We expected to replicate Sharma's (2018) finding of a general slowdown for the studied [CsC] block compared to the unstudied neutral words [C] that is an indicator of task conflict from proactive control. We also extend this research to using studied negative words and expected to find a similar general slowdown for a [NsC] block compared to the unstudied [C] block.

If there is a general hypervigilance for negative stimuli in high anxiety, then this may appear either as longer response times for negative words than neutral words in block [NC] or [NsC], and/or as a general slowing in block [NC] or [NsC] compared to [C]. However, previous research on mixing negative and neutral words has shown weak effects (Williams et al, 1996). Indeed, there is strong evidence that priming plays an important role in the emotional Stroop effect (Richards et. al., 1992; Holle et al., 1997; Lundh & Czyzykow-Czarnocka, 2001). For example, Richards et. al. (1992) showed that high anxious participants do not show an emotional Stroop effect when neutral and negative words were randomly mixed. However, a more robust effect occurred after negative mood induction or when negative and neutral words were blocked during test (see also Holle et. al., 1997). Priming the anxiety schema prior to testing can also have similar effects (see Lundh & Czyzykow-Czarnocka, 2001). This suggests that negative words produce interference in high anxiety but only when they have been primed. In line with Richards et al. we expected to find an emotional Stroop effect for high anxious participants in the block containing studied negative words, [NsC]. Comparing the neutral words in the [NsC] block and the [C] block could help to distinguish between response conflict and task conflict. The general prediction is that if negative stimuli increase response conflict, then response latencies will speed up across trials due to the feedback from conflict monitoring increasing activation of the colour naming task demand unit (Botvinick et al., 2001). If negative words increase activation of the word reading task demand unit, then the PC-TC model would predict a slower response to neutral words in the [NsC] block than the [C] block.

In line with Attentional Control Theory we also expected there to be a reduced effect of proactive control in high trait anxiety (Eysenck et al., 2007; Berggren & Derakshan, 2013; Kalanthroff et al. 2016). A reduced proactive control could be seen as a general slowdown from studied words that is larger in the low anxiety group than the high anxiety group. In addition, it suggests that further analysis of the mixed blocks may show signs of reactive control that is more apparent in the high anxiety group than the low anxiety group. In particular we contrasted pairs of consecutively presented trials: CsCs or NsNs trials with CCs or CNs trials respectively. If the effects of reactive control are due to response conflict, then the PC-TC model predicts a sequential modulation effect in which studied words are faster to respond to after studied words. However, as shown by Sharma (2018), if the effects of reactive control lead to task conflict, then the PC-TC model predicts a reversed sequential modulation effect: slower responses to studied words on the trial after a studied word.

Method

Participants

A hundred and twenty native English-speaking students from the University of Kent took part in this study for course credits or 5 pounds in cash. The sample comprised of 104 females and 16 males, aged 18-49, mean age of 20.72 (SD = 4.755). Ethical approval was given by the School of Psychology Ethics committee at the University of Kent.

Design

A 7 × 2 mixed factorial design was employed. Word category ([C]-C, [NC]-C, [NC]-N, [CsC]-C, [CsC]-Cs, [NsC]-C, [NsC]-Ns) was the within-subject factor, and Trait group (high, low) was the between-subject factor. The dependent variable was the mean correct response latency to respond to the ink colour of the word.

Apparatus and materials

The experiment program was written in Psychopy 1.83.04 and presented on a 21-inch Dell® widescreen monitor. Reaction time was measured during the Stroop tasks. The manual responses, presentation and randomisation of the words were controlled by Psychopy 1.83.04. The words used are shown in Table 6.7.1.

Forty negative emotional words were chosen from Affective Norms for English Words (Warriner, Kuperman, & Brysbaert, 2013) and separated into two sets of 20 words. One hundred twenty neutral words were selected from the English Lexicon Project (Balota et al., 2007) and divided into six sets of 20 words. Each set contained an equal number of 4, 5, 6, 7, 8, 9 and 10 letter words, which were matched for word frequency (average Log frequency HAL of 8.84), which was in the midrange for the corpus of words (Range 0–17) (Balota et al., 2007); word valence (average valence mean of 2.56 and 5.59 for negative emotional and neutral words respectively) (Range 1.26 – 8.53), and word arousal (average arousal mean of 5.52 and 3.87 for negative emotional and neutral words respectively) (Range 1.6 – 7.79) (Warriner et al., 2013).

Table 6.7.1

Word lists used in Experiment 7

Word lists							
Negative	Negative	Control	Control	Control	Control	Control	Control
fear	pain	area	card	pipe	game	hall	tool
hate	lose	limb	poem	unit	path	rock	deep
shun	thug	soar	trot	whiz	claw	raft	meat
angry	argue	chair	sugar	wheel	paint	hotel	queen
crime	abuse	plant	stage	river	metal	mouth	union
death	sorry	board	voice	class	press	title	month
horror	danger	enable	launch	expand	import	formal	phrase
cancer	threat	belief	bottle	bridge	custom	square	manage
betray	maggot	mascot	turret	tendon	wobble	cortex	pebble
anxiety	awkward	harvest	surgeon	whistle	surname	reactor	outlook
corrupt	illness	cartoon	lottery	texture	vaccine	predict	observe
selfish	hostile	tourist	sticker	shelter	pursuit	thermal	booklet
suicide	violent	segment	profile	prepare	academy	kitchen	formula
horrible	disaster	revision	retrieve	clinical	estimate	adequate	abstract
arrogant	massacre	mainland	activate	reminder	altitude	shipment	shepherd
nuisance	stubborn	tangible	teaspoon	molecule	landmark	nutshell	homeland
depressed	terrorist	voluntary	physician	librarian	diagnosis	ancestral	alignment
miserable	obnoxious	peninsula	machinery	offspring	geography	crossover	astrology
disgusting	frustrated	moderation	elementary	coordinate	adjustment	inevitable	convincing
suspicious	disability	subscriber	occupation	projection	calculator	curriculum	researcher

Procedure

An information sheet and a consent form were given to each participant upon their arrival at the lab. After signing the consent form, participants sat in front of a computer monitor and were asked to read through the instructions for experiment's procedure. There were four phases in this study: the study phase, test phase, recall phase, and questionnaire phase.

Study phase

Each participant was shown 40 words in white print on a black background, which mixed 20 negative emotional words from one of the two negative emotional word sets and 20 control words from one of the six neutral word sets, and was asked to memorise them as best as they can. To help participants enhance their working memory performance, after a word was shown, a five-point grading scale was presented (1 = 0%, 2 = 25%, 3 = 50%, 4 = 75% and 5 = 100%) in which they were asked to rate how strong they felt the word related to themselves. Each word was presented one at a time in white print at the centre of the screen for 1,500ms, followed by an 800ms blank screen prior to the five-point grading scale. The grading stage remained until a response was given before the next word was shown.

Test phase

Practice trials were provided before the experimental Stroop task, which consisted of 20 non-words (e.g., dfbvxz, whcag, vfjtd). These 20 non-words were printed in each of four colours (red, green, blue and yellow) for 80 trials and were randomly displayed on a black background. Each trial began with a 1,000ms fixation at the centre of the screen, followed by a non-word which remained until a response was provided before the next trial started. Participants were instructed to place their index and middle fingers from each hand on top of four keys (z = red, x = green, n = blue, m = yellow) on a QWERTY keyboard, and they were asked to ignore the non-words and respond to the ink colour as quickly and as accurately as possible.

The general instructions and procedure for the experimental Stroop task were identical to the practice phase. There were four blocks ([C], [NC], [CsC] and [NsC]) with two sets of words comprised of either two sets of 20 control words or 20 control words mixed with 20 negative words). In each block, 40 words were printed in each of four colours for 160 trials, resulting in 640 trials for the Stroop task. The two sets of negative emotional words and six sets of neutral control words were assigned to four experimental blocks and counterbalanced across participants. Each word was presented in a random order in each block.

As soon as a block was completed, participants were given an option to take a short break and were instructed to carry on with the next block by pressing the space bar. The order of four blocks was counterbalanced across participants.

Recall phase

The test phase was followed by the recall phase in which participants had 180 seconds to write down as many words they had seen during the study phase as they could remember on a blank sheet of paper.

Questionnaire phase

The questionnaire phase followed the recall phase. The Spielberger State-Trait Anxiety Inventory (STAI) was given to participants, consisting of 20 statements for state anxiety which indicates how you feel right now, and trait anxiety implying how you feel in general, respectively (Spielberger et al., 1983).

Results

Analysis of the Stroop task

Data preparation

Scores on the STAI-trait ranged from 20 to 78 ($M = 48.80$, $SD = 12.33$). Based on norms collected between 2005-2007 ($N = 368$) from students at the University of Kent, trait anxiety scores of 50 or above represent percentile ranks 75% [85% (for males) and 72% (for females)]. Participants were assigned to the low (< 50) or high (>= 50) trait anxiety group for the analysis of variance. Average STAI-trait score in the high anxiety group (range 50-78, $M = 58.56$, $SD = 7.39$, $N = 59$) and in the low anxiety group (range 20-49, $M = 39.36$, $SD = 8.02$, $N = 61$).

Four participants' data were removed: one was due to a high error rate (18.9%) and the other three data due to long reaction times (above 2.5 standard deviation). The error rate of the remaining 116 participants (Low trait: $N = 59$; High trait: $N = 57$) was 4.50%. Prior to the analysis of mean correct response latencies, the first trial of each block and trials with a RT less than 200ms and larger than 3,000ms, which was 5.5% of the trials, were excluded.

Analysis of response latencies

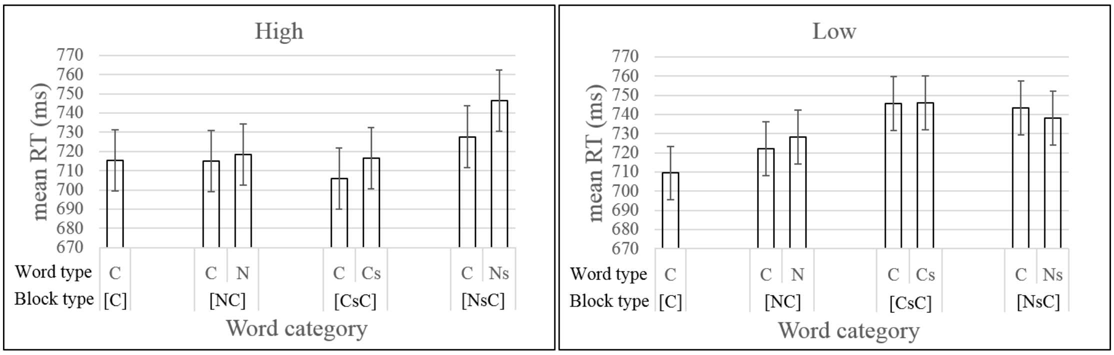
The first analysis was executed on the mean correct reaction times, using a 7 × 2 two-way mixed analysis of variance (ANOVA), with Word category ([C]-C, [NC]-C, [NC]-N, [CsC]-C, [CsC]-Cs, [NsC]-C, [NsC]-Ns) as the within-subject factor, and Trait group (high, low) as the between-subject factor. Greenhouse-Geisser corrected values were reported when the sphericity assumption was violated.

The analysis revealed a significant main effect of Word category, $F(3.29, 375.18) = 3.59$, MSe = 6133.02 , $p = .011$, $\eta p^2 = .031$. Bonferroni corrected t-tests indicated that there was a significant difference between [NsC]-Ns (M = 742.25ms, SE = 14.17) and [C]-C (M = 712.37ms, SE = 12.41) words ($t(115) = 3.71$, $p = .007$). A main effect of Trait group was not significant $F(1, 114) = 0.277$, MSe = 114719,80 $p = .600$, $\eta p^2 = .002$. However, there was an interaction between Word category and Trait group, $F(3.29, 375.18) = 2.67$, MSe = 6133.02 , $p = .042$, $\eta p^2 = .023$. Bonferroni corrected t-tests indicated that in the low trait anxiety group, [CsC]-C (M = 745.62ms, $t(58) = 4.02$, $p = .004$), [CsC]-Cs (M = 745.96ms, $t(58) = 4.06$, $p = .003$), [NsC]-C (M = 743.45ms, $t(58) = 3.41$, $p = .025$) words took longer to respond to than the [C]-C (M = 709.42ms) words. On the other hand, in the high trait anxiety group, the

[NsC]-Ns (M = 746.40ms, $t(56) = 4.04$, $p = .003$) words were longer than [CsC]-C (M = 705.76ms) words (see Figure 6.7.2).

Figure 6.7.2

Mean correct reaction times for the high and low trait anxiety groups in each Word category.



Note. Error bars represent the 95% confidence interval adjusted for the within-subject design, calculated separately for the high and low trait anxiety groups (Masson & Loftus, 2003). C, neutral word; N, negative word; s, word is studied.

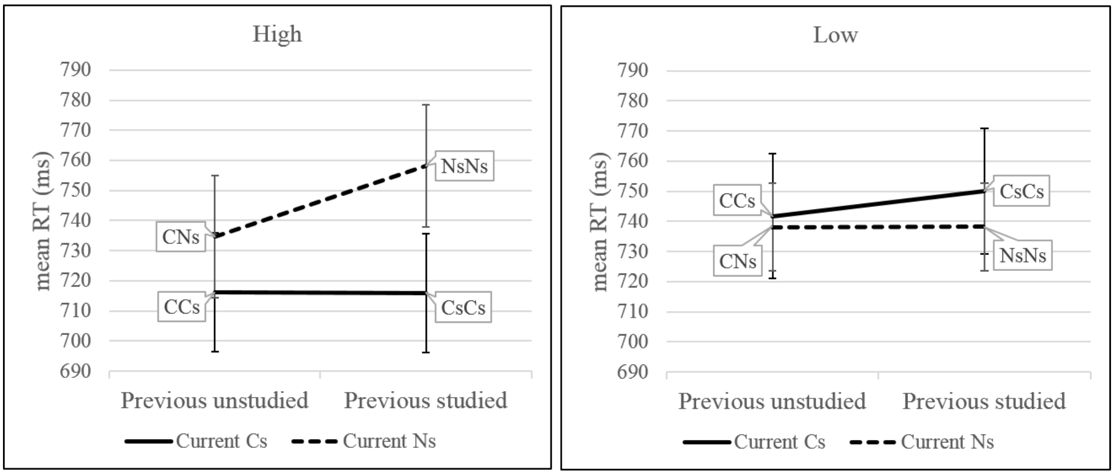
Further analysis of this interaction involved planned comparisons. First, there was an emotional Stroop effect for high trait anxiety with studied negative words, $F(1, 56) = 8.19$, $p = .006$, $\eta p^2 = .13$, but not unstudied negative words, $F(1, 56) = .45$, $p = .51$, $\eta p^2 = .008$. There was no emotional Stroop effect for low trait anxiety (both F's < 1, p's > .37). Second, we looked for evidence for proactive task conflict across the blocks. For each trait group we asked if the mixed blocks took longer than the baseline block [C]. For the low anxiety group this was significant ([C] vs [CsC], $F(1, 58) = 18.86$, $p < .001$, $\eta p^2 = .25$; [C] vs [NsC], F(1,

58) = 10.44, p = .002, , ηp^2 = .15). This replicates similar findings by Sharma using neutral words and extends these to studied negative words. For the high trait anxiety group this was not significant for [NsC] vs [C], $F(1, 56) = 3.19$, p = .08, , ηp^2 = .05, or [CsC] vs [C], $F(1, 56) = .12$, p = .73, $\eta p^2 < .01$, or [NC] vs [C], $F(1, 56)$=.61, p = .4, ηp^2 = .01. These findings suggest that in high trait anxiety studied words tend not to slow latencies for blocks with studied words. The above results generally indicate that blocks with studied words tend to have longer latencies than a block of unstudied control words and that this seems to reduce with trait anxiety. Correlations with trait anxiety scores, however, showed that this impression was only supported for [CsC] (r(114) = -.22, p = .016) but not [NsC] (r(114) = -.019, p = .84).

