Does Neutral Proportion Modulate Attentional Control of Task Conflict in the Stroop Task?

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Statement of Originality

This thesis has not been submitted for a higher degree to any other university or institution. The sources of information used in the thesis have been cited intext and listed in the reference section. Ethics approval was obtained from the Macquarie University Human Research Ethics Committee (approval number: 5201200036).

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Abstract

The Stroop interference effect is finding that it takes longer to name the colour that a word is displayed in when the word spells the name of an incongruent colour (e.g. the word RED display in blue), relative to when the word is displayed using a non-linguistic string (e.g. XXXX displayed in blue). The Stroop interference effect is commonly thought to reflect an informational conflict between the information that is supplied by the word dimension of the stimulus and the information supplied by display colour dimension of the stimulus. However, more recently, it has been proposed that the Stroop interference effect may also be due to a task conflict (Goldfarb & Henik, 2007). Task conflict refers to competition between task-sets, which are the sets of cognitive processes used to perform specific tasks. A word displayed in colour is associated with two task sets: reading and colour naming. Stroop interference occurs when the word dimension of the Stroop stimulus automatically triggers the task set of reading, which then conflicts with the task set of colour naming (Monsell, Taylor & Murphy, 2001).

However, the automaticity of reading has been called into question by the finding that the Stroop interference effect can be modulated, which has been taken as evidence that the task of reading can be controlled using attention. Specifically, Goldfarb and Henik (2007) have shown that the Stroop interference effect is magnified when there is a high proportion of non-linguistic neutral trials (e.g., a row of Xs), and argued that this is because when people do not experience conflict, attentional control over the task of reading is relaxed, and they open themselves up to the interfering effects of word distractors.

The present thesis examined whether the task conflict is modulated by attentional control by examining the effect of neutral trial proportion on colour-unrelated word distractors (e.g. ABBEY or CHART). Previous research by Kinoshita, De Wit and Norris

(2017) found that colour unrelated words interfered with colour naming, but this interference was absent when the response to the colour was manual, in what would amount to a low neutral proportion condition. In the present thesis, the word interference effect was magnified when there was a high proportion of neutral trials, in both the vocal and manual Stroop tasks. Using both an analysis of RT distribution and the effect of previous trial type (the "Gratton effect"), I examined the mechanism of attentional control of task conflict. RT distribution analysis showed that the magnification of the word- interference effect in the high neutral proportion condition was constant across the RT bins in the manual task and increased in size across the RT bins of the vocal task. Previous trial type modulated the size of the word interference only in the vocal task, and only in the low neutral proportion condition. Taken together, it is suggested that increasing the proportion of neutral trials relaxes attentional control of the task set of reading and that the reactive form of control operates only when a high level of conflict is experienced.

Contents

List of Tables

List of Figures

1. Introduction

The Stroop interference effect, first reported in 1935 by J Ridley Stroop, is the finding that it takes longer to name the display colour that a word is presented in when the word is the name of an incongruent display colour (e.g. the word BLUE displayed in red), relative to when the display colour is presented in a non-linguistic string of symbols (e.g. XXXX displayed in red). It is widely agreed that the Stroop interference effect reflects a conflict between the display colour dimension and the word dimension of the stimulus. Although the Stroop interference effect is often described as a "gold standard" demonstration of the automaticity of reading (MacLeod, 1992) – in the sense that a literate person cannot help but read the word – it is also the case that the size of the Stroop interference effect can be modulated, and this finding is taken as evidence for the attentional control of conflict (e.g., Braver, 2012). What is currently unknown, however, is the precise nature of the conflict, and which aspects of the conflict can be controlled by attention. The present thesis investigates this issue.

1.1 Task Conflict vs. Informational Conflict

Traditionally, the Stroop interference effect has been interpreted in terms of informational conflict (also called response conflict). Informational conflict refers to the competition between the information provided by the word and display colour dimensions of the stimulus (Goldfarb & Henik, 2007). For example, when the word BLUE is displayed in red, the meaning of the word ("blue") conflicts with the colour information provided by the display colour (red), and resolving this conflict takes time. More recently, a second type of conflict, namely, task conflict, has been recognized (Goldfarb & Henik, 2007; Monsell, Taylor & Murphy, 2001). Task conflict refers to the competition between the task sets. The concept of a task set comes from the task-switching literature (e.g., Rogers & Monsell, 1995), and refers to the automatic tendency triggered by the stimulus to perform the task associated with it. According to Monsell et al. (2001), a Stroop stimulus (a word presented in colour) affords two task sets: reading the word, and identifying/naming the colour. In the task-switching literature, such stimuli are referred to as “bivalent”. In contrast, a non-linguistic neutral stimulus like a row of Xs is associated with only one task set (as it cannot be read), and is said to be “univalent”. An incongruent Stroop stimulus, where the display colour is presented in a word that spells the name of a different display colour, contains both an informational conflict (between the colour related information supplied by word and display colour), and a task conflict (between the task sets of reading and colour naming). In contrast, in a congruent Stroop stimulus (e.g., the word RED displayed in red), where the display colour and word dimensions of the stimulus both refer to the same colour, there is no informational conflict, but there is a task conflict between the task sets of reading and colour naming. A neutral stimulus like a row of Xs presented in colour contains neither the task conflict nor the informational conflict.

As noted earlier, although the Stroop interference effect is often taken as demonstrating the automaticity of reading, the fact that the size of the effect can be modulated has been taken as evidence that conflict can be controlled by attention. In the Stroop literature, it is well-established that manipulations such as presenting the word in a separate spatial location from the to-be-named colour (e.g., Kahneman & Henik, 1981; Spieler, Balota & Faust, 2000) or by colouring only one letter of the word stimulus (e.g., Besner, Stolz, & Boutilier, 1997) can reduce, or even eliminate, the Stroop effect. These are manipulations of spatial attention, and research using other methods such as masked priming (e.g., Lachter, Forster & Rutheruff, 2004) has provided corroborative evidence that reading requires spatial attention. Spatial attention is a form of exogenous (stimulus-driven) attention. It is less clear, in contrast, whether and how reading can be controlled by endogenous (voluntary, internally-driven) attention, and it is to this issue I turn to next.

1.2 Attentional Control of the Task of Reading

A standard method to manipulate endogenous attention is to manipulate the proportion of trial types (i.e. manipulate the proportion of congruent, incongruent or neutral trials). A well-known finding is that manipulating the proportion of congruent trials relative to incongruent trials modulates the Stroop interference effect, with a larger Stroop interference effect being found when the congruent proportion is high relative to when congruent proportion is low (Cheeseman & Merikle, 1986; Schmidt & Besner, 2008). In addition, increasing the proportion of congruent trials has been found to increase the size of the Stroop facilitation effect (the finding of faster RTs on congruent trials than on neutral trials) (Cheesman & Merikle, 1986; Schmidt & Besner, 2008). This pattern of effects resembles that found with the semantic priming effects. In the semantic priming literature, the effect of trial proportion manipulations has been explained as being due to the use of a consciously controlled predictive strategy, whereby the prime, which is presented shortly before the target word, becomes increasingly predictive of the target as the proportion of semantically related prime/target pairs (e.g. *cat* followed by DOG) increases relative to the proportion of semantically unrelated prime target pairs (e.g. *bread* followed DOG) (Posner & Snyder, 1975). From this perspective, the modulation of the Stroop interference and facilitation effects by congruent proportion could be explained as being due to the word being a valid predictor of the display colour on congruent trials but not on incongruent trials, which results in the word becoming increasingly predictive of the display colour as the proportion congruent increases (Cheesman & Merikle, 1986; Schmidt & Besner, 2008). The use of the word stimulus to predict the display colour stimulus results in faster RTs on congruent trials, where the word and display colour match, and slower RTs on incongruent trials, where the word and display colour do not match (Cheesman & Merikle, 1986; Schmidt & Besner, 2008). The manipulation of congruency proportion would be considered a manipulation of how much attention is paid to the the information in the word dimension of the stimulus - In the words of Dishon-Berkovitz and Algom (2000), “when the nominally irrelevant dimension is in fact correlated with the relevant dimension, participants then attend to the irrelevant dimension and thus open themselves up to Stroop interference” (p. 1437).

A different type of trial proportion manipulation that has been shown to modulate the Stroop interference effect is the proportion of neutral trials, with the Stroop interference effect being larger when neutral proportion is high relative to when neutral proportion is low (Goldfarb & Henik, 2007; Tzelgov, Henik, & Berger, 1992). Unlike the congruent proportion effect, the neutral proportion effect can’t be explained as being due to the use of a predictive strategy as neutral trials do not contain information that could be used to predict the display colour. Instead, it has been proposed (Goldfarb & Henik, 2007; Tzelgov, et al, 1992) that as neutral trials do not contain conflict – neither informational or task conflict - increasing the proportion of neutral trials reduces the proportion of conflict trials, which in turn reduces the expectation of conflict and the recruitment of attentional control.

More specifically, the manipulation of the proportion of neutral trials is considered to impact on the task conflict. In the words of Kalanthroff & Henik (2014), when the experience of conflict is low i.e., when there is a high proportion of neutral trials, the attentional control over the task is “put to sleep”, which opens performance on the colour naming task to the influence of the more automatic reading task, magnifying the influence of the conflicting information from the incongruent word dimension. Evidence that the proportion of neutral trials relaxes the task control can be found in the “reverse facilitation effect”, i.e., faster response in the neutral condition than the congruent condition observed in the high neutral proportion condition (Goldfarb & Henik, 2007). Recall that the congruent trials (e.g., the word RED presented in red) are considered to contain task conflict because they are bivalent (because a word can be read), whereas a neutral trial like a row of Xs presented in colour is univalent (a row of Xs cannot be "read") and does not contain task conflict. According to Goldfarb and Henil (2007), reducing task control increases the contribution of task conflict (which impacts on bivalent stimuli), and hence yields a reverse facilitation effect.

To reiterate, increasing the proportion of non-linguistic, neutral trials (like a row of Xs) in a Stroop task is assumed to relax task control, and this results in an increased interference due to the task of reading. This thesis will make use of this manipulation to investigate the attentional control of the task of reading.

1.3 The task of reading

Based on the theoretical distinction between informational conflict and task conflict, and empirical works by Goldfarb and Henik (2007) and colleagues, I have made the case above that it should be possible to modulate the size of Stroop interference effect due to the task of reading, by manipulating the proportion of non-linguistic neutral trials (e.g., a string of #s). To date, the Stroop literature has treated "the task of reading" as a unitary process. In contrast, in word recognition research, there is a recognition that the task of reading is not invariant, but instead it could refer to a number of different processes depending on the task goal: For example, "reading" could refer to reading aloud: the generation of a speech response from the printed letter string (which may involve the application of sublexical letter-to-sound correspondence rules, or the retrieval of stored phonology from lexical memory), or it could refer to the retrieval of meaning of a word from lexical memory, or it could refer to orthographic processing (processing of letter identities and letter order contained in the spelling of the stimulus input).