To investigate whether priming words results in task conflict from reactive control we carried out a series of planned comparisons within the two mixed blocks. We asked whether studied words took longer to respond to when preceded by studied words compared to unstudied words (i.e., trial CsCs vs. trial CCs or trial NsNs vs. trial CNs). For the low anxiety group there was no significant reversed sequential modulation effect in [CsC], $t(58) = .81$, p = .42, nor in [NsC], $t(58) = .002$, p = .99. For the high anxiety group there was a significant reversed sequential modulation effect in [NsC], $t(56) = 2.31$, p = .025 but not [CsC], $t(56) = .02$, p = .98 (see Figure 6.7.3). The modulation found in high anxiety for studied negative words suggests that the reversed sequential modulation increases with higher levels of trait anxiety. This was supported by a positive correlation between trait anxiety scores and reversed sequential modulation scores in the [NsC] block, r(114) = .187, *p* = .04. The correlation between trait anxiety and reversed sequential modulation scores in the [CsC] block was not significant, r(114) = -.155, *p* = .097, though the negative direction indicates that lower anxiety may be associated with a reversed sequential modulation effect from studied neutral words.

Figure 6.7.3

Showing the reversed sequential modulation effects within block [CsC] (trial CsCs vs. trial CCs) and block [NsC] (trial NsNs vs. trial CNs) for the high and low trait anxiety groups.



Note. Error bars represent 95% confidence interval for the difference between two paired means, computed separately for the effects within block [CsC] and block [NsC] (Pfister & Janczyk, 2013). C, neutral word; N, negative word; s, word is studied.

Analysis of Recall phase

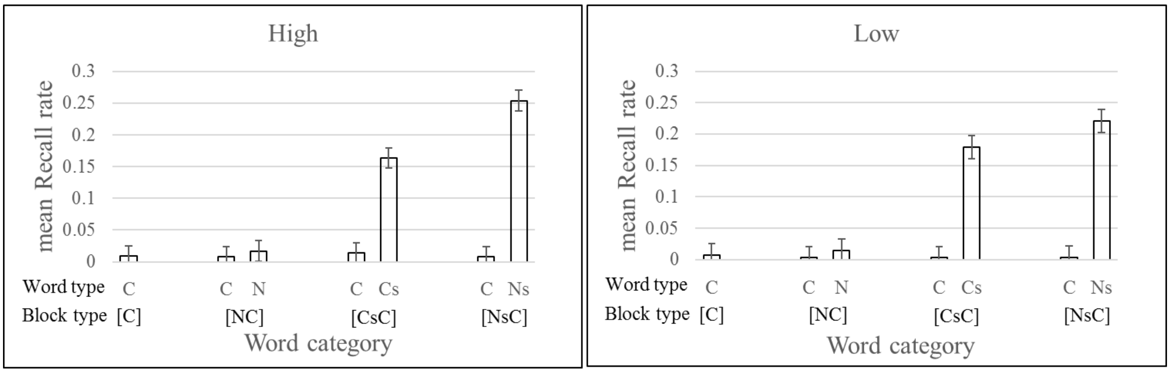
Prior to the analysis, the words written down by participants during the recall phase were checked. Misspellings were accepted (e.g., masaccare for massacre) but the altered forms were excluded (e.g., angry changed to anger).

A 7 × 2 mixed ANOVA was conducted with Word category ([C]-C, [NC]-C, [NC]-N, [CsC]-C, [CsC]-Cs, [NsC]-C, [NsC]-Ns) as the within-subject factor, and Trait group (high, low) as the between-subject factor. The results revealed a significant main effect for Word category $F(2.25, 256.76) = 253.23$, MSe = .012, $p < .001$, $\eta p^2 = .69$ but not for Trait group $F(1, 114) = 1.26$, MSe = .006, $p = .264$, $\eta p^2 = .011$, nor for the Word category × Trait group interaction, $F(2.25, 256.76) = 1.32$, MSe = .012, $p = .270$, $\eta p^2 = .011$. Mean recall rates for studied words [NsC]-Ns (M = 0.24) and [CsC]-Cs (M = 0.17) are significantly higher than other word categories, all *t*'s > 12.85, *p*'s < .01 (see Figure 6.7.4). Moreover, mean recall rate was significantly higher for [NsC]-Ns (M = 0.24) than [CsC]-Cs (M = 0.17), $t(115) = 4.76$, $p < .001$. We also checked if the difference between [NsC]-Ns and [CsC]-Cs correlated with trait anxiety scores; it did not, r(114) = .120, $p = .199$.

We also note that the results were the same when analysed using the lenient criteria in which altered forms were accepted as well (only the main effect of Word category was significant $F(2.41, 274.19) = 252.55$, MSe = 4.60, $p < .001$, $\eta p^2 = .69$; all other main and interaction effects were not significant *F*'s < 2.2, *p*'s > .1).

Figure 6.7.4

Mean recall rate for the high and low trait anxiety groups in each Word category.



Note. Error bars represent 95% confidence interval adjusted for the within-subject design, calculated separately for the high and low trait anxiety groups (Masson & Loftus, 2003). C, neutral word; N, negative word; s, word is studied.

Discussion

The memory results were as expected: (a) Higher recall for studied words than unstudied words; (b) Studied negative words have higher recall than studied neutral words; (c) No interaction with trait anxiety. As expected, these results show the typical episodic memory advantage for recently attended words and words that are semantically related. The lack of interaction with trait anxiety is consistent with previous reviews of the memory bias literature (see Williams et al., 1997; Mitte, 2008). There is some evidence that a memory bias with trait anxiety can occur for free recall memory tasks but only when the depth of processing is shallow during the study phase (for a review see Herrera et. al., 2017). Our findings are consistent with these reviews as a high level of processing (words were rated for self-relevance) was required during the study phase.

The main findings, however, are from the response latencies to the non-colour (neutral and negative emotional) words. For the low anxiety group, there are two key findings. First, neutral words in the studied block [CsC] took longer to respond to than neutral words in the unstudied block [C]. This evidence is consistent with the task conflict hypothesis that is driven by proactive control and replicates findings by Sharma (2018) for studied neutral words. Within the PC-TC model this could be due to a stronger proactive activation of the word reading task demand unit in studied blocks. Second, the slowdown for studied neutral words also generalises to a block with studied negative words (i.e., [NsC]) and therefore suggests that negative words can also slow down responses in low anxiety but only when these words have been primed. As there was no difference between the two studied (neutral and negative) blocks, together these two findings highlight the influence of studying words in the non-colour Stroop task. Therefore, this extends the original work of MacLeod (1996) and replicates the findings by Sharma (2018) to further demonstrate that the study-test methodology can be used to investigate implicit memory in the non-colour word Stroop task.

For the high trait anxious group, there are three main findings. First, an emotional Stroop effect in the [NsC] block but not in the [NC] block. This supports previous research that priming a negative schema (in our study by learning negative and neutral words during an initial study phase) can generate attentional biases (c.f. Richards et al. 1992; Holle et al., 1997; Lundh & Czyzykow-Czarnocka, 2001). In our study, the priming was specific to negative words for the high trait anxiety group and replicates the findings by Richards et al. (1992) and Holle et al. (1997) where negative words induced interference after negative mood induction or by presenting negative words in a single block of trials. More generally this finding also implicates the importance of memory processes when considering interference in the non-colour word Stroop task. For example, it is possible that the priming effects found for studied negative words in high anxiety may have activated episodic memory (see Figure 6.7.1). In addition, it is possible that such memory activation also initiates higher thought processes such as rumination or self-reflective processes. This may also explain why studied neutral words did not show a similar effect in the high anxiety group. Further research is therefore required to further explore this possibility.

Second, although the high trait anxiety group showed an emotional Stroop effect in the [NsC] block, there was no evidence of a general slowdown for the neutral words in the [NsC] block and in the [CsC] block compared to the baseline [C] block. The lack of a general slowdown contrasts with the slowdown seen for the low trait anxiety group. This finding is consistent with Attentional Control Theory which suggests that in high trait anxiety the balance of control shifts away from proactive control. In the PC-TC model this could be implemented as a reduced top-down activation of the word reading task demand unit.

Third, in high trait anxiety studied negative words took longer to respond to when preceded by studied negative words compared to unstudied neutral words. Here we speculate on several potential explanations for the reversed sequential modulation effect. Sharma (2018) reported a similar finding with studied neutral words, namely a reversed sequential modulation effect for studied neutral words. He suggested a possible reactive control mechanism that activates task conflict in the PC-TC model. A similar mechanism could be suggested for studied negative words in high trait anxiety. However, it is also possible to suggest the influence of a proactive control mechanism. In Figure 6.7.1, the word reading task demand node can be activated by proactive control from episodic memory. Although this influence may be weaker in high trait anxiety, our results suggest that the episodic memory unit may be activated when responses are made to two consecutively presented studied negative words. These two suggestions point to task conflict as a potential mechanism. However, it is also possible to suggest that task conflict is not involved if it is assumed that two consecutively presented studied negative words require greater attentional resources that subsequently results in a relaxation of cognitive control as suggested by the Dual Competition Model (Pessoa, 2009). In a connectionist model without task conflict this could be implemented by inhibition of the conflict monitoring unit analogous to the inhibition from the negative emotion unit in the Adaptive Attentional Control model (Wyble et al., 2008). If this was the case, then more detailed predictions from the Wyble et al.'s model would suggest that studied words slow down subsequent neutral trials analogous to the slow effect reported by McKenna and Sharma (2004) for negative stimuli. We checked for a slow effect from studied words (negative or neutral) but could not find any evidence. Future research could examine the conditions under which slow effects appear. However, we believe the current work is more parsimonious with a model that includes task conflict.

Two puzzling features of our results suggest further avenues for future research. First, we did not find a reversed sequential modulation effect for studied words in the low anxiety group. This did not replicate the reversed sequential modulation effect for studied neutral words found by Sharma (2018). We suggest this may be due to the stronger proactive control from episodic memory to the word reading task demand unit in our study than in Sharma. This may be due to using a larger set of studied words (40 in our experiment compared to 20 in Sharma) and/or using negative words which forms a stronger semantic category than the neutral words. Second, for the high anxiety group the reversed sequential modulation effect did not occur for the studied neutral words. This is surprising particularly as it is thought that in high anxiety the balance of control shifts towards reactive control. One explanation might be that using a larger studied word set may have reduced the saliency of each individual item.

However, for the studied negative words their stronger semantic associations may have enabled them to maintain a stronger level of priming.

In conclusion our findings provide further evidence in support of using the priming technique to elucidate the role of task conflict in the non-colour word Stroop task. For low anxiety, studying (neutral and negative) words resulted in a general slowdown that was attributed to task conflict resulting from a proactive control mechanism that increases activation of the word reading task demand node. For high anxiety, the general slowdown is limited suggesting a reduced influence from proactive control.

Experiment 8 – Studied Marijuana-related words

Introduction

In Experiment 7, I can see task conflict and how it operates in anxiety. For low trait anxiety, compared to the baseline unstudied [C] block, the general slowdown was found in both the [CsC] and [NsC] blocks with studied neutral and studied negative words, respectively. These results replicated the null effect in which colour-responding did not differ between studied and unstudied words in the studied block reported by MacLeod (1996) and Sharma (2018), showing that the word reading task can be triggered by studied words in a top-down proactive mechanism, resulting in colour naming interference for both studied and unstudied words. In contrast to low trait anxiety, no general slowdown was observed for high trait anxiety in the [CsC] block, nor in the [NsC] block. However, an emotional Stroop effect was observed that was limited to the studied negative words in the [NsC] block, indicating an attenuated proactive control due to the exposure to negative stimuli prior to the colour naming task.

In the current study, I attempted to generalise the results from the anxiety group to a group of substance users to examine the role of task conflict in addiction, using the PC-TC model since it is a novel way to look at addiction-related attentional bias. I happened to choose marijuana as substance-related stimuli as the use of marijuana is prominent among university students. In this experiment, the negative words from Experiment 7 were replaced with marijuana-related words. Participants study both marijuana-related and neutral words during the study phase followed by the test phase consisting of four blocks with different word categories: (1) a block of unstudied neutral words [C]; (2) a block of unstudied marijuana-related and neutral words, [MC]; (3) a mixed block of studied and unstudied neutral words, [CsC] and (4) a mixed block of studied marijuana-related and unstudied neutral words, [MsC]. This results in seven word categories, which are represented by the following labels: (note that letters within square brackets refer to the type of block and letters outside the square brackets refer to the type of word) [C]-C, [MC]-C, [MC]-M, [CsC]-C, [CsC]-Cs, [MsC]-C, [MsC]-Ms.

For non-users, I predicted a general slowdown for the studied [CsC] and [MsC] blocks compared to the unstudied neutral words [C]-C, reflecting the influence of task conflict from proactive control due to the priming effect. In addition, if priming with marijuana-related words activates a general marijuana schema, then I expected there also to be a slowdown for the [MC] block. That is, I hypothesised that the average response latencies of the [MC], [CsC] and [MsC] blocks would be longer than the baseline [C] block.