Based on this assumption, Kinoshita, De Wit and Norris (2017), investigated which aspect of reading conflicts with colour processing by comparing performance on a vocal

Stroop task, where the display colours were named aloud, with performance on a manual Stroop task, where the response to the colour did not require speech output but instead required the categorisation of display colours by means of manual button presses (e.g. press the ‘z’ key for red; press the ‘x’ key for pink). The colours were displayed in five types of distractors that were not related to colour and varied in their degree of pronounceability: real words (e.g., hat), pseudo-words (hix), consonant strings (hgk), symbol strings (%$#), and neutral row of Xs (XXX). In the manual task, the pronounceability of the distractor had no effect on the size of Stroop interference (words = pseudowords = consonant strings = symbol strings = row of Xs), while in the vocal task, Stroop interference increased as the pronounceability of the distractor increased (words = pseudowords > consonant strings > symbol strings = row of Xs). The finding that interference was driven by the pronounceability of the distractor in the vocal Stroop task but not in the manual Stroop task was taken as evidence that the aspect of reading that produces interference in a Stroop task varies depending on the task goal (Kinoshita et al., 2017). In the vocal task, the task goal is to name the colour aloud, which involves speech production, while in the manual task the task goal is to categorise the colours using manual button presses. The pronounceability of the word drives interference in the vocal task but not in the manual task, due to only the vocal task requiring the use of phonology to generate a speech response.

In this thesis, I will examine the Stroop interference effect due to the task of reading by comparing the interference with responding to the colour produced by colour-unrelated words (e.g., ABBEY, NOVEL) relative to a string of #s, in the vocal Stroop task (Experiment 1) and the manual Stroop task (Experiment 2). These two types of distractors (colour-unrelated word and a string of #s) will be presented in an environment containing a high- vs. low-proportion of neutral trials (75% neutral vs. 25% neutral). On the assumption that when the experience of conflict is low, the attentional control over the task set is “put to sleep”

(Kalanthroff & Henik, 2014), it is expected that the Stroop interference due to the task conflict will be magnified in the high-neutral proportion condition. Further, based on the findings reported by Kinoshita et al. (2017), the "task of reading" was assumed to differ in the vocal Stroop task and the manual Stroop task. Specifically, the expectation was that the generation of phonology from a written word interferes with the task of naming the colour required in the vocal task, but not with the task of classifying the colour in the manual task. Accordingly, the word interference effect was predicted to be magnified in the high-neutral proportion condition in the vocal Stroop task; in contrast, in the manual task, the word interference effect was expected to be minimal overall, and not to be modulated by the neutral proportion manipulation.

In order to gain a finer understanding of the mechanism by which the attentional control over the task of reading can be achieved, I will analyse: 1) the modulation of the word interference effect by the previous trial type (the "Gratton effect"), and 2) the RT distribution. The rationale for these analyses will be described in the next two sections.

1.4 Dual Mechanism of Attentional Control: The Gratton Effect

An important theory of attentional control which provides a useful framework for explaining the management of task conflict in tasks like the Stroop task is the dual mechanism of control framework proposed by Braver (2012). According to this framework, there are two modes of control that differ in their temporal dynamics: proactive control and reactive control. Proactive control is an early selection mechanism that is engaged before the occurrence of conflict, which allows for the sustained maintenance of goal relevant information so that perception and behaviour can be guided by the task goal. In contrast, reactive control is a "late correction" mechanism, that is deployed as needed, on a trial by trial basis, following the detection of conflict. In other words, proactive control is goal driven and is used pre-emptively when conflict is expected, while reactive control is stimulus driven and is deployed after the conflict is detected.

If attentional control is deployed reactively following the experience of conflict it would be expected that there would be higher levels of reactive control following a conflict trial than following a trial that does not contain conflict. The effect of the experience of conflict on the recruitment of attentional control has commonly been investigated using the flanker task (Gratton, Coles & Donchin, 1992), where participants identify the direction of a central arrow that is flanked on either side by arrows. On congruent trials, the central arrow and the flanker arrows point in the same direction (e.g., << < <<), while on incongruent trials, the flanker arrows point in the opposite direction to the central arrow (e.g., << > <<). The flanker effect is the finding that participants are faster to identify the direction of the central arrow on congruent trials relative to incongruent trials, which has been taken as evidence that the irrelevant information about the direction of the flanker arrows is processed automatically and influences the speed at which participants respond to the central arrow. The finding that the flanker effect is reduced when the previous trial is incongruent relative to when the previous trial is congruent has been referred to as the 'Gratton effect' (Gratton et al. 1992).

Kerns et al. (2004) investigated whether the Gratton effect could be found using the Stroop task, by testing for the effect of previous trial type, which were either incongruent (where the word and display colour do not match) or congruent trials (where the word and display colour match). A Gratton effect was found, with the Stroop effect being smaller when the previous trial was an incongruent trial, relative to when the previous trial was a congruent trial. Furthermore, simple effects analysis revealed that RTs for incongruent trials were faster when the previous trial was an incongruent trial relative to when the previous trial was a congruent trial. These findings were explained as being due to the increased control following a conflict (an incongruent) trial. Kerns et al (2004) pointed out that unlike previous studies using the flanker task, their finding was obtained after excluding trials which involved exact stimulus repetitions (i.e., where the previous trial involved the same distractor-target configuration as the current trial) and hence provides direct support for the reactive control mechanism posited by the dual mechanism of control framework (Braver, 2012).

It is important to note that Kerns et al. (2004) did not include the neutral trials and what they assessed was whether the difference between the congruent and incongruent trials was modulated by previous trial type. Congruent trials are bivalent and hence according to Goldfarb and Henik (2007) are not free of task conflict. Their finding of the modulation of the congruence effect by previous trial type may therefore reflect greater reliance on the information originating in the nominally irrelevant word dimension following a congruent trial, rather than the control of the task of reading per se.

In the present thesis, I will examine the word interference effect as a function of previous trial type, as an index of reactive control. As the colour-unrelated words (e.g., ABBEY, NOVEL) do not contain information that are useful for determining the response (i.e., generating the speech code for the response colours or the semantic information relevant to which key to press), any modulation by previous trial type (word vs. a string of #s) cannot be due to the modulation of informational conflict; it can only reflect the modulation of task conflict (conflict due to the task of reading).

1.5 RT Distribution Analysis

While most Stroop studies have analysed interference effects at the level of mean RT, the present thesis will attempt to gain richer information by analysing the whole of the RT distribution. The method of RT distribution analysis used in the present study is quantile analysis (Balota & Yap, 2011). Quantile analysis is a non-parametric method of RT distribution analysis that involves rank ordering the RTs for each participant in each condition from fastest to slowest and then dividing them into equal size bins known as quantiles (e.g. the first quantile contains the fastest 25% of RTs, the second quantile contains the next faster 25% of RTs and so on). The quantile estimates for each condition can then be depicted graphically using a quantile plot (see plot A of Figure 1) and the size of the experimental effect as a function of quantiles can be depicted using a delta plot (see plot B of Figure 1).

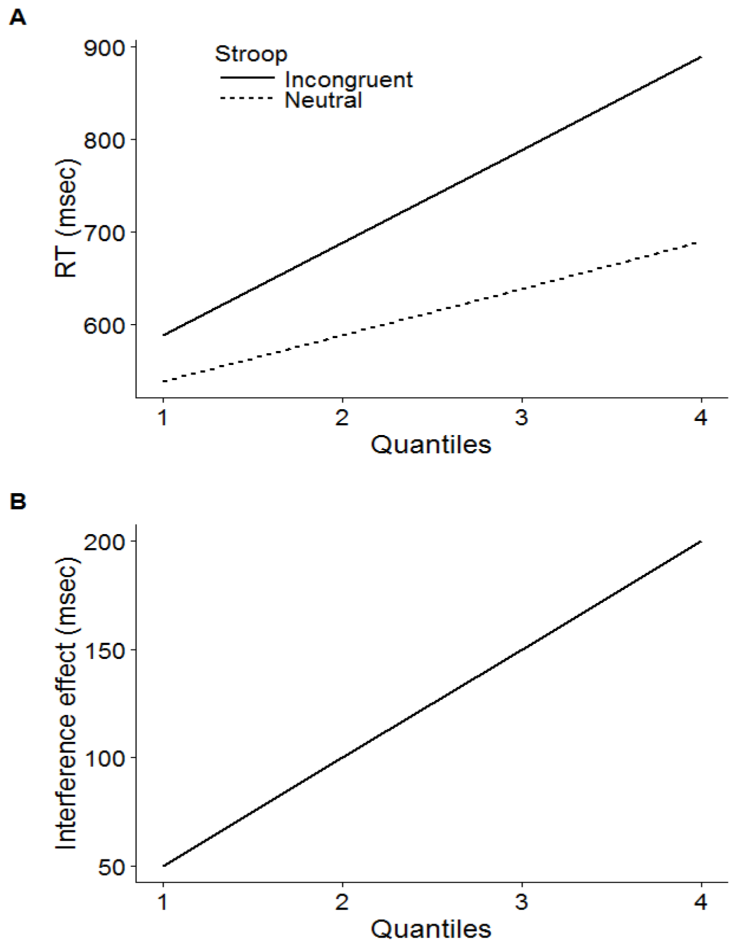

Figure 1. Idealised quantile plot (A) and delta plot (B) of a comparison between two experimental conditions.

Conflict tasks, such as the Stroop and Simon tasks (the Simon task will be described shortly) have been found to produce three general delta plot patterns (Pratte, Rouder, Morey & Feng, 2010): In one pattern, the delta slope shows a positive increase across the quantiles, indicating that the size of the effect increases as responses slow (see plot A of Figure 2). In another pattern, the delta slope is flat, indicating that the size of the effect remains constant across the quantiles (see plot B of Figure). In the third pattern, the delta slope is negative, indicating the size of the effect decreases as responses slow (see plot C of Figure 2).