It is suggested that priming substance users with substance-related stimuli would lead to an increase in their craving for the substance (Field & Cox, 2008, for a review). According to the theory of current concerns (Cox et al., 2006; Field & Cox, 2008; Klinger, 1975, 1977, 1987, 1996; Klingers & Cox, 2004), when a substance user is in pursuit of a substance, the substance-related stimuli would become the focus of the substance user's attentional processing both explicitly and implicitly. In the PC-TC model, this could be considered as an increase in activation of the word reading task demand unit from top-down proactive control. Accordingly, for marijuana users, firstly in addition to a slowdown to the [CsC] block, I expected a slowdown in both of the [MC] and [MsC] blocks compared to the [C] block and the unstudied control words in the [CsC], [MC] and [MsC] blocks (i.e., [CsC]-C, [MC]-C and [MsC]-C) would be slower than those in the baseline [C] block. Secondly, marijuana-related words would show longer response latencies than neutral words in the [MsC] block as well as the [MC] block due to the exposure to marijuana-related words during the study phase. Thirdly, I predicted that the unstudied control words (C) in the [MsC] block would be longer than those in the [MC] block as a result of studied words due to the episodic memory effect (i.e., RT for [MsC]-C > RT for [MC]-C).

Furthermore, for both the user and non-user groups, if there is any effect of reactive control due to task conflict within the [MC], [CsC] or [MsC] block, as evidenced by Sharma (2018), the PC-TC model predicts a reversed sequential modulation effect in which marijuana-related words would be slowed down when preceded by marijuana-related words compared to neutral control words (trial MM vs. trial CM or trial MsMs vs. trial CMs) and a slowdown for studied neutral words when preceded by studied neutral words compared to unstudied neutral words (trial CsCs vs. trial CCs). Whereas if there is any reactive control effect resulting from response conflict, the PC-TC model predicts a sequential modulation effect: shorter response latencies for two consecutively presented marijuana-related words compared to a marijuana-related word after a neutral control word (trial MM vs. trial CM or trial MsMs vs. trial CMs), or faster colour-responding to two successively shown studied neutral words compared to a studied neutral word after an unstudied neutral word (trial CsCs vs. trial CCs).

Method

The general methodology (design, apparatus, and procedure) was similar to that in Experiment 7 in all respects except the following changes.

Participants

Ninety-six native English-speaking students from the University of Kent took part in this study in exchange for course credits. The sample consisted of 65 females and 31 males, aged 18-24, mean age of 20.21 (SD = 1.52). Based on a pre-screen questionnaire, participants were divided into two groups, 48 marijuana users and 48 non-users. Participants who answered that they still smoke marijuana either daily, weekly, monthly or yearly were assigned to the marijuana user group, while those who answered that they have never smoked marijuana or no longer smoke marijuana were assigned to the non-user group (See Table 6.8.1). All of the participants were treated in accordance with the ethical standards of British

Psychological Association and ethical approval was provided by the School of Psychology Ethics committee at the University of Kent.

Table 6.8.1

Initial questionnaire containing 15 questions regarding drug and alcohol use

Questions
1. Have you ever drunk alcohol? (Yes, No)
2. If yes, do you still drink alcohol? (Yes, No, Not applicable)
3. If you do still dink alcohol, how often do you drink it? (Daily, Weekly, Monthly, Yearly, No applicable)
4. Have you ever smoked cigarettes? (Yes, No)
5. If yes, do you still smoke cigarettes? (Yes, No, Not applicable)
6. If you do still smoke cigarettes, how often do you smoke them? (Daily, Weekly, Monthly, Yearly, No applicable)
7. Have you ever smoked marijuana? (Yes, No)
8. If yes, do you still smoke marijuana? (Yes, No, Not applicable)
9. If you do still smoke marijuana, how often do you smoke it? (Daily, Weekly, Monthly, Yearly, No applicable)
10. Have you ever used cocaine? (Yes, No)
11. If yes, do you still use cocaine? (Yes, No, Not applicable)
12. If you do still use cocaine, how often do you use it? (Daily, Weekly, Monthly, Yearly, No applicable)
13. Have you ever used ecstacy? (Yes, No)
14. If yes, do you still used ecstacy? (Yes, No, Not applicable)
15. If you do still use esctacy, how often do you use it? (Daily, Weekly, Monthly, Yearly, No applicable)

Design

A 7 × 2 mixed factorial design was employed. Word category ([C]-C, [MC]-C, [MC]-M, [CsC]-C, [CsC]-Cs, [MsC]-C, [MsC]-Ms) was the within-subject factor, and Marijuana user group (user, non-user) was the between-subject factor. The dependent variable was the mean correct response latency to respond to the ink colour of the word.

Materials

Forty marijuana-related words were selected from an online website (Smoking with Style, 2015) and divided into two sets of 20 words. One hundred twenty neutral words were chosen from the English Lexicon Project (Balota et al., 2007) and separated into six sets of 20 words (see Table 6.8.2). Each word set consisted of an equal number of 4, 5, 6, 7 and 8 letter words, which were matched for word frequency (average Log frequency HAL of 8.47), which was at the midrange for the collection of words (Range 0–17) (Balota et al., 2007).

Table 6.8.2

Word lists used in Experiment 8

Word lists							
Marijuana	Marijuana	Control	Control	Control	Control	Control	Control
dope	bong	malt	wary	hale	yawn	drip	tile
deal	high	ones	mint	mike	next	keep	fact
food	cash	song	held	base	bank	sign	link
drug	draw	town	lord	edge	legs	jump	fill
herb	buzz	peer	foul	dire	hive	arch	guts
burn	blow	disc	fell	quit	dumb	diet	cuts
hash	leaf	foam	mama	neon	ties	guru	cops
roach	zoned	cooks	unfit	manly	dunce	prude	boron
skunk	baggy	hiked	irate	clung	bloke	grins	flask
stash	fatty	pupil	sable	skits	groin	hawks	wager
blunt	baked	shrug	gangs	blurb	whack	stain	knots
ounce	faded	pains	coats	azure	rival	glove	bravo
tired	smoke	steps	organ	crash	asian	enemy	feels
joint	scale	trees	stack	goals	clock	boxes	bible
blazed	reefer	bloods	beheld	debuts	tennors	plough	conned
fluffy	stoned	subdue	scenic	clumsy	misuse	lineup	govern
wasted	hungry	triple	invite	assign	pirate	brazil	flower
tobacco	circles	enhance	happily	pending	obscure	foolish	blessed
medicine	pleasure	violence	electric	becoming	reliable	millions	conflict
paranoid	cannabis	acoustic	weakness	stranger	intimate	feasible	covenant

Results

Data preparation

Three participants' data were removed from the analysis: two were due to high error rates (No. 18 with 34.1% & No. 58 with 17.2%) and one (No. 62) had long average response latencies that were above 2.5 standard deviation. Moreover, first five participants' data were not included in the analysis due to a technical issue where their responses were not recorded (No. 1, No. 2, No. 3, No. 4, No. 5). The error rate of the remaining 88 participants (Marijuana user: N = 46; Non-user: N = 42) was 4.20%. Prior to the analysis of the mean correct response latencies, the first trial of each block and trials with a RT less than 200ms and larger than 3,000ms, which was 5.1% of the trials, were excluded.

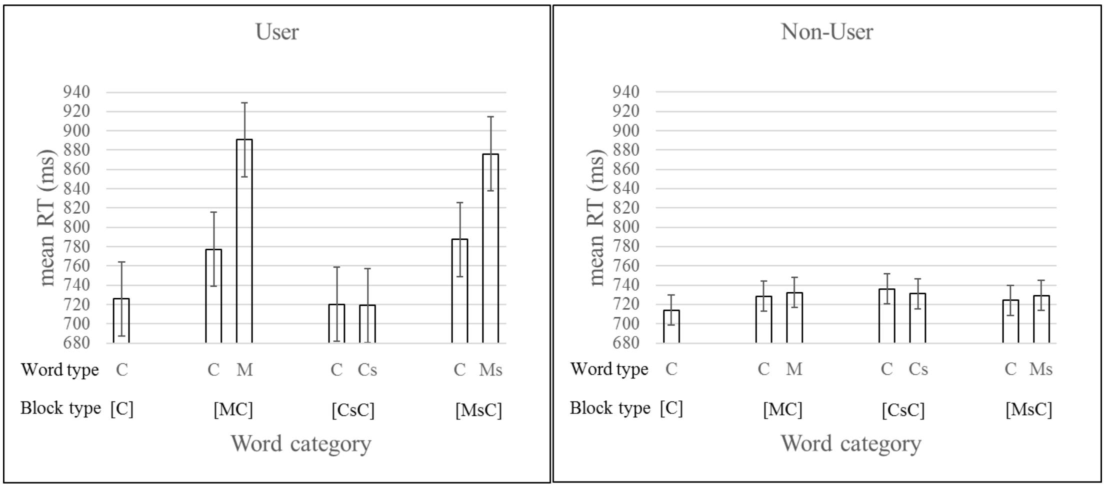
Analysis of response latencies

The first analysis was executed on the mean correct reaction time, using a 7 × 2 two-way mixed analysis of variance (ANOVA), with Word category ([C]-C, [MC]-C, [MC]-M, [CsC]-C, [CsC]-Cs, [MsC]-C, [MsC]-Ms) as the within-subject factor, and Marijuana user group (user, non-user) as the between-subject factor. Greenhouse-Geisser corrected values were reported when Mauchly's sphericity test was violated.

The analysis revealed a significant main effect of Word category, $F(2.17, 186.67) = 11.67$, MSe = 28766.63 , $p < .001$, $\eta p^2 = .119$, demonstrating that participants were slowest when responding to [MC]-M (M = 811.55ms, SE = 22.95) and were fastest when responding to [C]-C (M = 720.00ms, SE = 12.84). A main effect of Marijuana user group was also significant, $F(1, 86) = 5.03$, MSe = 100391.44 , $p = .028$, $\eta p^2 = .055$, illustrating that marijuana users (M = 785.31ms, SE = 17.66) were generally slower than non-users (M = 728.00ms, SE = 18.48). There was also a significant 2-way interaction between Word category and Marijuana user group $F(2.17, 186.67) = 10.78$, MSe = 28766.63 , $p < .001$, $\eta p^2 = .111$. I looked into the interaction and found a simple main effect of Word Category that was significant for the user group $F(1.85, 83.30) = 13.86$, MSe = 56693.47, $p < .001$, $\eta p^2 = .235$ but not for the non-user group $F(2.40, 98.36) = .80$, MSe = 6580.51, $p = .473$, $\eta p^2 = .019$ (see Figure 6.8.1).

Figure 6.8.1

Mean correct reaction times for the marijuana user and non-user groups in each Word category.



Note. Error bars represent the 95% confidence interval adjusted for the within-subject design, calculated separately for the marijuana user and non-user groups (Masson & Loftus, 2003). C, neutral word; M, marijuana-related word; s, word is studied.

Further analysis of the 2-way Word category × Marijuana user group interaction involved planned comparisons. First, for the marijuana user group, I found that the latencies of marijuana-related words were longer compared to unstudied control words within blocks [MsC], $F(1, 45) = 8.48$, MSe = 21338.88, $p = .006$, $\eta p^2 = .158$, and [MC], $F(1, 45) = 12.70$, MSe = 23405.96, p = .001, ηp^2 = .220, indicating an attentional bias towards marijuana-related words. The addiction attentional bias in these two blocks did not differ from each other, suggesting that the addiction attentional bias was driven by activating a schema. There was no marijuana-related attentional bias for the non-user group in the [MsC] block, $F(1, 41)$ = .590, MSe = 866.92, p = .447, ηp^2 = .014, nor in the [MC] block, $F(1, 41)$ = .536, MSe = 568.15, p = .468, ηp^2 = .013.

Second, I looked for evidence for task conflict from proactive control across the blocks. For the non-user group, I asked if the mean response latencies for all other blocks were longer than the baseline [C] block. This was significant ([MC] + [CsC] + [MsC] vs. [C], $F(1, 41)$ = 4.20, MSe = 1297.39, p = .047, ηp^2 = .093). Note that when comparing the [C] block with each of the other three blocks, the difference was only significant for the [MC] block, but not for the [CsC] block, nor for the [MsC] block ([MC] vs. [C], $F(1, 41)$ = 6.19, p = .017, ηp^2 = .131; [CsC] vs. [C], $F(1, 41)$ = 2.75, p = .105, ηp^2 = .063; [MsC] vs. [C], $F(1, 41)$ = 1.13, p = .293, ηp^2 = .027) although the [MC] block did not differ from the [CsC] block, nor from the [MsC] block ([MC] vs. [CsC], $F(1, 41)$ = .07, p = .797, ηp^2 = .002; [MC] vs. [MsC], $F(1, 41)$ = .07, p = .791, ηp^2 = .002).

For the user group, I examined whether there was a slowdown in the [MC], [CsC] and [MsC] block compared to the baseline [C] block. This was significant for the [MC] and [MsC] blocks, but not for the [CsC] block ([MC] vs [C], $F(1, 45)$ = 17.52, $p < .001$, ηp^2

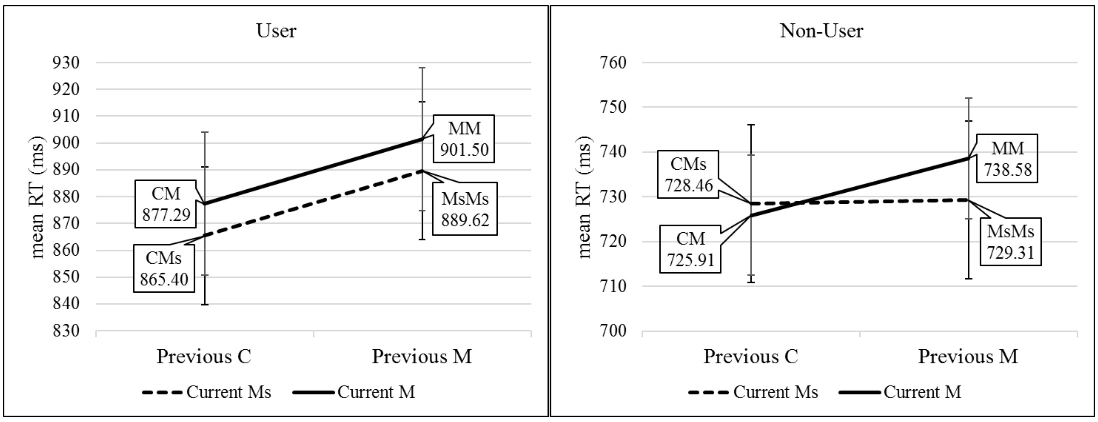
= .280; [MsC] vs [C], $F(1, 45) = 18.70$, $p < .001$, , $\eta p^2 = .294$; [CsC] vs [C], $F(1, 45) = .42$, $p = .521$, $\eta p^2 = .009$). Moreover, the unstudied neutral control words in the [MC] and [MsC] blocks were significantly longer than those in the baseline [C] block ([MC]-C vs. [C], $F(1, 45) = 14.35$, $p < .001$, $\eta p^2 = .242$; [MsC]-C vs. [C], $F(1, 45) = 21.23$, $p < .001$, $\eta p^2 = .321$). These findings suggest that for marijuana users, marijuana-related words tend to slow down the blocks with marijuana-related words regardless of whether they are studied or unstudied, whereas studied neutral words do not slow colour-responding, which could be due to activating a schema that was for marijuana-related words but not for studied neutral words (at least implicitly because the recall results do indicate a better recall for studied neutral words than unstudied neutral words). Further, I compared the unstudied neutral control words in the [MC] block and those in the [MsC] block, however, the difference was not significant ([MC]-C vs. [MsC]-C, $F(1, 45) = .48$, $p = .494$, $\eta p^2 = .010$).