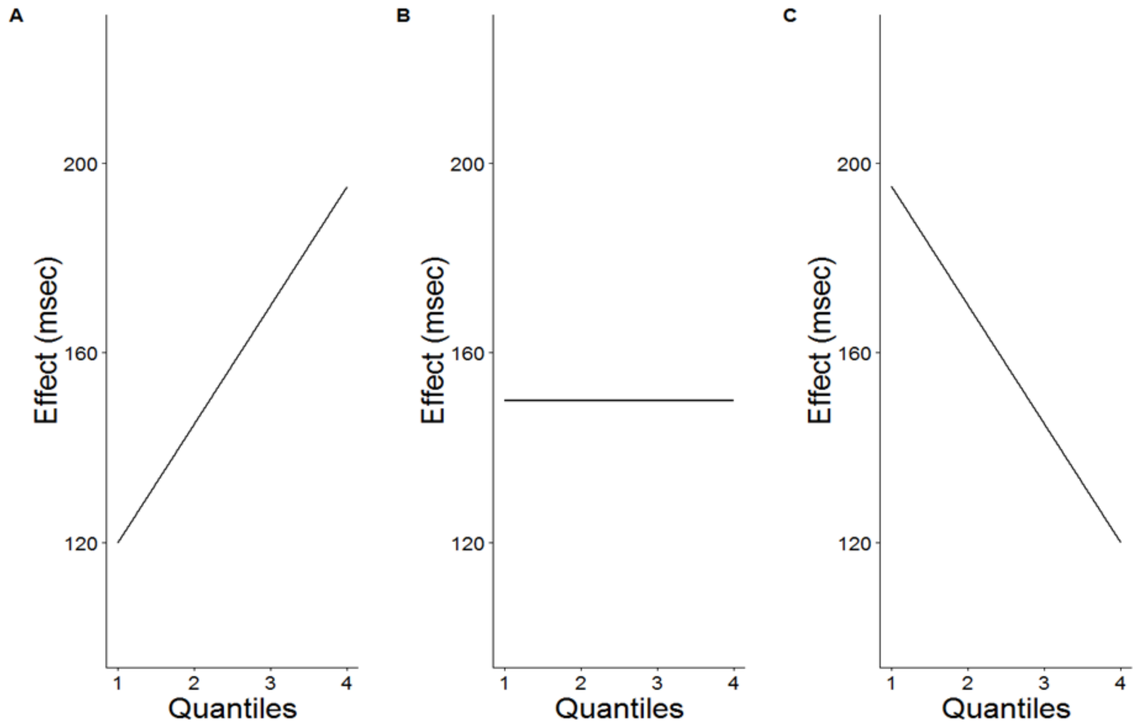

Figure 2. Idealised delta plot patterns. Plot A shows a positive delta slope; Plot B shows a flat delta slope; Plot C shows a negative delta slope.

Pratte et al. (2010) proposed that a positive delta slope is concordant with many evidence accumulation models, such as the diffusion model (Ratcliff, 1978) and the linear ballistic accumulator (Donkin, Brown & Heathcote, 2011). According to these models, information about a decision accumulates over time until a criterion is reached. Pratte et al. (2010) proposed that a positive delta slope could be explained as being due to a difference in the rate at which evidence accumulates between the experimental conditions. Pratte et al. (2010) found that the Stroop interference effect produced a positive delta slope, which was explained as being due to conflicting information from the word dimension of the stimulus being incorporated into the process of accumulating information towards the identification of the display colour. Specifically, the task of colour naming involves continuously sampling information from the display colour until the criterion is reached. When the display colour and word are spatially integrated, sampling information from the display colour inadvertently leads to sampling information from the word, which results in incongruent stimuli having a slower rate of evidence accumulation than neutral stimuli.

In contrast, in the primed Stroop task, where the distractor word is presented before the presentation of the target colour, the delta slope for the Stroop effect has been found to be flat, indicating that the size of the Stroop effect remains constant across the quantiles (Kinoshita, de Wit, Aji & Norris, 2017). This mirrors the delta plot pattern found in the semantic categorisation task (de Wit & Kinoshita, 2014), where participants respond as to whether a word belongs to a target semantic category (e.g. does the word *cat* belong to the semantic category *living thing).* The semantic priming effect is the finding that words are responded to faster when they are preceded by a semantically related prime than when they are preceded by a semantically unrelated prime (i.e. *dog*- CAT responded to faster than *bread*-CAT). As in the primed Stroop, the semantic priming effect has been shown to produce a flat delta slope (de Wit & Kinoshita, 2014). In both the primed Stroop and the semantic categorisation task, the primes are temporally separated from the target. Kinoshita et al. (2017) explained the flat slope in both tasks as being due to the process of accumulating evidence from the prime stopping when the prime ends. This results in the prime not influencing the rate at which evidence is accumulated towards the identification of the target as the processing of the prime has already finished before the target is presented. Instead, the information from the prime comes online before the presentation of the target, and provides a "head start" in the process of accumulating evidence towards the identification of the target.

The Simon effect has been shown to produce a negative delta slope, with the size of the Simon effect decreasing as RT slows (Pratte et al. 2010). In the Simon task (Simon, 1969), participants identify the colour of a stimulus, that is presented on the right or left side of the computer screen, using right or left button presses. The Simon effect is the finding that colours are identified faster when they are presented on the same side as the response button, relative to when they are presented on the opposite side to the response button. The Simon effect has been taken as evidence that irrelevant information about the spatial location of the distractor relative to the response button is processed automatically (Wiegand & Wascher, 2005). Pratte et al. (2010) suggested that the negative delta slope may reflect distracting information from the irrelevant dimension of the stimulus triggering the activation of a short-lasting motor response that decays over time. Further, Pratte et al. (2010) found that occasionally the Simon effect reverses for responses in the slowest quantile, which was explained in terms of increasing inhibition of the motor response over time.

1.6 Aims and predictions

The aim of the present research was to investigate the attentional control of the task of reading, by comparing the interference produced by colour-unrelated word distractors (e.g., NOVEL, ABBEY) relative to the non-linguistic string of #s, presented either in an environment containing a high proportion of neutral trials (75% neutral, 25% words) or a low proportion of neutral trials (25% neutral, 75% words). Based on the assumption that experiencing a high proportion of conflict-free (neutral) trials relaxes the attentional control of task sets and opens up the performance to task conflict (Goldfarb & Henik, 2007; Kalanthroff & Henik, 2014) the basic prediction was that a greater word interference effect would be observed in the high neutral proportion condition. Based on the findings of Kinoshita et al. (2017), it was assumed that the task of reading differs in the vocal and manual tasks, with the task of generating phonology from a written word interfering in the vocal task where speech output is required, but not in the manual task where colours are classified using manual button presses. It was therefore predicted that in the vocal task, the word interference effect would be magnified when neutral proportion was high relative to when neutral proportion was low, while in the manual task the word interference effect was predicted to be minimal and not modulated by neutral proportion. In addition to mean RT, quantile analysis was used to examine the effect of neutral proportion on the word interference effect at the level of the RT distribution

The second aim of the study was to investigate the cognitive mechanisms underlying attentional control of the task of reading. According to the dual mechanisms of control framework (Braver, 2012), attentional control can operate proactively, in a goal directed manner, or reactively, following the experience of conflict. Consistent with increased reactive control following the experience of conflict, previous research (Kerns et al., 2004) found that the size of the Stroop effect (incongruent trials slower than congruent trials) was reduced when the previous trial was incongruent relative to when the previous trial was congruent. In the present study, the modulation of the word interference effect by previous trial type was used as an index of reactive control. The modulation of the word interference effect by previous trial type cannot be due to reactive control modulating informational conflict, as the colour unrelated words do not contain colour related information that could compete with the information provided by the display colour, but would instead reflect the modulation of task conflict. It was therefore predicted that if neutral proportion modulates reactive attentional control of the task conflict, that the reduction in the word interference effect when the previous trial was a word trial relative to when the previous trial was a neutral trial, would be larger in the low neutral proportion condition, than in the high neutral proportion condition.

2. Experiment 1 (Vocal Stroop task)

2.1 Method

Participants. Forty undergraduate Macquarie University psychology students participated in the experiment in return for course credit. The participants were randomly assigned to either the high neutral proportion condition or the low neutral proportion condition, based on their order of arrival. In the low neutral proportion condition, there were 21 participants (13 females and 8 males), with an age range of 18 to 43 years (M = 21, SD = 6). In the high neutral proportion condition, there were 19 participants (17 females and 2 males), with an age range of 18 to 39 years (M = 21, SD = 5).

Design. The experiment was a vocal Stroop task, with distractor type (words vs. hash signs) manipulated within subjects and neutral proportion (25% neutral proportion vs. 75% neutral proportion) manipulated between groups. The dependent variable was colour naming RT measured in milliseconds.

Materials. The word distractors were 180, five-letter words that were not associated with specific colour (e.g., ABBEY, NOVEL) selected from the English Lexicon Project (ELP) database (Balota, et al. 2007, available at http://elexicon.wustl.edu/). The neutral distractor was a string of # signs. They were presented in one of four colours: red, pink, green or blue. As overlap between the initial letters of word and display colour stimuli has been shown to reduce the Stroop interference effect (Coltheart, Woollams, Kinoshita & Perry, 1999) the initial letters of the word stimuli did not match the initial letters of the display colour stimuli (i.e. the word stimuli did not begin with the letters R, P, G or B). The words were low frequency (range of 2-20 per million, M = 10.94, SD = 5.04) based on the SUBTLEX corpus (Brysbaert & New, 2009) and had an orthographic neighbourhood density ("Coltheart's N", Coltheart et al., 1977) that ranged from 0 to 13 (M = 2.87, SD = 2.68).

Stimulus lists were generated for the high and low neutral proportion conditions. Each list contained a total of 240 trials, made up of 120 critical trials and 120 filler trials. The critical trials were the same in both conditions and consisted of 60 word trials and 60 hash symbol trials. In the high neutral proportion condition, the filler trials were 120 hash symbol trials and in the low neutral proportion condition the filler trials were 120 word trials. In total, the low neutral proportion list contained 180 word trials (75% of trials) and 60 hash symbol trials (25% of trials) and the high neutral proportion list contained 60 word trials (25% of trials) and 180 hash symbol trials (75% of trials). The words used in the critical trials are listed in Appendix A.

Apparatus and procedure. The stimuli were displayed using a flat-screen computer monitor, and participants made their responses using a head-worn microphone. DMDX software was used to present the stimuli and to record the colour naming RTs (Forster & Forster, 2003). Stimulus display was synchronised to screen refresh rate (10.01ms).

Participants were tested individually, seated in front of the computer monitor, wearing a head-mounted microphone. The participants were instructed that they would be presented with a series of words, or hash signs, printed in colour and that their task was to name aloud the colour as quickly and as accurately as possible, using the microphone. The participants then completed a block of 16 practice trials, which contained the same proportion of trial types (colour unrelated and hash symbols) as in the experimental blocks. Following the practice trials, the participants completed 240 experimental trials, which were divided into three blocks of 80 trials, with each block containing a representative proportion of the trial types, occurring in each of the four response colours equally often. At the end of each block, the participants were instructed to take a self-timed break. During the experiment, the experimenter recorded the errors.

Each trial began with a fixation signal (a plus sign) that was presented in the centre of the screen for 250 ms, followed by a blank screen for 50 ms. Following the blank screen, either a word, or a string of hash symbols, printed in one of the four colours (red, pink, green, blue), was presented in the centre of the screen. The stimulus remained on screen until the participants made their response, or the trial timed out after 2000 ms. Following the participant's response or trial timeout, the experiment proceeded to the next trial. Stimuli were always presented using Arial font, size 10, against a black background. No feedback was given to the participants during the experiment.

2.2 Results

Two sets of analyses are reported below. One is an analysis of individual trial RTs from correct trials using the linear mixed effects model (LME), with subjects and stimuli as crossed random effects (Baayen, 2008). This was used to analyse the modulation of word interference effect by the neutral proportion, and the trial sequence effect (the modulation of word interference effect by previous trial type). The second analysis examined the effect of neutral proportion on the word interference effect at the level of the RT distribution.

Linear mixed effects model: Neutral proportion effect. Preliminary treatment of the data involved excluding 391 error trials, and 19 trials where the RT was less than 250 ms as fast outliers. The shape of the RT distribution was examined and a log transform was used to normalise the data so that it met the distributional assumption of the LME model. The filler trials (4599 trials) were excluded from the analysis and the remaining critical trials (4591 trials) were analysed using the LME model. The mean RTs for the critical trials are summarised in Table 1.

The LME model analysis was performed using the lme4 package (Bates, Maechler, Bolker, & Walker, 2016) in R 3.3.1 (R Core Team, 2016-06-21). The lmerTest package

(Kuznetsova, Brockhoff, & Christensen, 2016, version 2.0-32) was used to estimate the degrees of freedom using Satterthwaite approximations and to calculate the p-values. The fixed factors used in the analysis were distractor type (words vs. hash symbols) and neutral proportion (low neutral proportion vs. high neutral proportion). Distractor type was referenced to the neutral #-sign condition and neutral proportion was deviation contrast coded (-.5, .5). The random effect factors were subjects (41) and stimuli (64 colour-distractor combinations). More complex models that included random slopes were tested, and where the model fit was no better, the simpler model with the subject and stimulus intercepts are reported. The LME output generated by the R statistical package can be found in Appendix B.

A model with random slopes for distractor type on subjects is reported as it had improved model fit relative to the random intercept model. Using R syntax, the reported model is: logRT ~ distractor_type * neutral_ proportion + (1 | stimulus) + (distractor_type | subject). Averaged over the high- and low- neutral proportion conditions, the effect of distractor type was significant ($t = 5.09$, $p < .0001$), with slower RTs for words than for hash symbols (by 83 ms). The interaction between the interference for words and neutral proportion was significant ($t = 3.87$, $p < .001$) indicating a neutral proportion effect, with the interference for words being larger in the high neutral proportion condition (106 ms) than in the low neutral proportion condition (62 ms).

The low- and high- neutral proportion conditions were then analysed separately. For both analyses, the model with random slopes for distractor type on subjects is reported: In R syntax: logRT ~ distractor_type + (distractor_type | subject) + (1 | stimulus). In the low neutral proportion condition, the distractor type effect was significant ($t = 3.48$, $p < .01$), with slower RTs for words than for hash symbols (62 ms). In the high neutral proportion condition also, the distractor type effect was significant ($t = 6.41$, $p < .001$), with slower RTs for words than for hash symbols (106 ms).

Table 1
Mean and Standard Deviations (in Parentheses) of Colour Response Latencies (RT, ms) and Word Interference Effect (Word-Neutral) for critical trials in Experiment 1 (Vocal) as a function of distractor type and neutral proportion

	Distractor type		
	Word	Neutral	Word Interference (Word-####)
Example	mercy	####	
High neutral proportion	657 (156)	551 (131)	106 (203)
Low neutral proportion	604 (134)	542 (106)	62 (169)

Linear mixed effects model: The trial sequence effect. Analysing for the effect of previous trial type usually involves excluding response colour repetition trials, which are trials that have the same response colour as the previous trial (Kerns et al., 2004). This was not necessary in the present experiment as the experimental lists were pseudorandomised so that they did not contain response colour repetitions. The first trial for each subject (40 trials), error trials (385 trials) and trials with an RT less than 250 ms (19 trials) were excluded from the analysis. The shape of the RT distribution was examined and a log transform was applied to normalise the distribution to meet the distributional assumption of the LME model. In this analysis, in order to ensure that there were enough trials, both filler trials and critical trials were included in the analysis, which resulted in a total of 9156 trials being analysed using the LME model.

The fixed effect factors used in the analysis were distractor type (words vs. hash symbols), previous trial distractor type (words vs. hash symbols) and neutral proportion (low vs. high). Neutral proportion was deviation contrast coded (-.5, .5). A model with random slopes for distractor type on subjects is reported as it had improved model fit relative to the random intercept model. Using R syntax, the reported model is: logRT ~ distractor_type * previous_distractor_type * neutral_ proportion + (1 | stimulus) + (distractor_type | subject).

The mean RTs as a function of previous trial distractor type and neutral proportion are shown in Table 2. The interaction between distractor type and previous trial type was not significant ($t = 0.713$, $p = .48$), however, the interaction between neutral proportion, word interference and previous trial type was marginally significant ($t = 1.976$, $p = .048$), which suggests that the effect of previous trial type was modulated by neutral proportion.

The low- and high- neutral proportion conditions were then analysed separately. For both analyses, the model with random slopes for distractor type on subjects is reported: In R syntax: logRT ~ distractor_type * previous_distractor_type + (1 | stimulus) + (distractor_type | subject). In the low neutral proportion condition, there was a significant interaction between distractor type and previous trial type ($t = 2.175$, $p < .05$), with the magnitude of the interference for words being significantly reduced when the previous trial distractor was a word (19 ms) relative to when the previous trial distractor was a string of hash symbols (60 ms). In contrast, in the high neutral proportion condition, the interaction between the distractor type and previous trial type was non-significant ($t < 1$, $p = .841$). As can be seen in Table 2, the magnitude of the word interference effect was the same when the distractor in the previous trial was a word (106 ms) or neutral hash symbols (107 ms).

Table 2

Mean and Standard Deviations (in Parentheses) of Colour Response Latencies (RT, ms) and Word Interference effect (Word-Neutral) in Experiment 1 (Vocal) as a function of distractor type, previous trial type and neutral proportion

		Distractor type		
Neutral proportion	Previous trial type	Neutral	Word	Word Interference (Word – Neutral)
Low	Word	572 (122)	591 (125)	19 (176)
	Neutral	541 (105)	601 (136)	60 (169)
High	Word	550 (124)	656 (157)	106 (196)
	Neutral	556 (120)	663 (133)	107 (171)

RT distribution analysis. The correct RTs were analysed using QMPE version 2.0 (Brown & Heathcote, 2001). The quantiles were estimated by ordering the correct RTs, for each subject in each condition, from fastest to slowest and then dividing them into four equal sized bin (the first bin contains the fastest 25% of RT, the second bin contains the next fastest 25% and so on). The average of the slowest trial of the upper bin and the fastest trial of the lower bin made the four quantile estimates, which results in the quantile estimates not being unduly affected by fast or slow outliers. The quantiles were analysed using a 4 (quantiles) X 2 (neutral proportion: high vs low) X 2 (distractor type: words vs neutral) ANOVA. The main effect of distractor type was significant, $F(1, 38) = 214.904$, $p < .001$, i.e. word distractors interfered with colour naming relative to neutral # symbols. There was a significant two-way interaction between distractor type and neutral proportion, $F(1, 38) = 15.886$, $p < .001$, with the word interference effect being larger in the high neutral proportion condition than in the low neutral proportion condition. There was a significant two-way interaction between distractor type and the linear trend contrast of the quantiles factor: $F(1, 38) = 40.336$, p = < .001, indicating that averaged across the high- and low- neutral proportion conditions, the word interference effect increased across the quantiles. The three-way linear interaction between distractor type, linear trend contrast of the quantiles factor and neutral proportion was non-significant: $F(1, 38) = 1.044$, $p = .313$, indicating that the rate of increase in the word interference effect across quantiles (the delta slope) was constant in the high- and low- neutral proportion conditions (see Figure 3).

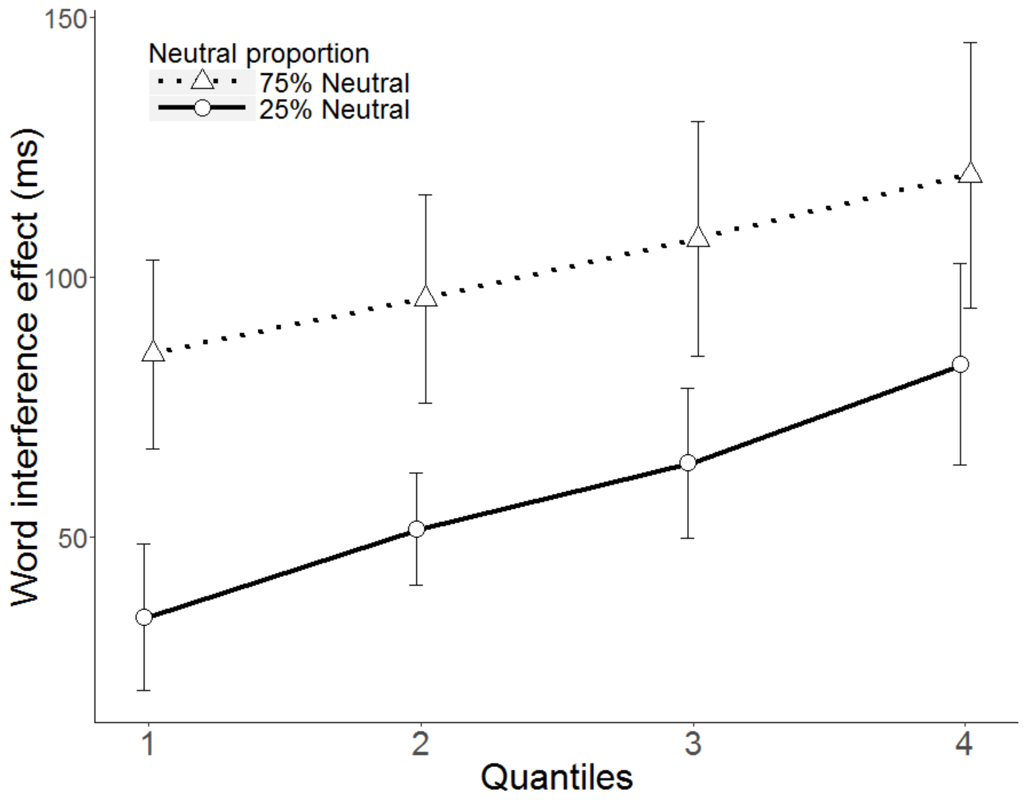

Figure 3. The delta plot depicts the size of the word interference effect (Word – Neutral) as a function of quantiles and neutral proportion in the vocal task used in Experiment 1. The error bars are 95% confidence intervals.

2.3 Discussion

The aim of the present research was to investigate attentional control of task conflict by comparing the interference for words vs non-linguistic strings when neutral proportion was high relative to when neutral proportion was low. Based on the assumption that a high proportion of neutral trials would reduce the expectation of conflict and the recruitment of attentional control (Goldfarb & Henik, 2007), it was predicted that the word interference effect would be larger in the high neutral proportion condition relative to the low neutral proportion condition. It was also assumed that the task of reading differs in the vocal and manual tasks, with the process of generating phonology from a written word interfering with colour naming in the vocal task, where phonology is used to generate a speech response, but not in the manual task, where responses are made by way of manual button presses (Kinoshita et al. 2017). It was therefore predicted that in the vocal task, the word interference effect would be magnified in the high neutral proportion condition relative to the low neutral proportion condition, while in the manual task, it was predicted that word interference would be minimal and not modulated by neutral proportion.