To investigate whether there was task conflict from reactive control due to priming, I conducted a series of planned comparisons within the [MC], [CsC] and [MsC] blocks. For the [CsC] and [MsC] blocks, I questioned whether studied words showed longer response latencies when preceded by studied words compared to unstudied words (i.e., trial CsCs vs. trial CCs or trial MsMs vs. trial CMs). For the [MC] block, I examined whether two consecutively presented marijuana-related words took longer to respond to compared to marijuana-related words preceded by unstudied neutral control words (i.e., trial MM vs. trial

CM). For the user group, there was a marginally significant reversed sequential modulation effect in the [MsC] block, $t(45) = 1.90$, $p = .065$, and in the [MC] block, $t(45) = 1.83$, $p = .074$, but not in the [CsC] block, $t(45) = 1.43$, $p = .161$. For the non-user group, a marginally significant reversed sequential modulation effect was found in the [MC] block, $t(41) = 1.91$, $p = .063$, but not in the [CsC] block, $t(41) = .61$, $p = .543$, nor in the [MsC] block, $t(45) = .10$, $p = .923$ (see Figure 6.8.2).

Figure 6.8.2

Showing the reversed sequential modulation effect within block [MC] (trial CM vs. trial MM) and block [MsC] (trial CM vs. trial MsMs) for the marijuana user and non-user groups.



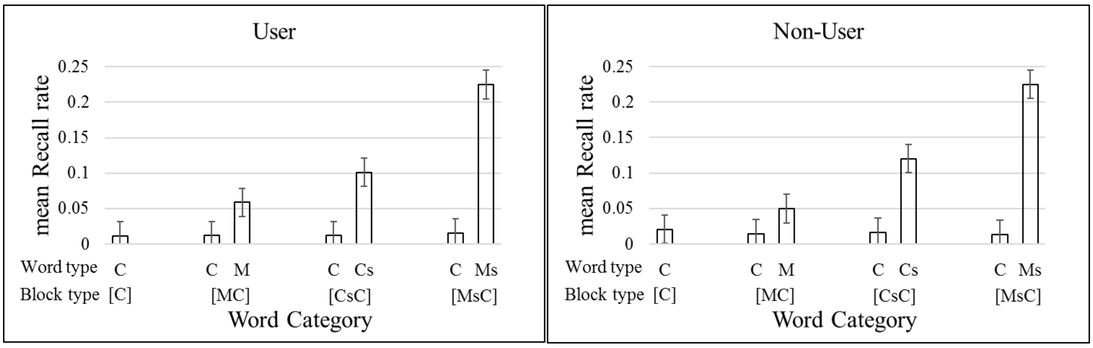
Note. Error bars represent the 95% confidence interval for the difference between two paired means, computed separately for the effects within block [MC] and block [MsC] (Pfister & Janczyk, 2013). C, neutral word; M, marijuana-related word; s, word is studied.

Analysis of Recall phase

A 7 × 2 mixed ANOVA was conducted with Word category (C]-C, [MC]-C, [MC]-M, [CsC]-C, [CsC]-Cs, [MsC]-C, [MsC]-Ms) as the within-subject factor, and Marijuana user group (user, non-user) as the between-subject factor. The results revealed a significant main effect for Word category $F(2.98, 256.14) = 118.67$, MSe = .009, $p < .001$, $\eta p^2 = .580$, but not for Marijuana user group $F(1, 86) = .553$, MSe = .003, $p = .459$, $\eta p^2 = .006$, nor for the interaction between Word category and Marijuana user group, $F(2.98, 256.14) = .371$, MSe = .009, $p = .773$, $\eta p^2 = .004$. Mean recall rates for studied words [MsC]-Ms (M = 0.23), [CsC]-Cs (M = 0.11) and [MC]-M (M = 0.05) are significantly higher than other word categories, all t's > 4.58, p's < .001 (see Figure 6.8.3). Moreover, mean recall rate was significantly higher for [MsC]-Ms (M = 0.23) than [CsC]-Cs (M = 0.11), $t(87) = 7.69$, $p < .001$ and [MC]-M (M = 0.05), $t(87) = 10.63$, $p < .001$, and higher for [CsC]-Cs (M = 0.11) than [MC]-M (M = 0.05), $t(87) = 3.90$, $p < .001$.

Figure 6.8.3

Mean recall rate for the marijuana user and non-user groups in each Word category.



Note. Error bars represent 95% confidence interval adjusted for the within-subject design, calculated separately for the marijuana user and non-user groups (Masson & Loftus, 2003). C, neutral word; M, marijuana-related word; s, word is studied.

Discussion

The memory results illustrated that: (a) There was no difference between marijuana users and non-users; (b) The recall rate was higher for studied words than unstudied words as a result of the priming effect, which was consistent with findings from Experiment 7; (c) Studied marijuana-related words had a higher recall rate than studied neutral control words; (d) Higher recall rate for unstudied marijuana-related words, [MC]-M, than other unstudied words suggested an activated general marijuana schema.

The recall data indicated that the two groups behaved similarly on the explicit memory. However, the findings from the Stroop test indicated a different pattern for the two groups on the implicit memory. For the marijuana user group, there are three main findings. First, I did not find a slowdown in the [CsC] block compared to the [C] block. However, there was evidence of a slowdown for the neutral control words in the [MC] and [MsC] blocks compared to those in the baseline [C] block. This indicates effects of task conflict from top-down proactive control, which could be explained by the theory of current concerns (Cox et al., 2006; Field & Cox, 2008; Klinger, 1975, 1977, 1987, 1996; Klingers & Cox, 2004) that marijuana users engaged in looking for the marijuana-related stimuli after being primed with marijuana-related words during the study phase. As a result and despite being asked to ignore words and pay attention to colours, the attentional resources were allocated to attend to the words. In the PC-TC model, this could be accounted for as a strengthened top-down proactive activation of the word reading task demand unit, causing a competition between the word reading task and the colour naming task, thereby slowing down both neutral control and marijuana-related words in the [MC] and [MsC] blocks. However, contrary to my prediction that the unstudied neutral control words in the [MsC] block were not longer than those in the [MC] block, suggesting that the effect of studied marijuana-related words did not differ from that of unstudied marijuana-related words. This maybe be due to an effect of semantic memory association or more generally activating a schema for marijuana-related words. It is possible that priming a marijuana word could result in producing other semantically associated marijuana words in mind, thereby implicitly priming marijuana-related words that were not presented during the study phase (Rooke, Hine & Thorsteinsson, 2000). On the other hand, priming neutral words did not activate a schema for neutral words among marijuana users, resulting in no effect of studied words slowing down the [CsC] block. Note that in the explicit recall task, marijuana users demonstrated a higher recall rate for studied neutral words than unstudied neutral words.

Second, attentional biases towards marijuana-related words were observed in both of the [MsC] and [MC] blocks. This suggests a priming effect in which marijuana users became vigilant to marijuana-related words regardless of whether the words were studied or unstudied after the exposure to marijuana-related words during the study phase. This is also consistent with findings of other studies using the addiction Stroop task suggesting that marijuana users display attentional bias towards marijuana-related words compared to non-users. (Cousijn et al., 2013; Field, 2005; Field & Cox, 2008). Further, this attentional bias also indicated a shift in attentional control between proactive and reactive processes. In the PC-TC model, if the proactive activation to the word reading task demand unit remains strong, the model predicts a general slowdown to both marijuana-related and neutral control words in both the [MsC] and [MC] blocks. Accordingly, attentional bias towards marijuana-related words would not be observed. The shift in the balance of control is supported by the finding of the trial-by-trial effect that is going to be discussed in the following paragraph.

Third, for the marijuana user group, the marginally significant reversed sequential modulation effects found in both the [MC] and [MsC] blocks suggested a tendency that marijuana-related words took longer to respond to when preceded by marijuana-related words compared to neutral control words. This is consistent with the finding by Sharma (2018), and supports a reactive control mechanism that results from task conflict. Alternatively, there is also the possibility that the slowdown for the two consecutively presented marijuana words was due to response conflict rather than task conflict. Cane, Sharma and Albery (2009) reported a slow effect among marijuana users in which control words took longer to respond to when preceded by marijuana words compared to control words. Based on Wyble et al.'s model of adaptive attentional control, the presence of a marijuana-related word could have weakened the top-down cognitive control, leading to less attentional resources for the processing of the subsequent trial which results in the slow effect. If this is the case, a marijuana-related word would slow down a marijuana-related word as well as a neutral control word on the next trial compared to a neutral control word preceded by a neutral control word (i.e., trial MC vs. trial CC). I checked for this slow effect and found some evidence in the [MC] block, $t(45) = 2.61$, $p = .012$, but not in the [MsC] block, $t(45) = 1.74$, $p = .090$. In general, these results support evidence for interference from marijuana-related words being due to task conflict rather than response conflict.

For the non-user group, there are two main findings. First, the slowdown for the average of [MC], [CsC] and [MsC] blocks compared to the baseline [C] block provided further evidence for the existence of task conflict from proactive control. When looking into each block, the general slowdown was only observed in the [MC] block but not in the [CsC] and [MsC] blocks. Although the marijuana-related words in the [MC] block were unstudied, they slowed down the neutral control words within the block, showing an effect of task conflict from proactive control. This indicates that studying marijuana-related words could activate a general marijuana schema for marijuana non-users in which when engaging in the colour naming task, the non-users might have noticed that there was a group of words that belonged to the marijuana-related words they had seen during the study phase. The activated general marijuana schema was also supported by the explicit recall data in which non-users significantly recalled more unstudied marijuana-related words than other unstudied neutral control words. In the PC-TC model, this could be considered as the activation of proactive control to the word reading task demand unit due to activating episodic memory, resulting in task conflict. On the other hand, I did not find any slowdown in the [CsC] block nor in the [MsC] block. However, based on the findings of Sharma (2018), and my previous findings (i.e., Experiment 1, 3 and 7) where blocks with studied words generally showed longer response latencies compared to blocks without studied words, I consider that this could be due to the power issue.

Second, a marginally significant reversed sequential modulation effect was found in the [MC] block, suggesting that non-users tended to slow down when seeing two consecutively shown marijuana-related words compared to a marijuana-related word after a neutral control word. This provides evidence for reactive control effect due to task conflict. I checked whether there was a slow effect in the [MC] block, and the result was in line with a finding by Cane, Sharma and Albery (2009) in which non-users did not show any slow effect.

In conclusion, the findings of Experiment 8 provide evidence that the design of study-test procedure can be used to investigate the selective attention not only for anxiety but also for addiction. In the explicit recall task, there was no difference in memory performance between marijuana users and non-users in which both groups recalled more marijuana-related words and studied neutral control words than other unstudied neutral control words. Whereas in the implicit Stroop task, for the user group, priming with marijuana-related words resulted in a slowdown in the blocks with marijuana-related words compared to the baseline block with unstudied neutral words which was an indicator of task conflict from proactive control. In addition, the attentional bias towards marijuana-related words could be attributed to task conflict resulting from a reactive activation of the word reading task demand unit. For the non-user group, studying marijuana-related words led to a general slowdown that was due to activating a general marijuana schema.

Section 4: General Discussion

Summary of findings

Table 7.1 below summarises the presence and absence of three key effects (i.e., PC, Reversed sequential modulation and Block half) across eight experiments.

Table 7.1

Summary of the presence/absence of key effects across 8 experiments

Experiment\Effect		PC	Reversed sequential modulation	Block half
Exp 1	10 words	○	×	×
Exp 2	30 words	×	×	×
Exp 3	10 and 30 words	○	○	○
Exp 4	Within-subject	○	×	○
Exp 5	Between-subject	○	×	×
Exp 6	Between-subject	○	×	×
Exp 7	Low anxiety	○	×	×
	High anxiety	×	○	×
Exp 8	Non-user	○	○	×
	User	○	○	×

Note. The presence and absence of effects are represented by the symbols ○ and ×, respectively.

Across three experiments in Chapter 4, I attempted to investigate whether the magnitude of task conflict from proactive control (i.e., $RT_{mixed\ block} - RT_{pure\ block}$) can be affected by the level of the working memory load (i.e., the number of studied words). In comparison with the 20 studied words employed by Sharma (2018), the number of studied words I used was 10 for the low working memory load condition and 30 for the high working memory load condition. As expected for the explicit memory recognition task, participants in the low load condition recognised more studied words than those in the high load condition;

for the implicit Stroop colour naming task, although statistically there was no significant difference in the amount of task conflict from proactive control between the low and high load conditions, the results demonstrated a tendency in which the more studied words and the more number of trials in the test blocks, the less effect of priming and the smaller amount of task conflict. I also set out to find evidence of task conflict from reactive control (i.e., attentional bias towards studied words, $RT_{studied} - RT_{unstudied}$, or the reversed sequential modulation effect, trial CCs vs. trial CsCs) and I observed the effects in Experiment 3 which took place in the first half of the mixed block, differing from the pattern reported by Sharma (2018) where the effect of reactive control arose in the second half of the mixed block.