Consistent with predictions, in the vocal task used in Experiment 1, there was a large word interference effect (RTs for words were 83 ms slower than RTs for non-linguistic strings) which was moderated by neutral proportion, with the interference for words being larger in the high neutral proportion condition (106 ms) than in the low neutral proportion condition (62 ms). Neutral proportion has been found to moderate the standard Stroop interference effect (Tzelgov et al. 1992; Goldfarb & Henik, 2007), but this is the first time it has been found using words that were not related to colour (e.g. ABBEY; MERCY). The most common explanation for the Stroop interference effect is that there is an informational conflict between the colour related information supplied by the word and display colour dimensions of the stimulus (Goldfarb & Henik, 2007). However, the word interference effect in Experiment 1 was not consistent with informational conflict, due to the word stimulus being unrelated to colour. More recently, it has been recognised that the Stroop stimuli contain another form of conflict, namely, task conflict, which refers to a conflict between the task-sets associated with the stimulus. The concept of a task-set comes from the task-switching literature (e.g., Rogers & Monsell, 1995), and refers to the automatic tendency triggered by the stimulus to perform the task associated with it. The word stimulus used in Experiment 1 were “bivalent”, which means that they were associated with two task-sets: the task-set of reading and colour naming. It is proposed that the word interference effect in Experiment 1 was due to a task conflict between the task-sets of reading and colour naming. Furthermore, the finding that the word interference effect was magnified in the high neutral proportion condition relative to the low neutral proportion condition, is taken as evidence that the task conflict can be controlled using attention. To quote Kalanthroff & Henik (2014), when the expectation of conflict is low, the attentional control over the task is "put to sleep", which opens up performance on the colour naming task to interference from the task of reading, which results in increased interference from the word dimension of the stimulus.

In addition to mean RT, quantile analysis was used to examine the effect of neutral proportion on the word interference effect at the level of the RT distribution. The results of the quantile analysis indicated that the word interference effect produced a positive delta slope, which indicates that the size of the word interference effect increased in magnitude across the quantiles of the RT distribution. According to Pratte et al. (2010) a positive delta slope is concordant with a number of evidence accumulation models, such as the diffusion (Ratcliff, 1978) and linear ballistic accumulator (Donkin, Brown & Heathcote, 2011) models, which propose that evidence towards a decision slowly accumulates over time until a criterion is reached. These models explain a positive delta slope as being due to a difference in the rate at which evidence accumulates between experimental conditions. Pratte et al. (2010) found that the delta slope for the Stroop interference effect was positive, which was explained as being due to a reduced rate of evidence accumulation for incongruent word stimuli (e.g. the word RED displayed in blue) relative to neutral stimuli (e.g. #### displayed in RED), due to conflicting information from the incongruent word being incorporated into the process of accumulating information towards the identification of the display colour. A significant difference between the present research and the research by Pratte et al. (2010) is that in the present research the word stimuli were not semantically related to colour. Therefore, the positive delta slope cannot reflect the accumulation of conflicting semantic information from the word. One possibility is that the phonological information provided by the word stimulus conflicted with the phonological information provided by the display colour. For example, for the word ABBEY displayed in blue, there is a conflict between the initial phonemes of the word and display colour. From this perspective, the positive delta slope for the word interference effect in Experiment 1 reflects a reduced rate of evidence accumulation for words relative to non-linguistic strings, due to conflicting phonological information from the word being incorporated into the process of accumulating evidence towards the identification of the display colour.

Interestingly, the delta slope for the interference for words was not modulated by neutral proportion, with the slope of the delta plot being equivalent in the high and low neutral proportion conditions. Instead, neutral proportion magnified the interference for words from the earliest quantiles, which then remained constant across the quantiles. A flat delta slope has also been found for the Stroop effect in the primed Stroop task (Kinoshita et al. 2017) and for the semantic priming effect in the semantic categorisation task (de Wit & Kinoshita, 2014). These findings were taken as evidence that the information from the prime did not influence the rate of evidence accumulation towards the target, but instead changed the starting point of the evidence accumulation process, with the prime providing a “head start” in the process of accumulating evidence towards the identification of the display colour. In line with Kinoshita et al. (2017), it is proposed that the flat delta slope for the neutral proportion effect in Experiment 1 indicated that neutral proportion did not influence the rate of evidence accumulation, but instead influenced the starting point of the evidence accumulation process. Specifically, it is proposed that attentional control was relaxed in the high neutral proportion condition which resulted in the task-set of reading being triggered exogenously by the word dimension of the stimulus. This meant that before the process of accumulating evidence from the display colour could begin, the task of reading needed to be inhibited. However, when neutral proportion was low and conflict was expected, attentional control could be used to prevent the word from triggering the task-set of reading, which resulted in the task of colour naming starting sooner in the low neutral proportion condition relative to the high neutral proportion condition.

The second aim of the thesis was to investigate the cognitive processes that allow for attentional control of the task conflict. According to the dual mechanisms of control framework, there are two modes of attentional control that differ in their temporal dynamics: Proactive control, that is goal directed and is deployed before the experience of conflict and reactive control, which is a “late correction mechanism” that is deployed following the experience of conflict. Consistent with reactive control, Kerns et al. (2004) found that the Stroop effect was modulated by previous trial type, i.e. there was a “Gratton effect”. Following on from Kern’s et al. (2004) the present study used the Gratton effect as a measure of reactive control. It was predicted that if neutral proportion modulates reactive control, then the modulation of the word interference effect by previous trial type would be greater in the low neutral proportion condition relative to the high neutral proportion condition. Consistent with predictions, it was found that neutral proportion modulated the effect of previous trial type on the word interference effect. In the low neutral proportion condition, the word interference effect was reduced when the previous trial was a word trial relative to when the previous trial was a neutral trial. In contrast, in the high neutral proportion condition, the effect of previous trial type did not influence the word interference effect.

An important difference between the Kerns et al. (2004) research and the present research is that Kerns et al. (2004) examined the modulation of the Stroop congruence effect (RTs faster for congruent trials faster than for incongruent trials) by previous trials type. Also, congruent stimuli may not be conflict free, due to being “bivalent” and containing a task conflict between the task-sets of reading and colour naming. Kerns et al. (2004) findings may therefore reflect greater reliance on the information in the word dimension following a congruent trial, rather than previous trial type modulating task conflict. In the present study, colour unrelated words were used, which did not contain information related to a specific colour. It is therefore proposed that the modulation of the word interference effect in Experiment 1 by previous trial type, reflected the modulation of reactive control over task conflict.

In conclusion, the results of Experiment 1 indicated that the word interference effect was modulated by neutral proportion, with a larger word interference effect when neutral proportion was high relative to when neutral proportion was low. This was taken as evidence that neutral proportion modulates attentional control of task conflict. Further information about the cognitive mechanisms underlying the neutral proportion effect was gained by investigating whether neutral proportion modulated the effect or previous trial type on the word interference effect. In the low neutral proportion condition, the word interference effect was larger when the previous trial was a word trial relative to when the previous trial was a neutral trial, while in the high neutral proportion condition, previous trial type did not modulate the word interference effect. This was taken as evidence that neutral proportion modulated the recruitment of reactive control of task conflict.

The next experiment will investigate the effect of neutral proportion on the word interference effect in a manual Stroop task, where responses are made using manual button presses. Based on the findings of Kinoshita et al. (2017), that the process of generating phonology from a written word interferes in the vocal task, where a speech response is required, but not in the manual task, it was predicted that the word interference in the manual task would be minimal and not modulated by neutral proportion.

3. Experiment 2

3.1 Method

Participants. Forty-nine undergraduate Macquarie University psychology students participated in the experiment in return for course credit. The participants were randomly assigned to either the high neutral proportion condition or the low neutral proportion condition, based on their order of arrival. In the low neutral proportion condition, there were 25 participants (18 females and 7 males), with an age range of 18 to 35 years (*M* = 22, *SD* = 6). In the high neutral proportion condition, there were 24 participants (20 females and 4 males), with an age range of 18 to 39 years (*M* = 21, *SD* = 5).

The *design, materials, stimuli, apparatus & procedure* used in Experiment 2 were the same as those used in Experiment 1 with the exception that the participants made their responses using a computer keyboard, with the Z key corresponding to *red*, the X key corresponding to *yellow*, the N key corresponding to *green* and the M key corresponding to *blue*.

3.2 Results

Two sets of analyses were performed: Linear mixed effects model (LME), with subjects and stimuli as crossed random effects (Baayen, 2008), was used to analyse the effect of neutral proportion on the interference for words, and to analyse for the trial sequence effect (the modulation of interference by previous trial type). The effect of neutral proportion on the interference for words was analysed at the level of the RT distribution using quantile analysis.

Analysis of the neutral proportion effect. Preliminary treatment of the data involved excluding 599 error trials and 5594 filler trials. The shape of the RT distribution was examined and a log transform was applied to normalise the data so that it met the distributional assumption of the LME model. In total, 5567 trials were analysed using the LME model. The mean RTs for the critical trials in Experiment 2 as a function of neutral proportion and distractor type are summarised in Table 3.

The fixed factors used in the analysis were distractor type (words vs. hash symbols) and neutral proportion (low neutral proportion vs. high neutral proportion). Neutral proportion was deviation contrast coded (-.5, .5), the reference category for distractor type was words. The model with random slopes for distractor type on subjects is reported. Using R syntax, the reported model is: LogRT ~ distractor_type * neutral_ proportion + (1 | stimulus) + (distractor_type| subjects).

The interference for words (12 ms) was not significant (t = 1.397, p = .179). However, the interaction between the interference for words and neutral proportion was significant (t = 3.216, p < .01), with the interference for words being larger in the high neutral proportion condition (30 ms) than in the low neutral proportion condition (-7 ms).

In the analysis of the low neutral proportion condition, the random intercept model is reported due to the inclusion of random slopes not improving model fit. In R syntax, the reported model is: LogRT ~ distractor_type + (1 | subject) + (1 | stimulus). In the low neutral proportion condition, the interference for words (-7 ms) was not significant (t < 1, p = .597).

In the analysis of the high neutral proportion condition, the model with random slopes is reported. Using R syntax, the reported model is: LogRT ~ distractor_type + (1 | stimulus) + (distractor_type | subject). In the high neutral proportion condition, the interference for words (30 ms) was significant (t = 2.63, p < .05).

Table 3

Mean and Standard Deviations (in Parentheses) of Colour Response Latencies (RT, ms) and Word Interference (ms) for Critical Trials in Experiment 2 (Manual) as a Function of Distractor Type and Neutral Proportion

	Distractor type		
	Word	Neutral	Word interference (Word – Neutral)
Example	mercy	XXXX	….
High neutral proportion	667 (235)	637 (245)	30 (339)
Low neutral proportion	630 (240)	637 (242)	-7 (345)

Analysis of the effect of previous trial type. Preliminary treatment of the data involved excluding response colour repetition trials (2702 trials), the first trial for each subject (49 trials) and error trials (591 trials). The shape of the RT distribution was examined and a log transform was applied to normalise the distribution to meet the distributional assumption of the LME model. To ensure that there were enough trials, both filler trials and critical trials were included in the analysis, which resulted in a total of 8418 trials being analysed using the LME model.

The fixed factors used in the analysis were distractor type (words vs. hash symbols), previous trial distractor type (words vs. hash symbols) and neutral proportion (low neutral proportion vs. high neutral proportion). Neutral proportion was deviation contrast coded (-.5, .5), the reference category for distractor type was words and the reference category for previous trial distractor type was hash symbols. A model with random slopes for distractor type on subjects is reported as it had improved model fit relative to the random intercept model. Using R syntax, the reported model is: logRT ~ distractor_type * previous_distractor_type * neutral_ proportion + (1 | stimulus) + (distractor_type | subject). The mean RT as a function of distractor type, previous trial type and neutral proportion are shown in Table 4.

The interaction between the interference for words and previous trial type was not significant ($t = 0.267$, $p = .79$), with there being no significant difference between the magnitude of the interference for words when the previous trial distractor was a word (23 ms) relative to when the previous trial distractor was a string of hash symbols (11 ms). There was no significant interaction between neutral proportion, word interference and previous trial type ($t < 1$, $p = .83$).

Table 4

Mean and Standard Deviations (in Parentheses) of Colour Response Latencies (RT, ms) and Word Interference (Word-XXXX) in Experiment 2 (Manual) as a function of distractor type, previous trial type and neutral proportion

		Distractor type		
Neutral proportion	Previous trial type	Neutral	Word	Word interference (Word – Neutral)
Low	Neutral	674 (273)	674 (254)	0 (372)
	Word	667 (241)	674 (252)	7 (345)
High	Neutral	677 (253)	699 (238)	22 (349)
	Word	689 (259)	727 (257)	38 (355)

In the analysis of the low neutral proportion condition, the model with random intercepts is reported. Using R syntax, the reported model is: logRT ~ distractor_type * previous_distractor_type + (1 | stimulus) + (1 | subject). In the low neutral proportion condition, there was no significant interaction between the interference for words and previous trial type ($t < 1$, $p = .999$), with there being no significant difference between the magnitude of the interference for words when the previous trial distractor was a word (7 ms) relative to when the previous trial distractor was a string of hash symbols (0 ms).

In the analysis of the high neutral proportion condition, the model with random slopes for distractor type on subjects is reported. Using R syntax, the reported model is: logrt ~ distractor_type * previous_distractor_type + (1 | stimulus) + (distractor_type| subject). In the high neutral proportion condition, there was no significant interaction between the interference for words and previous trial type ($t < 1$, $p = .729$), with there being no significant difference between the magnitude of the interference for words when the previous trial distractor was a word relative (38 ms) to when the previous trial distractor was a string of hash symbols (22 ms).

Quantile analysis. The quantile analysis was performed using a 4 (quantiles) X 2 (neutral proportion: high vs low) X 2 (distractor type: words vs hash symbol strings) ANOVA.

Averaged across the neutral proportion conditions, the interference for words was not significant, F (1, 48) = 2.323, p = .134. There was a small increase in the interference for words across the quantiles, however it did not reach significance, as shown by the non-significant two-way linear interaction between the interference for words and quantiles: F (1, 48) < 1 , p = .66. The word interference effect was modulated by neutral proportion, as shown by the significant two-way interaction between distractor type and neutral proportion, F (1, 48) = 5.77, p < .05, with the interference for words being larger in the high neutral proportion condition (27 ms) than in the low neutral proportion condition (- 6 ms). The slope of the delta plot for the interference for words was not moderated by neutral proportion as shown by the non-significant three-way linear interaction between interference for words, quantiles and neutral proportion: F (1, 48) = 1.147, p= .29.

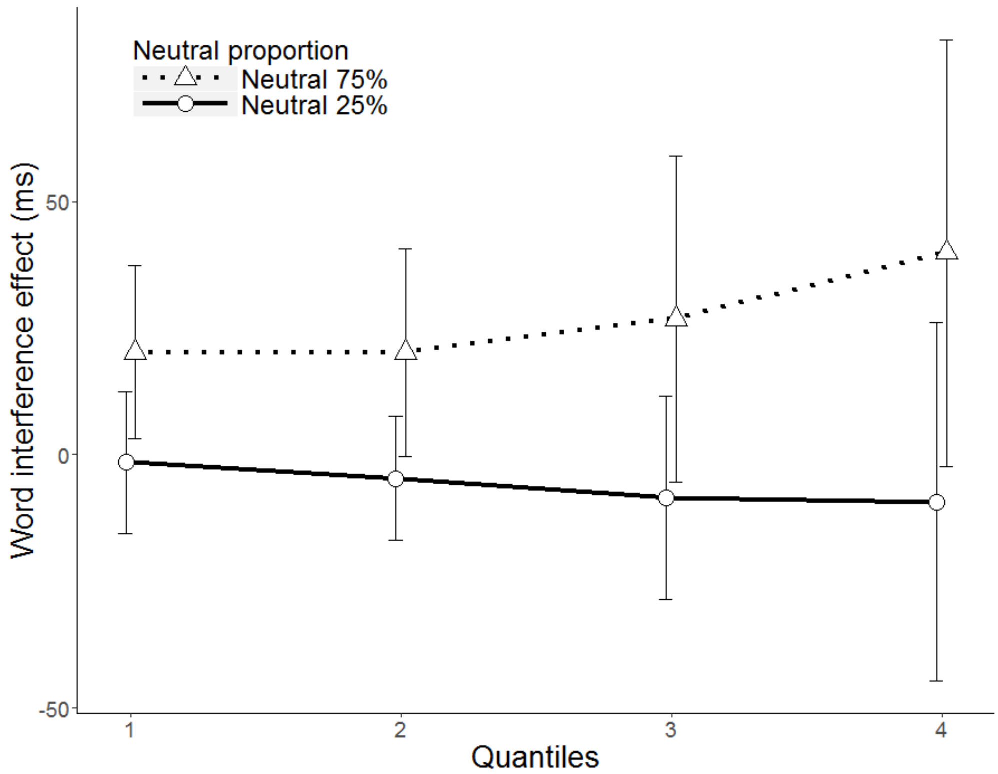

Figure 4. The delta plots depict the size of the interference for words as a function of quantiles and neutral proportion in the manual task used in Experiment 2. The error bars are 95% confidence intervals.

3.3 Discussion

The key findings for the manual task in Experiment 2 was that (a) (contrary to expectation), the word interference effect was moderated by neutral proportion, with strong interference for words being found in the high neutral proportion condition. (b) Previous trial type did not moderate the interference for words in the manual task; (c) The quantile analysis revealed that the word interference produced a flat delta slope that was not moderated by neutral proportion; The implications of these findings will be discussed in the general discussion.

4. Comparison of Experiment 1 and 2.

To gain a finer understanding of the difference between the vocal and manual tasks, Experiment 1 and 2 were combined and effects involving the response modality (vocal vs. manual) factor was examined.

Analysis of the neutral proportion effect. The critical trials in Experiment 1 and 2 were analysed using LME. The fixed factors used in the analysis were response modality (vocal vs manual), distractor type (words vs. hash symbols) and neutral proportion (low neutral proportion vs. high neutral proportion). Neutral proportion was deviation contrast coded (-.5, .5), the reference category for distractor type was words. The random intercept model is reported due to the inclusion of random slopes not improving model fit. Using R syntax, the reported model is: logRT ~ response modality*distractor_type * neutral_ proportion + (1 | stimulus) + (1| subject).

The interaction between response modality and the interference for words was significant ($t = 11.342$, $p < .0005$), with the interference for words being larger in the vocal task (83 ms) than in the manual task (5 ms). The interaction between response modality, neutral proportion and the interference for words, was not significant ($t < 0$, $p = .906$)

indicating that the neutral proportion modulated the word interference effect similarly in the vocal and manual tasks.

In the analysis of the low neutral proportion condition, the random intercept model is reported. In the low neutral proportion condition, the interaction between response modality and the interference for words was significant ($t = 8.486$, $p < .0005$), with the interference for words being larger in the vocal task (62 ms) than in the manual task (-7 ms).

In the analysis of the high neutral proportion condition, the random slopes model is reported. In the high neutral proportion condition, the interaction between response modality and the interference for words was significant ($t = 5.008$, $p < .0005$), with the interference for words being larger in the vocal task (106 ms) than in the manual task (30 ms)

Quantile analysis. The correct RTs were analysed using a 4 (quantiles) X 2 (neutral proportion: high vs low) X 2 (distractor type: words vs neutral) X 2 (response modality: vocal vs manual) ANOVA. The main effect of distractor type was significant, $F (1, 85) = 100.746$, $p < .001$, i.e. averaged across response modality and neutral proportion the word distractors interfered with colour naming relative to neutral # symbols.

The two-way interaction between distractor type and response modality was significant, $F (1, 85) = 59.851$, $p < .001$, indicating that averaged across neutral proportion, the word interference effect was stronger in the vocal task than in the manual task.

There was a significant two-way interaction between distractor type and neutral proportion, $F (1, 85) = 17.889$, $p < .001$, indicating that averaged across response modality the word interference effect was larger in the high neutral proportion condition than in the low neutral proportion condition.

The three-way interaction between response modality, neutral proportion and word interference effect was not significant, $F(1, 85) = 0.364$, $p = .548$, indicating that response modality did not modulate the effect of neutral proportion on the word interference effect.

There was a significant two-way interaction between distractor type and the linear trend contrast of the quantiles factor: $F(1,85) = 9.071$, $p < .01$, indicating that averaged across response modality and neutral proportion, the word interference effect increased across the quantiles.

The three-way linear interaction between distractor type, linear trend contrast of the quantiles factor and neutral proportion was non-significant: $F(1, 85) = 0.221$, $p = .639$, indicating that averaged across response modality, the rate of increase in the word interference effect across quantiles (the delta slope) was constant in the high- and low-neutral proportion conditions.

The three-way linear interaction between distractor type, linear trend across the quantiles and response modality was significant, $F(1, 85) = 5.146$, $p < .05$, indicating that averaged across neutral proportion, the rate of increase in the word interference effect across quantiles, was larger in the vocal task than in the manual task.

The four-way interaction between distractor type, linear trend contrast of the quantiles factor, neutral proportion and response modality was non-significant, $F(1, 85) = 1.741$, $p = .191$, indicating that the influence of response modality on the rate of the increase in the word interference effect across quantiles was not modulated by neutral proportion.

5. General discussion

Kinoshita et al. (2017) proposed that the task of reading in the Stroop task varies according to the task goal. In the vocal task, the task goal involves speech articulation, and the task of reading that interferes is the phonological component of reading. It is proposed that the word interference observed in the vocal task in Experiment 1 was due to a conflict between the phonological information provided by the word and display colour dimensions of the stimuli. In the manual task, the task goal is colour categorisation by way of manual button press, which does not require the use of phonology, which results in phonological information not interfering in the manual task (Kinoshita et al. 2017). Consistent with this idea, the word interference was absent in the low neutral proportion condition of the manual task, where attentional control over the task of reading was high. However, unexpectedly, when attentional control was relaxed in the high neutral proportion condition, strong interference for words was found. It is proposed that this interference does not reflect a conflict between the phonological information provided by the word and display colour dimensions of the stimuli, but instead reflects a conflict at the level of task-sets. According to Monsell et al. (2001) stimuli have a tendency to automatically evoke the performance of the task that they are associated with. It is proposed that when attentional control is high, that the triggering of the task-set of reading by the word dimension of the stimulus can be inhibited using attentional control, however, when attentional control is relaxed, due to a high proportion of neutral trials, that the word dimension of the stimulus exogenously triggers the task-set of reading, which then interferes with the task of colour classification.