Across three experiments in Chapter 5, I aimed to explore whether the amount of task conflict from proactive control (i.e., $RT_{word} - RT_{non\text{-}word\ rectangle}$) could be affected by the proportion of non-word rectangle stimuli relative to word stimuli, which was manipulated in the two test blocks where one was the 75/25 block that consisted of 75% of rectangle trials and 25% of word trials, and the other was the 25/75 block which was composed of 25% of rectangle trials and 75% of word trials. My findings illustrated that for the explicit memory recognition task, more studied words were identified by the studied block group relative to the unstudied block group; for the implicit Stroop colour naming task, the performance did not differ between the studied block and unstudied block groups. Through the three experiments, a larger amount of task conflict from proactive control in the 75/25 block than the 25/75 block was repeatedly observed. The observation of the change in the magnitude of task conflict between two blocks was attributed to the rectangles that slowed down in the 25/75 block compared to the 75/25 block and the words that remained the same in RT over the two blocks. No evidence of the reversed sequential modulation effect was found in Chapter 5.

Across two experiments in Chapter 6, I set out to examine whether the finding of task conflict by studied neutral words can be generalised to studied salient words – negative emotional words for Experiment 7 and marijuana-related words for Experiment 8. My findings demonstrated that for the explicit memory recall task, there was no difference between the low and high anxiety groups in Experiment 7 and between marijuana non-users and users in Experiment 8 where all of the participants showed higher recall rates for studied words than unstudied words and for salient words than neutral words. For the implicit Stroop colour naming task in Experiment 7, the low anxiety group's responses to studied negative words were similar to their responses to studied neutral words where blocks with studied words were slower compared to the baseline block of unstudied neutral words, replicating the finding of task conflict from proactive control in Chapter 4 and Sharma (2018). However, no evidence of task conflict from reactive control was revealed among participants with low anxiety. On the contrary, for the high anxiety group, there was no effect of task conflict from proactive control in which studied words did not slow down the responses to blocks with studied words. But, participants with high anxiety exhibited an attentional bias towards studied negative words and a reversed sequential modulation effect, showing the effect of task conflict from reactive control. For the implicit Stroop colour naming task in Experiment 8, marijuana non-users' responses were faster for the baseline block of unstudied neutral words than their responses to the average of all other three blocks, reproducing the observation of task conflict from proactive control in Chapter 4 and Sharma (2018). On the other hand, marijuana users' responses were slower for blocks with marijuana-related words regardless of whether the words were studied or unstudied compared to the baseline block, implying that there was an effect of proactive activation to word reading. In addition, within the blocks with marijuana-related words, users displayed hypervigilance to marijuana-related words and marginally significant reversed sequential modulation effects, indicating the effect of task conflict from reactive control.

The concepts of priming, working memory, episodic memory, their cognitive processes and proactive control to word reading

Before discussing the implications, I first clarify the concepts of priming, working memory, episodic memory used in the thesis and their distinct contributions in cognitive processes. In the last paragraph of this section, a rationale for the use of proactive control to word reading within the framework of the PC-TC model was provided.

First, *priming* is a technique to investigate the implicit memory where the processing of a prime is shown to have an impact on a response to a subsequent target. Priming can exert an impact on a response because the processing of a prime makes the information relevant to the target in memory become accessible. As a result, the chance the prime comes into consciousness increases upon perceiving a target. Moreover, the prime has a higher chance to affect a response to a target in a context where the target is related to the prime than in a context in which the target is unrelated to the prime (see Janiszewski & Wyer, 2014; Jones & Estes, 2012; Kristjánsson & Campana, 2010, for reviews). Second, *working memory* refers to a capacity-limited storage that allows us to temporarily hold information (e.g., a limited number of recent events and thoughts) while carrying out ongoing cognitive tasks (for a review see Chai, Abd Hamid & Abdullah, 2018; Cowan, 2014). Third, *episodic memory* refers to our ability to recollect personally experienced events that are exclusive to ourselves in terms of the event contexts, such as its location and the time it occurred (Mayes & Roberts, 2001; Rugg, Johnson & Uncapher, 2015; Rugg & Wilding, 2000; for a review see Tulving, 2002).

In my experiments, the priming technique was applied where in the prime phase participants were instructed to study a set of words for a subsequent test with a self-referencing method to boost their memory performance (Leshikar, Dulas & Duarte, 2015; Serbun, Shih & Gutchess, 2011). Studying words was expected to elicit two memory activities – an activity associated with working memory encoding and retention, and an activity linked with episodic memory formation. Brain imaging studies have found overlap in the brain regions (e.g., dorsolateral prefrontal cortex and medial temporal lobe) involved in encoding and recognition processes in working memory and episodic memory (Cabeza, Dolcos, Graham & Nyberg, 2002; Cabeza & Nyberg, 2000; Ranganath, Cohen & Brozinsky, 2005; Ranganath, Johnson & D'Esposito, 2003). Moreover, evidence suggests that the processing of information in working memory has an impact on episodic memory formation, for example, the formation of episodic memory can be weakened if the retention of information is disrupted at the beginning of working memory processing (Ranganath, Cohen & Brozinsky, 2005) or if the amount of information that requires to be maintained in working memory is large (i.e., high working memory load) (Axmacher et al., 2009). Whereas episodic memory formation can be improved by increasing the amount of time for attending to and processing information in working memory (Souza & Oberauer, 2017), or by enhancing associations between the elements of information held in working memory (Bartsch, Singmann & Oberauer, 2018; Blumenfeld & Ranganath, 2006). Accordingly, the self-referencing method applied in the prime phase would allow participants to elaborate the words in working memory, thereby strengthening the formation of episodic memory. After studying each word, participants had to hold the studied words in working memory across the prime and test phases. These studied words were then mixed with a set of unstudied words and were presented in the following test phase – the Stroop colour naming task where participants were required to identify the ink colours of word stimuli, which was an implicit memory task where intentional recollection of previously studied words was not instructed (Graf & Schacter, 1985; Schacter, 1992). However, in the presence of a Stroop stimulus, explicit memory processes could be involved if a) participants recognised that the currently presented word was the one they had recently attended to and memorised; b) participants recalled the study episode where they committed memorizing the word by rehearsing it or by referring it to themselves that included external perception of the word stimulus (e.g., how the word looked or sounded) and internally generated associations (e.g., their feelings and thoughts about the word). If the episodic memory of the study event was triggered, the proactive processes of the word reading task could be activated. Despite the task goal was to respond to the ink colours, it is possible that participants proactively turned their attention to the goal-irrelevant words which would lead to a task competition between the colour naming and word reading tasks, thus slowing down colour-responding to both studied and unstudied words (Monsell et al., 2001; Rogers & Monsell, 1995; Waszak, Hommel, & Allport, 2003).

To account for the general slowdown to studied and unstudied words, I resort to the PC-TC model of Kalanthroff et al. (2015) where conflict can occur in the task demand layer by activating the word reading task demand unit in a proactive mechanism, which leads to a competition between the word reading and colour naming task demand units (see Figure 6.7.1). In line with Sharma (2018), I refer this proactive mechanism to the *proactive control to word reading* which is a notion that participants direct their attention to the task-irrelevant word dimension prior to the Stroop stimulus presentation in contrast to the *proactive control to colour naming* which is a control process that helps participants to attend to the task-relevant colour dimension of Stroop stimuli in a preparatory fashion. Although contrasting with the concept of cognitive control where the proactive control to word reading introduces a processing cost (i.e., slower colour-responding) rather than a processing benefit (i.e., faster colour-responding), it provides an alternative point of view to comprehend that in the PC-TC model not only can the colour naming task demand unit be activated proactively, but also can the word reading task demand unit be activated in a proactive way. Thus, the proactive control to word reading is used to predict and interpret the findings through the thesis.

Chapter 4: Task conflict and the effect of number of studied words (working memory load)

Studies of working memory (WM) load suggest that WM load consumes attentional resources for the cognitive control to maintain the focus on ongoing tasks. As a result, in Stroop-like tasks, when the load of WM is high compared to low, performance is more likely to be disrupted by information from the task-irrelevant dimension of the stimulus, resulting in greater interference when responding to incongruent stimuli than congruent stimuli (de Fockert et al., 2001; Lavie, Hirst, De Fockert & Viding, 2004; Lavie & de Fockert, 2005; Pratt, Willoughby & Swick, 2011). In the connectionist models, this could be implemented by inhibition of the conflict monitoring unit which would lead to an attenuated proactive activation of the ongoing task demand unit, thereby enabling distractor information to have more influence on the performance. Kalanthroff et al. (2015) employed the WM load manipulation in the colour word Stroop task and reported the finding of larger Stroop interference and a reversed facilitation effect where the response latencies were longer for congruent trials than non-word neutral trials (i.e., task conflict) when the WM load was high. Kalanthroff and his colleagues suggested that this finding can be implemented in the PC-TC model (see Figure 6.7.1) as a reduced proactive activation of the colour naming task demand unit in the high WM load condition, allowing the activation of word input units to activate the word reading task demand unit in a reactive mechanism.

In Chapter 4, I examined whether the number of studied words (i.e., the level of WM load) has any effect on the amount of task conflict from proactive control (i.e., $RT_{mixed\ block} - RT_{pure\ block}$). In the study, 10 studied words were used for the low load condition, while 30 studied words were used for the high load condition. I expected there to be task conflict arising in a proactive mechanism in both the two conditions, and the amount of conflict would be larger in the low load condition than the high load condition. This is because using a larger studied word set might result in a dilution of the priming effect for the studied words since there were more words to be held in WM, thus reducing the saliency of each studied word. As expected, the results demonstrated that the performance on the explicit memory recognition task was better for the low load condition than the high load condition. As for the implicit Stroop task, contrary to my prediction, there was no significant difference in the amount of task conflict between the two conditions. However, there was a tendency for the amount of task conflict to be larger in the low load condition compared to the high load condition (see Figure 4.3.3 and 4.3.4).

It could be considered that the non-significant manipulation of the WM load (10 versus 30) was due to the numbers of studied words used in both experimental conditions which were larger than the typical limit of WM capacity. Studies of WM capacity suggest that the capacity is limited to around three to four items (Adam, Vogel & Awh, 2017; Luck & Vogel, 1997; Vogel, Woodman & Luck, 2001; Zhang & Luck, 2008), four items (for reviews see Cowan, 2001, 2005; Saults & Cowan, 2007; Sperling, 1960), or seven items (Miller, 1956, 1994; Pascual-Leone, 2001). But, the findings of the limit (i.e., 3, 4, or 7 items) were obtained from measures that differ from the design of Chapter 4. Firstly, WM capacity measured in these studies reflects a central storage which in the theoretical framework can be referred to the focus of attention (Cowan, 1988, 1995, 1999), or the episodic buffer (Baddeley, 2000, 2001; Baddeley, Allen & Hitch, 2011) (see Cowan, 2001, 2005; Baddeley, 2007; Logie, Camos & Cowan, 2020, for reviews). The studies gauged the limit of central storage by displaying a number of items all at once on a memory trial before an upcoming test trial. Importantly, variables that would help to enrich representations of the items in WM during the interval between the end of the presentation of items and the test trial were controlled for. As a result, strategies that could be employed to enhance memory performance such as rehearsal, chunking, grouping or the use of sensory information about how a stimulus looked, sounded, smelled, or felt like were prevented. On the contrary, in Chapter 4's design, on each memory trial only one word was shown at a time. Also, immediately after the presentation of each studied word a five-point Likert scale was provided for participants to judge how strong the studied word was relevant to themselves, which stayed on the screen until participants made a response. In such a way, participants were able to elaborate their memory representations of studied words by rehearsing the words and/or using sensory information to establish links between the studied words and existing semantic networks in long-term memory, encoding richly detailed memories of studied words (Craik & Tulving, 1975; Leshikar, Dulas & Duarte, 2015; Serbun, Shih & Gutchess, 2011). Thus, in this design the limit of WM capacity is expected to go beyond the typical number (i.e., 3, 4 or 7 items). The design of Chapter 4 did not include a measure to gauge the number of studied words participants could recall, however, the recognition data did illustrate that in both of the 10-word and 30-word conditions participants were able to discriminate between studied words and unstudied words in which the performance was better for participants in the 10-word condition relative to those in the 30-word condition. Therefore, I suggest that the non-significant manipulation of WM load was not a result of the numbers of studied words (i.e., 10, 30) used in both conditions that were higher than the typical limit of WM (i.e., 3, 4, 7).

My findings indicated that studied words were able to interfere with colour-responding in the non-colour word Stroop task, and the magnitude of interference resulting from task conflict was liable to be larger when the number of studied words was smaller (rather than larger). In the PC-TC model, the effect of task conflict from studied words can be implemented as a proactive activation of the word reading task demand unit due to activating episodic memory, and the degree of the proactive activation tends to be affected by the number of studied words to be held in WM where the less studied words that are required to memorise, the stronger proactive control to the word reading task demand unit which leads to a stronger inhibition of the colour naming task demand unit.

In brief, my finding in Chapter 4 illustrated that in the non-colour word Stroop task using the study-test procedure, there was a tendency in which using 10 studied words produced more task conflict than using 30 studied words. I suggest that when looking for task conflict, the chance of observing task conflict from proactive control is higher when using a smaller number (compared to a larger number) of studied words.

Chapter 5: Task conflict and the proportion manipulation (non-word vs. word)

The proportion manipulation has previously been employed not only for studying the proportion congruent effect but also for investigating the task conflict in the colour word Stroop task and the non-colour word Stroop task. In the colour word Stroop task, Goldfarb and Henik (2007) and Kalanthroff et al. (2013) proposed that the Stroop facilitation effect (i.e., faster responses to congruent trials than neutral trials) is observed when the degree of top-down proactive control to colour naming is high. Because the stimulus-driven task conflict can be resolved rapidly by the strong proactive control to colour naming, the interference of word reading induced by congruent trials is unnoticeable. Goldfarb and Henik (2007) hypothesised that task conflict can become detectable when the top-down proactive control to colour naming is weak. To test the hypothesis, the proactive control to colour naming was weakened by applying the trial type cueing method and presenting neutral stimuli that do not activate word reading processes (e.g., letter strings) more often than the colour word stimuli in the test block. As predicted, with the reduced proactive control, task conflict revealed itself by the reversed facilitation effect (i.e., slower responses to congruent trials than neutral trials).