Interestingly, the interference for words was larger in the vocal task (83 ms) relative to the manual task (5 ms), as shown by the significant interaction between response modality and word interference effect. In the vocal and manual task, the word stimuli are bivalent and contain a task conflict between the task-set of reading and colour identification, however, only the vocal task contains an informational conflict between the phonological information provided by the word and display colour stimuli. The larger word interference in the vocal task relative to the manual task may therefore be due to the vocal task containing phonological conflict in addition to task-set conflict, while the manual task only contained a task-set conflict.

The quantile analysis revealed different delta plot patterns in the vocal and manual tasks: In the vocal task, the word interference effect produced a positive slope, while in the manual task, the interference for words produced a flat slope. It is proposed that the positive delta slope in the vocal task reflected a decrease in rate of evidence accumulation due to the incorporation of conflicting phonological information from the word into the process of accumulating phonological information from the display colour. In the manual task, the task of reading does not involve the use of phonology to generate a speech response (Kinoshita et al. 2017). As such the phonological information provided by the word dimension of the stimulus did not did not affect the rate of evidence accumulation towards the identification of the display colour, as shown by the flat delta slope.

To investigate the cognitive processes underlying the neutral proportion effect, the present research investigated whether neutral proportion modulated the effect of previous trial type. In the vocal task, it was found that the effect of previous trial type interacted with neutral proportion. In the low neutral proportion condition of the vocal task, the word interference effect was significantly reduced when the previous trial was a word trial, relative to when the previous trial was a neutral hash sign trial, while in the high neutral proportion condition, there was no effect of previous trial type on the word interference effect. In contrast, in the manual task, previous trial type had no effect on the word interference effect in either the low or high neutral proportion conditions. Taken together, these findings suggest that neutral proportion modulates the recruitment of reactive control, which is recruited on a trial by trial basis in response to conflict. Previous trial type had an effect in the low neutral proportion condition of the vocal task, due to the high frequency of conflict trials in the low neutral proportion condition. It had no effect in the low neutral proportion condition of the manual task as there was no word interference effect in that condition.

In conclusion, the evidence suggests that neutral proportion modulates attentional control of the task of reading. In the vocal task the task of reading involves the accumulation of phonological information**.** This resulted in a large word interference effect that was magnified in the high neutral proportion condition relative to the low neutral proportion condition. The slope of the delta plot for the word interference in the vocal task was positive, which was interpreted as being due to the accumulation of conflicting phonological information from the word. In the manual task, the task of reading does not involve the accumulation of phonological information, which resulted the word interference being absent in the low neutral proportion condition, where attentional control was high**.** However, when attentional control was relaxed, in the high neutral proportion condition, there was strong interference for words, which was explained as being due to a task-conflict between the task-sets of reading and colour classification. Previous trial type only modulated the interference for words in the low neutral proportion condition of the vocal task, which was taken as evidence that neutral proportion modulates the recruitment of reactive control, which is recruited on a trial by trial basis, when conflict is experienced frequently.

5.1 Future directions

An avenue for future research is to investigate whether the semantic component of reading is modulated by attentional control. The semantic interference effect is the finding that words that are semantically related to colour (e.g. the word *sky* is semantically related to the colour BLUE) are responded to slower than colour unrelated words (e.g. *ABBEY; MERCY*). Augustinova, Flaudias & Ferrand (2007) found that manipulating spatial attentional control of the task of reading, by colouring only one letter of the word stimulus, did not modulate the semantic interference effect, which was taken as evidence that the semantic component of reading is automatic and cannot be controlled using attention. However, another possibility, is that due to the semantic interference effect being small, there was not enough power to detect the interaction between the semantic interference effect and the spatial attentional control manipulation. Future research could increase the size of the semantic interference effect by increasing the amount of semantic overlap between the distractor words and display colours. This could be achieved by presenting the display colours using words that spell the name of colours different to the display colours. For example, if the display colours are blue, red, orange and white, the colour words could be orange, pink, grey and green. It would be predicted that the finding of greater interference produced by colour words (e.g., *YELLOW, PINK*) relative to colour-neutral words (e.g., *WINNER*, *TANK*) would reflect greater semantic interference for colour words than colour neutral words. Furthermore, it would be predicted that if the semantic component of reading is moderated by attentional control, that the semantic interference for colours relative to colour unrelated words would be greater when neutral proportion is high relative to when neutral proportion is low.

Conclusion

The present study investigated attentional control of the task conflict, by investigating the effect of neutral proportion on the interference for words in a vocal Stroop task, where responses were made by means of a speech response and a manual Stroop task, where responses were made by way of manual button presses. Kinoshita et al. (2017) found that words interfered with colour naming in the vocal task, but not with colour categorisation in the manual task. Consistent with Kinoshita et al. (2017), in the present study it was found that when there was a low proportion of neutral trials, the words interfered in the vocal task but not in the manual task. However, when neutral proportion was high, the interference for words was magnified in both the vocal and manual tasks. The cognitive mechanisms underlying the neutral proportion effect were investigated using quantiles analysis and by looking at the effect of previous trial type on the neutral proportion effect. The quantile analysis revealed that neutral proportion resulted in a shift in the RT distribution, and that previous trial type only influenced the words interference effect in the low neutral proportion condition of the vocal task. It is proposed that neutral proportion modulates maintenance of the task goal of responding to the display colour rather than reading the word, and that the reactive form of control operates on trial by trial basis, following the experience of conflict.

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7. Appendix A

Table A1

Critical words and their lexical characteristics

Word	Subtitle frequency	Orthographic neighbourhood	Word	Subtitle frequency	Orthographic neighbourhood
ABBEY	3.18	0	LABEL	6.88	2
ABORT	4.61	1	LEMON	12.02	1
ABUSE	10.25	2	LIMIT	13.02	0
ADORE	7.73	2	LIVER	14.29	10
ADULT	14.29	0	LOBBY	12.69	3
ALBUM	10.24	0	LOGIC	6.71	0
AMUSE	2.61	1	MEDAL	11.57	3
ANGER	19.43	2	MINOR	12.82	2
ANGLE	14.92	2	MORAL	13.51	5
ARROW	7.84	0	MORON	14.78	1
AWARD	12.88	1	MOTOR	13.16	1
CABIN	19.65	0	NANNY	10.41	5
CAMEL	5.02	1	NASAL	2.08	2
CANOE	3.57	1	NOBLE	14.59	0
CARGO	9	1	NOVEL	10.06	2
CIGAR	12.94	0	OPIUM	2.24	0
CIVIL	15.94	1	ORBIT	5.65	0
COBRA	3.33	0	ORGAN	7.25	0
COMIC	10.82	2	SALON	4.59	2
CYCLE	5.88	0	SOBER	10.1	1

DAISY	13.51	2	SYRUP	5.1	0
DECOY	3.57	3	TALLY	3.49	6
EAGLE	11.49	0	TOKEN	4.02	1
ELBOW	6.14	0	USHER	2.37	0
ERASE	6.22	0	VENOM	2.33	0
ESSAY	6.14	1	VILLA	4.39	1
HABIT	14.47	0	VODKA	10.1	0
HOBBY	6.94	4	WAGON	17.76	0
IDEAL	7.33	1	WIDOW	12.1	0
IMPLY	2.69	1	ZEBRA	2.51	0

8. Appendix B

B1. Experiment 1 (Vocal) LME output

B1.1 LME analysis of neutral proportion effect

Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom
[lmerMod]
Formula: logRT ~ itemtype * neutprop + (1 | Stimulus) + (itemtype | subj)

REML criterion at convergence: -2722.1

Scaled residuals:

Min	1Q	Median	3Q	Max
-4.8939	-0.5552	-0.0048	0.5093	5.8742

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
Stimulus	(Intercept)	0.002397	0.04896	
subj	(Intercept)	0.013322	0.11542	
	itemtypeWord	0.001974	0.04444	0.12
Residual		0.030217	0.17383	

Number of obs: 4591, groups: Stimulus, 64; subj, 40

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	6.282564	0.030760	66.310000	204.246	< 2e-16 ***
itemtypeWord	0.136254	0.026741	42.900000	5.095	7.44e-06 ***
neutprop1	-0.009739	0.037254	38.000000	-0.261	0.79517
itemtypeWord:neutprop1	-0.067377	0.017429	37.980000	-3.866	0.00042 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:

	(Intr)	itmtyW	ntprp1
itemtypeWrd	-0.726		
neutprop1	-0.030	0.000	
itmtypWrd:1	0.000	-0.017	0.011

B1.2 LME analysis of word interference in low neutral proportion condition

Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom
[lmerMod]
Formula: logRT ~ itemtype + (1 | Stimulus) + (itemtype | subj)

REML criterion at convergence: -1565.9

Scaled residuals:

Min	1Q	Median	3Q	Max
-3.9531	-0.5246	-0.0009	0.5187	4.8156

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
Stimulus	(Intercept)	0.002796	0.05288	
subj	(Intercept)	0.011093	0.10532	
	itemtypeWord	0.001341	0.03662	-0.02
Residual		0.028389	0.16849	

Number of obs: 2417, groups: Stimulus, 64; subj, 21

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	6.27767	0.03536	46.89000	177.521	< 2e-16 ***
itemtypeWord	0.10236	0.02927	34.47000	3.497	0.00132 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:

	(Intr)
itemtypeWrd	-0.702

B1.3 LME analysis of word interference in high neutral proportion condition

Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom
[lmerMod]
Formula: logRT ~ itemtype + (1 | Stimulus) + (itemtype | subj)

REML criterion at convergence: -1136.9

Scaled residuals:

Min	1Q	Median	3Q	Max
-4.5423	-0.5713	-0.0115	0.5089	5.6792

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
Stimulus	(Intercept)	0.001884	0.04341	
subj	(Intercept)	0.015783	0.12563	
	itemtypeWord	0.002664	0.05161	0.21
Residual		0.032232	0.17953	

Number of obs: 2174, groups: Stimulus, 64; subj, 19

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	6.28741	0.03649	32.23000	172.325	< 2e-16 ***
itemtypeWord	0.16975	0.02650	27.32000	6.407	6.91e-07 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

	(Intr)
itemtypeWrd	-0.444

B1.4 LME analysis of Gratton effect

Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom
[lmerMod]
Formula: logrt ~ itemtype * previtemtype * neutprop + (itemtype | subj) + (1 | Stimulus)

REML criterion at convergence: -5696.3

Scaled residuals:

Min	1Q	Median	3Q	Max
-5.0132	-0.5486	-0.0124	0.5165	5.9370

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
Stimulus	(Intercept)	0.002809	0.05300	
subj	(Intercept)	0.013053	0.11425	
	itemtypeWord	0.001577	0.03971	0.12
Residual		0.029742	0.17246	