Following Goldfarb and Henik (2007) and Kalanthroff et al. (2013), Entel et al. (2015) replicated the finding of the reversed facilitation effect in the conditions when the proportion of non-readable neutrals (e.g., ####) was relatively high compared to that of colour words (e.g., 50/50 and 80/20). Moreover, it was found that the reversed facilitation effect diminished in the condition in which the proportion of non-word neutrals was lower relative to that of colour words (e.g., 20/80), providing evidence that task conflict can be modulated by the degree of proactive control to the colour naming task through the proportion manipulation. Note that the change in the magnitude of task conflict was due to the change in response latency for the congruent stimuli as response times for the neutral stimuli remained the same across all of the proportion manipulations.

Shichel and Tzelgov (2018) extended Entel et al.'s (2015) work by breaking down the Stroop effect into response conflict (response latency difference between two types of incongruent stimuli where one type had an identical response key for both the word distractor and its incompatible colour response, and the other type had two different response keys for the word distractor and the colour response), semantic conflict (RTs to congruent stimuli versus incongruent stimuli) and task conflict (RTs to non-readable non-word neutrals versus colour word stimuli), and tested whether any of the three conflict types can be influenced by the proportion manipulation. In terms of the task conflict, it was observed that the amount of conflict was greater in the high neutral condition (e.g., 75 % neutrals and 25% colour words) than the low neutral condition (e.g., 25% neutrals and 75% colour words). As it was observed in Entel et al. (2015), the proportion manipulation modulated the response latencies to colour word stimuli, but it did not have any impact on the neutral control stimuli.

In Chapter 5, I explored whether task conflict can be regulated by the proportion manipulation using the non-colour word Stroop task. In comparison with the task conflict in the colour word Stroop task where it is reflected by the reversed facilitation effect (i.e., the difference in RT between non-word neutrals and congruent colour words), task conflict from proactive control in Chapter 5 is defined as the response latency difference between non-word and word stimuli. I attempted to manipulate the proportion of non-readable rectangles versus readable non-colour neutral words and proposed that the proactive control to the colour naming task would be relatively high in the condition where the proportion of rectangles versus words was 25/75 compared to the 75/25 condition. Accordingly, I predicted that the latencies of word stimuli in the 25/75 condition would be faster than those in the 75/25 condition, whereas the latencies of rectangle stimuli would remain the same across the two conditions since they do not cause conflict, resulting in a larger amount of task conflict in the 75/25 condition relative to the 25/75 condition. The results showed that the amount of task conflict was consistently larger in the 75/25 condition compared to the 25/75 condition across three experiments, however, the words from the two conditions did not differ from each other throughout the three experiments (response latency difference between words of the 75/25 and 25/75 conditions: 20.79ms, 10.55ms and 10.62ms in Experiment 4, 5 and 6, respectively). This finding indicated that presenting word stimuli more frequently than non-word stimuli did not result in a tightened top-down proactive control to the colour naming task. In other words, the manipulation of the proportion of illegible rectangle stimuli relative to readable word stimuli did not trigger the control adaptation as it was observed in Goldfarb and Henik (2007), Kalanthroff et al. (2013), Entel et al. (2015) and Shichel and Tzelgov (2018). I suggest that the 75/25 and 25/75 proportion manipulation in Chapter 5 might have failed to activate the control adaptation in the non-colour word Stroop task or the word stimuli in the non-colour word Stroop task could be insensitive to the proportion manipulation. On the other hand, contrary to the word stimuli, the rectangle stimuli were faster in the 75/25 condition than the 25/75 condition in Experiment 5 and 6 (response latency difference between rectangles of the 75/25 and 25/75 conditions: 24.82ms and 17.58ms in Experiment 5 and 6, respectively). This result did not support the prediction and did not converge with the findings by Entel et al. (2015) and Shichel and Tzelgov (2018) where the colour-responding to neutral stimuli was not influenced by the proportion manipulation and remained the same across conditions. Based on the finding of Experiment 6, I suggest that this could be due to the sequential modulation effect that only occurred in the 75/25 condition in which responses to rectangle trials were faster when preceded by another rectangle trial than when preceded by a word trial (i.e., trial RR vs. trial WR), speeding up the responses to the rectangle stimuli in the 75/25 condition compared to the 25/75 condition. However, in light of Experiment 5's finding where I observed the sequential modulation effect in both conditions and the magnitude of the effect did not differ between the two conditions (24.31ms and 19.33ms for the 75/25 condition and the 25/75 condition, respectively), I cannot be certain that the latency difference for the rectangle stimuli between the two conditions was caused by the sequential modulation effect. An alternative explanation for the finding of faster responses for the rectangle stimuli in the 75/25 condition relative to the 25/75 condition could be the frequency effect where the more frequently a stimulus type appeared, the more the stimulus type became familiar and thereby it was faster to respond to. Whereas the less often the stimulus type displayed, the more uncommon it became and thus it took longer to respond to. This explanation, however, is inconsistent with the results of Goldfarb and Henik (2007), Kalanthroff et al. (2013) and Entel et al. (2015) which suggested that task conflict is not a consequence of the frequency effect but a result of the attenuated proactive control to colour naming.

It is possible that the speedup for rectangles in the 75/25 condition than the 25/75 condition was a consequence of ink colour repetition priming where colour-responding was likely to be faster when the same ink colour displayed on two consecutive trials. In my study, the ink colour repetition effect might have more impact on rectangle than word stimuli because all of the rectangles were identical in size. Thus, when the same ink appeared on two consecutive rectangle trials, it resulted in a complete stimulus-response repetition. Whereas when the same ink appeared on two word trials, the chance for the same ink to be paired with the same word was lower than the probability for the same ink to be paired with two different words. To test this assumption, I re-analysed Experiment 4, 5 and 6's data with repetition of ink colour removed from the analysis (on average, about 24.53% trials were excluded in each experiment) and examined whether the 2-way interaction between R/W proportion and Stimulus type was significant. The results indicated that (a) The 2-way R/W proportion × Stimulus type interaction remained significant across the three experiments (p = .055, p = .001 and p = .013 for Experiment 4, 5 and 6, respectively); (b) There remained no response latency difference for word stimuli between the 75/25 and 25/75 conditions throughout the three experiments; (c) The pattern for rectangle stimuli in Experiment 5 and 6 has become similar to that in Experiment 4. That is, in Experiment 5 and 6, the colour-responding for rectangle stimuli from the two conditions no longer differ from each other (p = .055 and p = .079 for Experiment 5 and 6, respectively). The re-analysis supported the assumption that the previous finding in which rectangle stimuli were faster to respond to in the 75/25 condition than the 25/75 condition was a result of the ink colour repetition priming. This also elucidated that the significant 2-way interaction was not attributed to the latency difference for rectangles between the two conditions. However, this still leaves us a question on whether it was task conflict or the frequency effect that led to the significant interaction. My data illustrated that the significant interaction was due to a non-significant decrease in response latency for words and a non-significant increase in response latency for rectangles in the 25/75 condition compared to the 75/25 condition.

In short, despite my findings of Chapter 5 which demonstrated a larger amount of task conflict in the 75/25 condition compared to the 25/75 condition, the proportion manipulation did not provide conclusive evidence that this was due to a change in the level of proactive control to colour naming. This conclusion is largely based on there being no response latency difference for word stimuli between the two proportion manipulation conditions, and therefore is inconsistent with the findings of Goldfarb and Henik (2007), Kalanthroff et al. (2013), Entel et al. (2015) and Shichel and Tzelgov (2018).

Chapter 6: Implications of the PC-TC model of Kalanthroff et al. (2015) for explanations of attentional bias in the emotional and addiction Stroop tasks

Previous models to account for the emotional Stroop effect and the addiction Stroop effect have implicitly assumed that attentional bias towards threat-related and addiction-related stimuli are due to response conflict. Williams, Mathews and MacLeod (1996) proposed three ways to consider how interference arising from emotionally salient stimuli could be implemented in the connectionist model of Cohen et al. (1990). First, input units representing words related to an individual's current concerns could be more practised than other input units and thus having higher connection weights in their corresponding word processing pathways. Second, input units which represent concern-related words compared to neutral words could have higher resting activation levels (i.e., lower activation thresholds). Third, concern-related input units could be regulated by a neuromodulatory system that controls our responses to environmental changes. This could be implemented by modulating the gain parameter. For example, in the presence of threat-related words a neurotransmitter (e.g., norepinephrine) released by the neuromodulatory system might result in an increase for the gain parameter, which enables threat-related words to have stronger connection weights in their processing pathways. Building on Williams and his colleagues' suggestions, Cox, Fadardi and Pothos (2006) resorted to the theory of current concern explaining how stimuli related to a person's current concerns have higher salience than other neutral stimuli, which provides a framework for understanding the addiction Stroop effect. The theory of current concerns suggests that during the time period when an individual is committed to pursuing a goal, stimuli associated with the goal pursuit take priority over those unrelated to the goal pursuit in the individual's cognitive processing. As a result, goal-relevant stimuli become salient relative to those goal-irrelevant stimuli (Cox et al., 2006; Field & Cox, 2008; Klinger, 1975, 1977, 1987, 1996; Klingers & Cox, 2004).

The attentional control theory (Eysenck et al., 2007) and the dual competition model of Pessoa (2009) suggest that in the presence of emotionally salient stimuli attentional resources, which have been allocated to the ongoing task, are reallocated to prioritise the processing of the emotional saliency, resulting in an impaired top-down proactive control and an increased bottom-up reactive control. In the connectionist model, this suggestion has been implemented as a negative emotional node (See Figure 1.7) which can inhibit the cognitive control node upon receiving activation from the negative emotional word input units via an excitatory connection (Wyble et al., 2008). The adaptive attentional control model of Wyble et al. (2008) provides a framework to understand that in the emotional Stroop task attentional bias not only can arise on trials where negative emotional stimuli are presented but also can take place on trials that follow negative emotional stimuli (Bar-Haim et al., 2007; McKenna & Sharma, 2004; Phaf & Kan, 2007). In similar fashion, Wyble et al.'s (2008) model has also been used to account for the finding of attentional bias for addiction-related stimuli in the addiction Stroop task. For example, Cane et al. (2009) reported attentional bias taking place on stimuli that followed addiction-related stimuli (i.e., slow effect) among cigarette smokers and marijuana users and suggested that this finding could result from a mechanism similar to the mechanism underlying the slow effect of negative emotional stimuli. Moreover, Sharma (2017) reported a diminished sequential modulation effect for incongruent trials that were preceded by alcohol images among heavy drinkers. In a model analogous to Wyble et al. (2008) which replaces the negative emotional node with an addiction node, the finding could be attributed to the attenuated cognitive control due to the inhibition from the addiction node.

My two studies in Chapter 6 for the first time took the role of task conflict into account to explain the emotional Stroop effect and the addiction Stroop effect. In the PC-TC model (See Figure 6.7.1), task conflict can arise by greater activation of the word reading task demand unit. This can be implemented in two ways – in a top-down proactive mechanism (e.g., by activation from a threat-monitoring task demand unit or more generally by priming negative schemas among high anxious individuals for the emotional Stroop effect; by activation from an addiction-monitoring unit or by activating substance-related schemas in substance users for the addiction Stroop effect) and in a bottom-up reactive mechanism (e.g., by activation from negative emotional word input units for the emotional Stroop effect; by activation from addiction-related word input units for the addiction Stroop effect) to enable the word reading task demand unit to compete with the colour naming task demand unit.

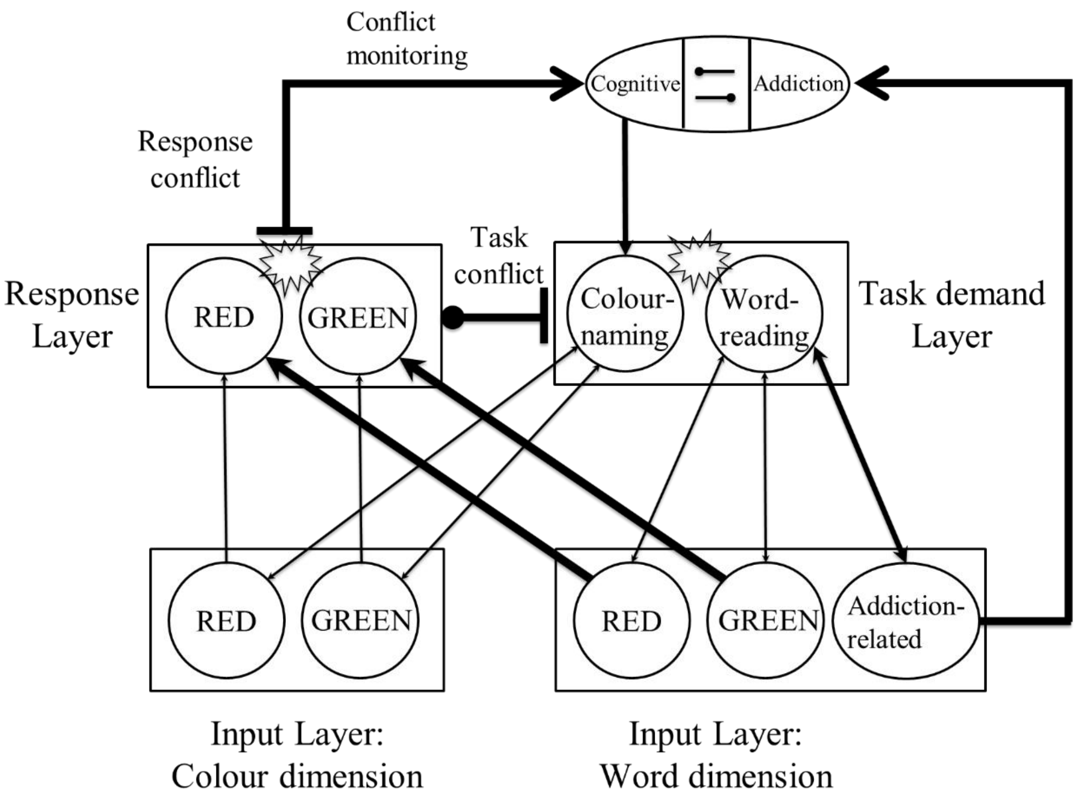
In Experiment 7, for the low trait anxiety group, studied (neutral and negative) words resulted in a general slowdown in the studied blocks [CsC] and [NsC] where response latencies to neutral words and studied words did not differ from each other within the studied blocks, but neutral words in the studied blocks took longer to respond to than neutral words in the unstudied block [C], replicating the findings by Sharma (2018) and Chapter 4. Moreover, there was no response latency difference between the two studied blocks (See Figure 6.7.2). In the PC-TC model, this indicates an effect of task conflict resulting from a strong proactive activation of the word reading task demand unit, slowing down colour-responding to both studied and unstudied words in the studied blocks. By contrast, participants with high trait anxiety demonstrated no effect of task conflict from proactive control in which studied (neutral and negative) words did not lead to a slowdown for neutral words in the studied blocks [CsC] and [NsC] compared to neutral words in the unstudied block [C]. However, the high trait anxiety group showed an emotional Stroop effect in the [NsC] block but not in the [NC] block, indicating an effect of reactive control in the [NsC] block (See Figure 6.7.2). This finding was consistent with Richard et al. (1992) and Holle et al. (1997) who suggested that the emotional Stroop effect can be produced when negative stimuli are presented in the blocked format (i.e., in a block comprising of only negative stimuli) or following a negative mood induction when negative stimuli are presented in the randomly intermixed format (i.e., in a block consisting of negative and neutral stimuli). The lack of a general slowdown and the finding of attentional bias towards studied negative words supported the predictions from the attentional control theory and the dual competition model which suggests that high trait anxiety can disrupt the balance of attentional control, resulting in a weakened influence of proactive control and a strengthened influence of reactive control. In the PC-TC model, this could be considered as a reduced top-down activation of the word reading task demand unit and an increased bottom-up activation of the word reading task demand unit. Moreover, when looking into the trial-by-trial effect in the [NsC] block, a reversed sequential modulation effect was revealed where responses to studied negative words were slowed down when preceded by studied negative words compared to unstudied neutral words (See Figure 6.7.3). Within the framework of the PC-TC model, I propose two suggestions to consider task conflict as a potential mechanism underlying the revered sequential modulation effect. First, I suggest that the reversed sequential modulation effect could be explained by the lack of a proactive mechanism to alleviate the task conflict that arises in a reactive mechanism, which contrasts with the sequential modulation effect that can be explained by the implementation of the conflict monitoring unit which enables the cognitive control to strengthen the proactive activation of the colour naming task demand unit in response to the rise of response conflict from reactive control. Second, it is possible that the word reading task demand unit can be activated by the episodic memory unit in a proactive mechanism even though the impact of proactive control might be weaker among high anxious individuals. That is, the episodic memory unit could be sensitised when two studied negative words are presented one after another, and thus the response latencies to the second studied negative word are longer than the first studied negative word.

In Experiment 8, for the marijuana non-user group, studied (neutral and marijuana-related) words had a tendency to slow down the studied blocks [CsC] and [MsC] compared to the unstudied block [C]. In addition, there was a slowdown in the unstudied block [MC] in comparison with the unstudied block [C], suggesting that studying marijuana-related words led to activating a general marijuana schema where when seeing the unstudied marijuana-related words in the [MC] block, the non-users might have become aware of a group of words that were associated with the marijuana-related words they had seen in the study phase (See Figure 6.8.1). In the PC-TC model, this could be accounted for as a robust proactive activation of the word reading task demand unit due to activating episodic memory. On the other hand, for the marijuana user group, marijuana-related words (studied and unstudied) resulted in a slowdown for the unstudied neutral words in the blocks [MC] and [MsC] compared to the neutral words in the unstudied block [C] and the studied block [CsC]. The unstudied neutral words in the [MsC] block did not take longer to respond to than those in the [MC] block. This finding suggested that priming with marijuana-related words resulted in activating a general schema for marijuana-related words in the marijuana user group and the schema could activate the effect of task conflict in a proactive mechanism. Whereas priming with neutral words did not activate a schema (at least implicitly because the results for the recall task indicated a better recall for studied neutral words than unstudied neutral words), leading to no effect for studied neutral words to slow down the [CsC] block. This could be explained by the theory of current concerns (Cox et al., 2006; Field & Cox, 2008; Klinger, 1975, 1977, 1987, 1996; Klingers & Cox, 2004) in which after being primed with marijuana-related words in the study phase, marijuana users might have become committed to attending to marijuana-related words during the colour naming task. In the PC-TC model, this could be implemented by a proactive activation of an addiction-monitoring unit which excites the word reading task demand unit, leading to a competition between the word reading and colour naming task demand units, thereby slowing down the responses to both marijuana-related and neutral words in the [MC] and [MsC] blocks. Moreover, within the blocks [MC] and [MsC], I found that the latencies of the marijuana-related words were much longer than that of the neutral words, which indicated a strong attentional bias for marijuana-related words and suggested that there was an effect of reactive control in addition to the influence of proactive control within these two blocks (See Figure 6.8.1). Note that the amount of attentional bias was the same in these two blocks, which suggests that the addiction attentional bias was driven by activating the schema for marijuana-related words. In the PC-TC model, the attentional bias for marijuana-related words could be implemented as a reactive activation of the word reading task demand unit. Additionally, for the trial-by-trial effect within the blocks [MC] and [MsC], I observed a trend in which a slowdown occurred when marijuana-related words were presented after other marijuana-related words than after unstudied neutral words, suggesting a reversed sequential modulation effect (See Figure 6.8.2). Similar to my two suggestions for the mechanism underlying the reversed sequential modulation effect in the previous paragraph, if the reversed sequential modulation effect is a result of task conflict, my results indicated that task conflict could take place either from a reactive fashion by successive activation flowing from the marijuana word input unit to the word reading task demand unit, or from a proactive mechanism by activation of an addiction-monitoring unit to the word reading task demand unit.

On the other hand, it is possible to suggest that the results for the marijuana user group could be due to task conflict from reactive control without involving an effect of proactive control. Here I suggest a model extending the framework of the PC-TC model of Kalanthroff et al. (2015) with an addiction node that can be activated by the addiction-related word input unit and thus inhibits the conflict monitoring unit in a similar way in which the negative node inhibits the cognitive control in Wyble et al.'s (2008) model (See Figure 7.1).

Figure 7.1

A model adapted from the adaptive attentional control model of Wyble et al. (2008) and the PC-TC model of Kalanthroff et al. (2015).



The following are the predictions from this model and how my results fit the model:

a) First, the presence of addiction-related words would lead to a weak proactive activation of the colour naming task demand unit, thereby allowing the bottom-up activation from the addiction-related word input unit to activate the word reading task demand unit. As a result, addiction-related words produce more interference than neutral words, demonstrating an attentional bias. This prediction is supported by the finding of attentional bias in the two blocks with marijuana words [MC] and [MsC];

b) Second, a slowdown would occur on trials (addiction-related and neutral words) that follow the presence of addiction-related words. As a consequence, the latencies of addiction-related words preceded by addiction-related words would become longer, which could be used to account for the mechanism underlying the reversed sequential modulation effect in the [MC] and [MsC] blocks;

c) Moreover, neutral words preceded by addiction-related words would take longer to respond to, producing a slow effect that is in line with the finding by Cane et al. (2009) and Sharma (2017), and this also suggests that my finding of the slowdown to the unstudied neutral words in both of the [MC] and [MsC] blocks compared to those in the baseline [C] block was due to task conflict from reactive control rather than proactive control. However, my finding only provided some evidence of slow effect in the [MC] block, suggesting that my data can be better explained by task conflict from both proactive control and reactive control rather than task conflict without the involvement of proactive control.

In short, I attempted to consider how my findings of the emotional and addiction Stroop effects can be incorporated into the PC-TC model and I suggest that in the non-colour word Stroop task the selective attention in high trait anxious individuals and marijuana users is driven by task conflict.

The variables of studied word number, trial number and the length of task across Experiment 2, 3, 7 and 8

Sharma (2018) was the first study to provide evidence that priming can interfere with the colour naming performance in the blocked format non-colour word Stroop task. In Sharma's study, participants memorised 20 words during the study phase and conducted two blocks of 160 trials in the following Stroop colour naming task. The findings suggested an effect of task conflict from proactive control due to priming where response latencies were longer for the mixed block with studied words than the pure block without studied words.

The design of Sharma (2018) was applied in Chapter 4 and 6. Across Experiment 2, 3, 7 and 8, words were used as stimuli and the number of words presented in the study phase and the number of trials in a block in the Stroop test phase were manipulated (See Table 7.2).

Table 7.2

The comparison of variables manipulated across Experiment 2, 3, 7 and 8

Variable\Experiment	Exp 2	Exp 3	Exp 7 & 8
The number of studied words	30	30	40
The number of trials in a block	240	80	160
The total number of trials in the Stroop task	480	160	640
The length of the Stroop task	20 mins	7 mins	30 mins

In Chapter 4, participants in Experiment 2 memorised 30 words prior to performing two blocks of Stroop colour naming task in which there were 240 trials in each block. The results of Experiment 2 demonstrated that there was no task conflict from proactive control (i.e., a null priming effect) where colour-responding did not differ between the studied and unstudied words in the mixed block and the unstudied words in the pure block. I propose three suggestions to account for Experiment 2's finding of null priming effect. First, the lack of task conflict in a proactive mechanism could be due to using 30 words, which was a larger number of studied words compared to the 20 studied words used in Sharma (2018), where the priming effect for each studied word might be reduced. Second, it could be argued that the null priming effect was caused by the large trial number, 240 trials in a test block which was larger than the 160 trials used in Sharma (2018), where the priming effect may spread over the large number of repeated test trials. Third, it is possible that the null priming effect was attributed to the length of the task where the priming effect could have diminished over the course of time. On average, it took around 20 minutes to complete the colour naming task of 480 trials in Experiment 2 compared to Sharma (2018) where it cost 12 minutes to complete the task of 320 trials.

To test my assumptions, participants in Experiment 3 were required to memorise 30 words in the study phase which was the same as participants in Experiment 2, however, in the following two blocks of colour naming task they had to respond to 80 trials instead of 240 trials in each block, which took about 7 minutes to complete. Contrary to Experiment 2's finding, the results of Experiment 3 revealed an effect of task conflict from proactive control, showing a priming effect from studied words in which response latencies were longer for the studied and unstudied words in the mixed block compared to the unstudied words in the pure block. Also, in Chapter 6, although participants in both Experiment 7 and 8 had to study 40 words, which was a larger studied word set compared to the 30 words in Experiment 2 and 3, before they carried out four blocks of colour naming task consisting of 160 trials in each block that took about 30 minutes to complete, the results of Experiment 7 and 8 provided evidence of task conflict from proactive control indicated by interference from salient and/or studied words. The findings of Chapter 4 and 6 supported my first suggestion indicating that rather than the number of studied words that were required to be held in working memory or the length of the colour naming task, it was the large number of trials in each test block that could have resulted in the practice and fatigue effects where participants might have got bored with the task or lost their focus during the task, thereby leading to the null priming effect in Experiment 2.

In short, the findings of Experiment 2, 3, 7 and 8 demonstrated that using the large trial number that was larger than 160 trials in a single test block could lead to a null priming effect. I suggest that when designing a study to investigate the priming effect in the blocked format non-colour word Stroop task, the number of trials in a block needs to be taken into account if it is higher than 160 to control for the potential practice and fatigue effects.

Task conflict and the reversed sequential modulation effect

The PC-TC model (see Figure 6.7.1) suggests that the presentation of an incongruent stimulus that induces the response conflict would strengthen the proactive control via the conflict monitoring unit to the colour naming task demand unit to moderate the amount of conflict from the upcoming incongruent stimulus. As a result, the colour-responding to an incongruent stimulus that follows the incongruent stimulus would speed up, showing the sequential modulation effect. In contrast to the control adaptation for response conflict, there is no top-down mechanism implemented to modulate task conflict on a trial-by-trial basis in the PC-TC model. As a result, a slowdown might occur when stimuli that induce task conflict are presented one after another.

To examine whether priming non-colour neutral words leads to response or task conflict, one of the ways Sharma (2018) argued this could be done was to investigate the pattern of the trial-by-trial effect in the mixed block where studied and unstudied non-colour neutral words were intermixed. Based on the PC-TC model, Sharma hypothesised that if studied words evoke response conflict, then similar to the control adaptation to two consecutively presented incongruent colour words, the response latency to the second studied word would be faster than the first studied word, showing the typical Gratton effect or the sequential modulation effect. By contrast, if studied words produce task conflict, without the control adaptation from top-down to strengthen the colour naming, the responses to studied words following other studied words would be slower (rather than faster), showing the reversed pattern of the sequential modulation effect. By carrying out the analysis on Previous study type (unstudied word, studied word) × Current study type (unstudied word, studied word) as a 2-way factorial ANOVA, Sharma reported that in the second half of the mixed block where studied words became salient and took longer to respond to than unstudied words, colour-responding to studied words preceded by studied words (CsCs) were slower compared to the other three conditions – studied words preceded by unstudied words (CCs), unstudied words preceded by studied words (CsC) and unstudied words precede by unstudied words (CC), suggesting that the effect of priming resulted in a slowdown to studied non-colour neutral words that was attributed to task conflict.

Following Sharma's (2018) work, I attempted to replicate the finding of the reversed sequential modulation effect. In terms of the contingency learning and repetition priming confounds for the sequential modulation effect (Mayr, Awh & Laurey, 2003; Schmidt, Crump, Cheesman & Besner, 2007; Schmidt & De Houwer, 2011; Schmidt, Augustinova & Houwer, 2018; see Algom & Chajut, 2019; Schmidt, 2013; 2019, for reviews), since each of the word stimulus was printed in each of the four colours equally and each word-colour pair was presented once throughout the test blocks in Chapter 4 and 6, both of the contingency learning and repetition priming confounds were controlled for in my design. As for the design in Chapter 5, I could not eliminate the confound of repetition priming since the proportion manipulation led to the repetition of the same word-colour pairs (e.g., the word MOVE printed in green colour was consecutively presented for two trials) although the percentage of the repetition trials was low across the three experiments: in Experiment 4, the percentage of the repetition of the same word-colour pairs in the 75/25 block and the 25/75 block was 0% and 0.6%, respectively; in Experiment 5, it was 0.4% and 1.6% in the 75/25 block and the 25/75 block, respectively; in Experiment 6, it was 0% and 1% in the 75/25 block and the 25/75 block, respectively.

For the analyses of task conflict from reactive control, I employed planned comparisons for the contrast between trial CCs and trial CsCs in addition to the approach of the Previous × Current 2-way ANOVA applied by Sharma (2018). In Chapter 4 where the same design of Sharma (2018) was used with different number of studied words and block trials, I did not observe any reversed sequential modulation effect by performing the 2-way ANOVA. However, in Experiment 3 of Chapter 4 (see Figure 4.3.2 and 4.3.5), by carrying out planned comparisons, a strong reversed sequential modulation effect was observed in the first half of the mixed block where the latencies of studied words were longer than unstudied words. In Chapter 5 where non-word rectangles were included as control stimuli along with neutral words, neither ANOVA nor paired comparisons revealed a reactive control that came from the reversed sequential modulation effect. However, I did observe a sequential modulation effect, an indication of reactive control in which colour-responding for rectangles preceded by rectangles was faster than for rectangles preceded by words. In Chapter 6 where I aimed to investigate the priming effect on salient stimuli, using planned comparisons but not ANOVA revealed that the exhibition of two primed salient stimuli also showed the reversed sequential modulation effect: in Experiment 7 (see Figure 6.7.2 and 6.7.3), longer responses to studied negative words preceded by studied negative words (NsNs) compared to studied negative words preceded by unstudied neutral words (CNs) were found in the [NsC] block along with the attentional bias towards studied negative words among the high anxiety group; in Experiment 8 (see Figure 6.8.1 and 6.8.2), regardless of whether marijuana-related words were studied or unstudied, larger latencies to marijuana-related words following marijuana-related words (trial MM or trial MsMs) relative to marijuana-related words following unstudied neutral words (trial CM or trial CMs) were observed in the [MC] and [MsC] blocks along with the attentional bias towards marijuana-related words among marijuana users. Also, slower reaction times to marijuana-related words preceded by marijuana-related words (trial MM) than marijuana-related words preceded by unstudied neutral words (trial CM) were found in the [MC] block for non-users.

To sum up, my findings of the reversed sequential modulation effect extended the work of Sharma (2018), providing further evidence that task conflict from reactive control emerges as the trial-by-trial effect. It seemed that the reversed sequential modulation effect had a tendency to take place in company with the occurrence of attentional bias towards salient or studied words in the block where salient or studied words were mixed with unstudied words (Chapter 4 and 6). On the other hand, the reversed sequential modulation effect did not occur when word stimuli were mixed with non-word stimuli, however, there was a sequential modulation effect (trial RR vs. trial WR), indicating an effect of task conflict from reactive control (Chapter 5).

Can the connectionist model with no account of task conflict such as Wyble et al. (2008) explain my findings?

Wyble et al. (2008) proposed an adaptive attentional control model to account for an interaction between emotional salience and proactive cognitive control (see Figure 1.7). The model suggests that the presence of negative emotional words would activate the negative emotional node which competes with the top-down cognitive control to the colour naming task demand unit for the limited attentional resources in order to address the perceived threat-related information, which is a slow process that does not have an immediate effect on the performance of the current negative trial but on the next trial. Accordingly, the reduced level of the cognitive control to the colour naming task demand unit leads to less activation to the colour processing pathways, allowing word units at the category layer to have more impact on the performance, resulting in a longer colour-responding to the trial following the negative word, which shows a slow effect of negative words. Moreover, for individuals with high trait anxiety, the model predicts a fast effect in which colour-responding on the current trials would be slower for negative words compared to neutral control words due to the effect of trait anxiety that strengthens the activation projecting from the negative word input unit to its corresponding unit in the category layer to compete with the colour unit. As a result, an attentional bias towards negative words on the current trials (i.e., fast effect) as well as a slowdown to negative and neutral control words on the subsequent trials (i.e., slow effect) would be observed.

By analogy, an adaptation of Wyble et al.'s (2008) model which replaces the negative emotional node with an episodic memory node would allow studied words to inhibit the cognitive control node, interfering with the colour naming task in a top-down proactive mechanism. Moreover, while the top-down cognitive control is weak, the priming effect would provide extra activation for a studied word to compete with a colour unit at the category layer via a bottom-up reactive mechanism. Accordingly, predictions from this adapted model would suggest that first, the presence of a studied word would lead to an attenuated proactive cognitive control to colour naming, thereby slowing down the subsequent studied words (i.e., a reversed sequential modulation effect) and unstudied words (i.e., a slow effect). As a consequence, across blocks, the response latencies would be longer for blocks with studied words compared to blocks without studied words. Second, the latencies of studied words would be longer than that of unstudied words. Consequently, within the block where unstudied words are mixed with studied words, there would be an attentional bias towards studied words.

Firstly, regarding the prediction from the adapted Wyble et al. (2008) model that studied words would slow down colour-responding to the subsequent words irrespective of whether the words are studied or unstudied, Sharma (2018) found the reversed sequential modulation effect but did not find any evidence of the slow effect within the mixed block. I checked if my findings of the reversed sequential effect occurred along with the slow effect by comparing the latencies of unstudied words preceded by studied words with that of unstudied words preceded by unstudied words (i.e., trial CC vs. trial CsC in the mixed block in Experiment 3, trial CC vs. trial NsC in the [NsC] block in Experiment 7, and trial CC vs. trial MsC in the [MsC] block in Experiment 8). I found some evidence to support the prediction in Experiment 3 where studied words slowed down the response latencies not only to the following studied words (the reversed sequential modulation effect) but also to the upcoming unstudied words (the slow effect). Secondly, as a result of the reversed sequential modulation effect and the slow effect, the model predicts a slowdown for blocks including studied words compared to blocks excluding studied words. This prediction was supported by Experiment 3's result where the responses were longer in the mixed block than the pure block. Thirdly, in terms of the prediction for an attentional bias towards studied words in the mixed block of studied and unstudied words, the finding of Experiment 3 provided evidence of the attentional bias towards studied words in the first half of the mixed block. However, this attentional bias disappeared in the second half of the mixed block, and in general there was no response latency difference between the studied and unstudied words within the mixed block, revealing a limitation of the adapted Wyble et al. (2008) model to account for the finding of the general slowdown within the mixed block.

To conclude, the adapted Wyble et al. (2008) model predicts a reversed sequential modulation effect that takes place along with a slow effect, and an attentional bias towards studied words. These predictions were supported by my findings in Experiment 3. However, the results of Experiment 7 and 8 did not provide evidence of the slow effect to support the model's prediction. Most importantly, the adapted Wyble et al. (2008) model does not predict a general slowdown for studied and unstudied words within the mixed block even though the general slowdown was found by Sharma (2018) and was repeatedly observed throughout my experiments in Chapter 4, 5 and 6. By contrast, the general slowdown can be explained within the PC-TC model via the top-down proactive control to word reading. Therefore, my data suggest that it is necessary to include the account of task conflict in network models to account for the priming effects in the non-colour word Stroop task. I discussed the implications of my data for the PC-TC model in the following section.

Implications of task conflict from priming for the PC-TC model of Kalanthroff et al. (2015)

The PC-TC model of Kalanthroff et al. (2015) suggests that the general findings of the standard Stroop effect (i.e., Stroop interference and facilitation effects) in the colour word Stroop task is a result of conflict from the response layer but not from the task demand layer due to a strong top-down proactive control to colour naming, which helps participants to maintain their attention on the task-relevant colour dimension of stimuli. That is, under the high level of top-down proactive control to the colour naming task demand unit, the bottom-up activation flowing from word input units to the word reading task demand unit is suppressed by the activated colour naming task demand unit, resulting in null conflict between the two task demand units. However, when the level of top-down proactive control to the colour naming task demand unit is low, the word reading task demand unit can be activated by the bottom-up activation from word input units, leading to the task competition between the colour naming and word reading tasks that inhibits a response to be made from the response layer. As a consequence, colour naming performance is slowed down by task conflict on top of the response conflict, producing a larger amount of Stroop interference and particularly a reversed facilitation effect compared to the standard Stroop effect.

The current thesis employed the study-test procedure in the blocked format non-colour word Stroop task that was introduced by MacLeod (1996) and was developed by

Sharma (2018). My results of Chapter 4 and 6 replicated the findings of the null effect by MacLeod (1996) and Sharma (2018) where responses to studied words did not differ from unstudied words when studied and unstudied words were intermixed in the mixed block (see Figure 4.1.1, 4.3.1, 6.7.2 and 6.8.1). When comparing the mixed block with the pure block that only consisted of unstudied words, it was revealed that the null effect was in fact a general slowdown in which both of the studied and unstudied words in the mixed block took longer to respond to than the unstudied words in the pure block. In line with Sharma (2018), I suggest that in the PC-TC model the general slowdown could be considered as a result of task conflict from proactive control to the word reading task demand unit. That is, during the study phase, the action of reading words is triggered as a proactive process in response to the task demand where participants are requested to study and memorise words. On the contrary, in the following test phase, the action of naming colours is activated as a proactive process with regards to the task goal in which participants are instructed to ignore reading the word and respond to the colour. However, during the test phase, the presence of studied words might trigger the episodic memory of the context in which words were studied in the study phase, resulting in activation to the word reading task demand unit. When the activation to the word reading task demand unit flows from top-down proactive control, the activation is sustained allowing the word reading task demand unit remain active, competing with the colour naming task demand unit. As a result, responses to any words are slowed down.

In addition to the replication of task conflict from proactive control, my results in Chapter 4 and 6 also reproduced the findings of task conflict from reactive control by Sharma (2018). First, the PC-TC model suggests that for the colour-responding to congruent stimuli in the colour word Stroop task, when the level of proactive control is low, the activation of the word units at the bottom of the framework would not flow to the response layer to engender response competition since congruent stimuli do not induce informational/response conflict due to that the meaning of the colour dimension corresponds to that of the word dimension. Instead, the bottom-up activation would project from the word units to the word reading task demand unit that leads to task competition, producing the reversed facilitation effect – a slowdown to the latencies of congruent stimuli compared to the non-word control stimuli. In the same reactive mechanism, my results of Experiment 3 in Chapter 4 illustrated longer response latencies to studied words than to unstudied words in the first half of the mixed block (see Figure 4.3.2), indicating that when the proactive control to both the colour naming and word reading task demand units is weak, as words in the non-colour word Stroop task do not cause informational/response conflict (i.e., non-colour word stimuli do not produce congruent or incongruent conditions), priming words can result in more activation arising from studied word units than from unstudied word units to the word reading task demand unit, producing a larger amount of task conflict for studied words than unstudied words. Moreover, this reactive mechanism also generalised to studied salient stimuli in my findings of Chapter 6 where participants with high anxiety showed attentional bias towards studied negative words in Experiment 7 (see Figure 6.7.2 left panel), and marijuana users exhibited selective attention towards both studied and unstudied marijuana-related words in Experiment 8 (see Figure 6.8.1 left panel).

Second, as previously discussed in the paragraph of task conflict and the reversed sequential modulation effect, the PC-TC model suggests that the cognitive control has a proactive mechanism to moderate the amount of response conflict caused by the successively exhibited incongruent stimuli. That is, when the existence of response conflict at the response layer is identified by the conflict monitoring unit, the top-down proactive control is triggered to boost the activation to the colour naming task demand unit to modulate the following response conflict, resulting in a faster response to the subsequent incongruent stimulus – the sequential modulation effect. On the contrary, within the framework of the PC-TC model, there is no such proactive mechanism to resolve the amount of task conflict resulting from the consecutively shown primed stimuli. Accordingly, I assumed that the responses to studied words preceded by studied words would take longer to respond to, showing a reversed pattern of the sequential modulation effect. Although my finding of Experiment 3 in Chapter 4 (see Figure 4.3.5) and Experiment 7 and 8 in Chapter 6 (see Figure 6.7.3 and 6.8.2) supported the assumption, I did not conduct modelling to examine how my data fits the PC-TC model and hence it remains unclear how the reversed sequential modulation effect can be implemented into the PC-TC model. Future research is therefore needed to elucidate whether the reversed sequential modulation effect is attributed to task conflict from reactive control and how the effect can be considered in the PC-TC model.

Thesis conclusion

I set out to provide further evidence in support of using the study-test procedure to reveal the role of task conflict in the blocked format non-colour word Stroop task that was originally designed by MacLeod (1996) and was developed by Sharma (2018). My main aim was to replicate the findings by Sharma (2018) who reported (a) A general slowdown in a studied block where studied and unstudied neutral words were intermixed compared to an unstudied block consisting of unstudied words, which in the PC-TC model of Kalanthroff et al. (2015) can be accounted for as an effect of task conflict in a proactive mechanism; (b) A reversed sequential modulation effect within the studied block in which colour-responding became slower when two studied words were successively presented, which in the PC-TC model can be interpreted as an effect of task conflict in a reactive mechanism. My second aim was to examine whether my results supported the predictions from the PC-TC model.

The thesis aims were achieved. First, by priming participants with different number of studied words (10 and 30 studied words) compared to the 20 studied words that were used in Sharma (2018), my results in Chapter 4 reproduced the findings of Sharma (2018), providing evidence of selective attention towards studied words that can be attributed to task conflict in either a proactive or a reactive mechanism due to activating episodic memory. Moreover. the results of Chapter 4 suggested a tendency in which the more the number of studied words participants had to memorise, the less the amount of task conflict from proactive control they showed. Second, by applying the proportion manipulation, my results in Chapter 5 did reveal a general slowdown for studied and unstudied words compared to rectangles within each of the two blocks, however, the magnitude of the general slowdown did not vary between the two blocks in response to the change in the proportion of illegible rectangles relative to legible words. This finding did not support the prediction from the PC-TC model where the proactive control to the colour naming task demand unit would be robust/weaken when the proportion of words relative to rectangles in a block becomes larger/smaller, but indicated that in the non-colour word Stroop task the level of proactive control to colour naming could be insensitive to the proportion of word stimuli in a block. Third, by priming participants with negative emotional words and marijuana-related words, my results in Chapter 6 suggested that for the explicit recall task, there was no difference between the low and high trait anxiety groups and no difference between marijuana user and non-user groups. However, for the implicit emotional Stroop task, low anxious participants showed a general slowdown for studied blocks compared to the baseline unstudied block, illustrating an effect of task conflict from proactive control due to activating episodic memory. This contrasted with high anxious participants who revealed no general slowdown for studied blocks but a hypervigilance for studied negative words and a reversed sequential modulation effect, suggesting that there was a decrease in the level of proactive control but an increase in the level of reactive control in high trait anxiety. For the implicit addiction Stroop task, marijuana non-users demonstrated a speedup in the baseline unstudied block compared to all other blocks, showing an activated general marijuana schema and an effect of task conflict from proactive control. Whereas marijuana users showed a slowdown for blocks with marijuana-related words compared to the baseline unstudied block, suggesting an impact of task conflict from proactive control. Moreover, within the blocks with marijuana-related words, marijuana users exhibited attentional bias towards marijuana-related words as well as a reversed sequential modulation effect, showing an effect of task conflict from reactive control. Overall, my findings suggested that studying words can result in the selective attention towards studied words that is driven by task conflict and the balance of attentional control can be affected by trait anxiety and substance addiction.

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