Number of obs: 9156, groups: Stimulus, 183; subj, 40

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	6.298e+00	3.285e-02	1.330e+02	191.710	< 2e-16 ***
itemtypeWord	1.078e-01	2.991e-02	1.270e+02	3.604	0.000449 ***
previtemtype1	-2.151e-02	1.414e-02	8.889e+03	-1.521	0.128178
neutprop1	9.983e-03	3.884e-02	4.800e+01	0.257	0.798222
itemtypeWord:previtemtype1	1.707e-02	2.396e-02	4.706e+03	0.713	0.476070
itemtypeWord:neutprop1	-8.441e-02	2.686e-02	3.660e+02	-3.143	0.001810 **
previtemtype1:neutprop1	-6.531e-02	2.826e-02	8.889e+03	-2.311	0.020843 *
itemtypeWord:previtemtype1:neutprop1	9.436e-02	4.776e-02	4.960e+03	1.976	0.048236 *

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

	(Intr)	itmtyW	prvtm1	ntprp1	itmtypWrd:p1	itmtypWrd:n1	prv1:1
itemtypeWrd	-0.751						

previtmtyp1	-0.186	0.205					
neutprop1	0.044	-0.078	-0.329				
itmtypWrd:p1	0.110	0.105	-0.590	0.194			
itmtypWrd:n1	-0.103	-0.101	0.475	-0.138	-0.814		
prvtmtyp1:1	-0.194	0.213	0.896	-0.315	-0.529	0.456	
itmtypW:1:1	0.115	-0.352	-0.530	0.187	-0.246	0.204	-0.592

B1.5 LME analysis of Gratton effect in low neutral proportion condition

Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom [lmerMod]
Formula: logrt ~ itemtype * previtemtype + (itemtype | subj) + (1 | Stimulus)

REML criterion at convergence: -2823.1

Scaled residuals:

Min	1Q	Median	3Q	Max
-4.6306	-0.5218	0.0053	0.5258	4.6588

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
Stimulus	(Intercept)	0.0029257	0.05409	
subj	(Intercept)	0.0110590	0.10516	
	itemtypeWord	0.0008833	0.02972	-0.08
Residual		0.0303180	0.17412	

Number of obs: 4796, groups: Stimulus, 183; subj, 21

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	6.30239	0.03815	95.00000	165.214	<2e-16 ***
itemtypeWord	0.06566	0.03161	130.00000	2.077	0.0398 *
previtemtype1	-0.05298	0.02814	4583.00000	-1.883	0.0597 .
itemtypeWord:previtemtype1	0.06546	0.03010	3880.00000	2.175	0.0297 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:

	(Intr)	itmtyW	prvtm1
itemtypeWrd	-0.779		
previtmtyp1	-0.344	0.415	
itmtypWrd:1	0.322	-0.410	-0.935

B1.6 LME analysis of Gratton effect in high neutral proportion condition

Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom [lmerMod]
Formula: logrt ~ itemtype * previtemtype + (itemtype | subj) + (1 | Stimulus)

REML criterion at convergence: -2846.7

Scaled residuals:

Min	1Q	Median	3Q	Max
-4.8399	-0.5723	-0.0238	0.5046	5.9941

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
Stimulus	(Intercept)	0.002172	0.04661	
subj	(Intercept)	0.015426	0.12420	
	itemtypeWord	0.002381	0.04880	0.27
Residual		0.029100	0.17059	

Number of obs: 4360, groups: Stimulus, 63; subj, 19

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	6.293e+00	3.695e-02	3.500e+01	170.320	< 2e-16 ***
itemtypeWord	1.648e-01	3.428e-02	3.800e+01	4.809	2.42e-05 ***
previtemtype1	1.102e-02	6.368e-03	4.255e+03	1.730	0.0838 .
itemtypeWord:previtemtype1	-9.054e-03	4.502e-02	6.300e+01	-0.201	0.8413

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:

	(Intr)	itmtyW	prvtm1
itemtypeWrd	-0.369		
previtmtyp1	0.031	-0.033	
itmtypWrd:1	-0.004	0.605	-0.141

B2. LME output of Experiment 2 (Manual)

B2.1 LME analysis of neutral proportion effect

Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom [lmerMod]
Formula: logrt ~ itemtype * neutprop + (itemtype | subj) + (1 | Stimulus)

REML criterion at convergence: 1797.3

Scaled residuals:

Min	1Q	Median	3Q	Max
-3.2771	-0.6536	-0.0805	0.5569	4.4527

Random effects:

Groups	Name	Variance	Std.Dev.	Corr
Stimulus	(Intercept)	0.0005884	0.02426	
subj	(Intercept)	0.0280187	0.16739	
	itemtype1	0.0021968	0.04687	-0.24
Residual		0.0772589	0.27795	

Number of obs: 5567, groups: Stimulus, 64; subj, 49

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	6.41152	0.02500	51.92000	256.420	< 2e-16 ***
itemtype1	0.02242	0.01604	18.32000	1.397	0.17905
neutprop1	0.02719	0.04841	46.94000	0.562	0.57709
itemtype1:neutprop1	0.06447	0.02005	46.64000	3.216	0.00236 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:

	(Intr)	itmty1	ntprp1
itemtype1	-0.265		
neutprop1	0.020	-0.002	
itmtyp1:nt1	-0.003	0.010	-0.155

B2.2 LME analysis of word interference in low neutral proportion condition

Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom [lmerMod]
Formula: logrt ~ itemtype + (1 | subj) + (1 | Stimulus)

REML criterion at convergence: 947.5

Scaled residuals:

Min	1Q	Median	3Q	Max
-3.1303	-0.6319	-0.0770	0.5296	4.3828

Random effects:

Groups	Name	Variance	Std.Dev.
Stimulus	(Intercept)	0.0008881	0.0298
subj	(Intercept)	0.0273036	0.1652
Residual		0.0784808	0.2801

Number of obs: 2820, groups: Stimulus, 64; subj, 25

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	6.39778	0.03434	26.34100	186.300	<2e-16 ***
itemtype1	-0.01006	0.01866	17.35100	-0.539	0.597

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:

	(Intr)
itemtype1	-0.162

B2.3 LME analysis of word interference in high neutral proportion condition

Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom

```
[lmerMod]
Formula: logrt ~ itemtype + (itemtype | subj) + (1 | Stimulus)

REML criterion at convergence: 836.8

Scaled residuals:
 Min       1Q        Median   3Q       Max
-3.2466   -0.6786   -0.0926   0.5680   4.3932

Random effects:
Groups     Name          Variance   Std.Dev.    Corr
Stimulus   (Intercept)   0.0004844  0.02201
subj       (Intercept)   0.0286392  0.16923
           itemtype1     0.0044476  0.06669     -0.42
Residual                 0.0756554  0.27506
Number of obs: 2747, groups:  Stimulus, 64; subj, 24

Fixed effects:
              Estimate  Std. Error  df         t value   Pr(>|t|)
(Intercept)   6.42512   0.03540     24.04400   181.499   <2e-16 ***
itemtype1     0.05435   0.02061     16.38900   2.637     0.0177 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
          (Intr)
itemtype1 -0.347
```

B2.4 LME analysis of the Gratton effect

```
Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of  freedom
[lmerMod]
Formula: logrt ~ cond * prevcond * neutprop + (cond | Subject) + (1 |      Stimulus)

REML criterion at convergence: 1921.2

Scaled residuals:
Min       1Q        Median   3Q       Max
-3.6591   -0.6341   -0.0988   0.5374  4.5076

Random effects:
Groups     Name          Variance    Std.Dev.   Corr
Stimulus   (Intercept)   0.0008577   0.02929
Subject    (Intercept)   0.0363526   0.19066
           condword      0.0014994   0.03872    -0.36
Residual                 0.0706936   0.26588
Number of obs: 8418, groups:  Stimulus, 184; Subject, 49

Fixed effects:
                                   Estimate    Std. Error   df        t value     Pr(>|t|)
```

(Intercept)	6.461e+00	3.212e-02	6.500e+01	201.151	<2e-16 ***
condword	2.178e-02	1.931e-02	3.300e+01	1.128	0.2675
prevcondword	1.152e-02	1.092e-02	8.221e+03	1.055	0.2914
neutprop1 -	2.510e-03	5.717e-02	5.400e+01	-0.044	0.9652
condword:prevcondword	-4.177e-03	1.564e-02	8.344e+03	-0.267	0.7894
condword:neutprop1	4.543e-02	2.483e-02	1.840e+02	1.830	0.0689 .
prevcondword:neutprop1	2.527e-02	2.183e-02	8.219e+03	1.158	0.2471
condword:prevcondword:neutprop1	-6.754e-03	3.127e-02	8.350e+03	-0.216	0.8290

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

	(Intr)	cndwrd	prvcnd	ntprp1	cndwr:	cndw:1	prvc:1
condword	-0.555						
prevcondwrd	-0.214	0.357					
neutprop1	-0.049	0.106	0.192				
cndwrd:prvc	0.150	-0.402	-0.699	-0.134			
cndwrd:ntp1	0.147	-0.232	-0.442	-0.366	0.300		
prvcndwrd:1	0.171	-0.284	-0.506	-0.241	0.354	0.555	
cndwrd:pr:1	-0.119	0.192	0.353	0.168	0.022	-0.627	-0.699

B2.5 LME analysis of the Gratton effect in the low neutral proportion condition

Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom [lmerMod]
Formula: logrt ~ cond * prevcond + (1 | Subject) + (1 | Stimulus)

REML criterion at convergence: 940.4

Scaled residuals:

Min	1Q	Median	3Q	Max
-3.6815	-0.6419	-0.1017	0.5355	4.5352

Random effects:

Groups	Name	Variance	Std.Dev.
Stimulus	(Intercept)	0.001139	0.03374
Subject	(Intercept)	0.036612	0.19134
Residual		0.069840	0.26427

Number of obs: 4285, groups: Stimulus, 184; Subject, 25

Fixed effects:

	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	6.463e+00	4.488e-02	4.200e+01	143.983	<2e-16 ***
condword	-1.702e-03	2.539e-02	7.600e+01	-0.067	0.947
prevcondword	-1.534e-03	1.879e-02	4.143e+03	-0.082	0.935
condword:prevcondword	3.405e-05	2.171e-02	4.193e+03	0.002	0.999

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

```
Correlation of Fixed Effects:
            (Intr) cndwrd prvcnd
condword    -0.483
prevcondwrd -0.315  0.558
cndwrd:prvc  0.273 -0.643 -0.866
```

B2.6 LME analysis of the Gratton effect in the high neutral proportion condition

```
Linear mixed model fit by REML t-tests use Satterthwaite approximations to degrees of freedom [lmerMod]
Formula: logrt ~ cond * prevcond + (cond | Subject) + (1 | Stimulus)

REML criterion at convergence: 969.2

Scaled residuals:
Min      1Q       Median   3Q      Max
-3.4841  -0.6374  -0.0923  0.5287  4.3543

Random effects:
Groups   Name        Variance   Std.Dev. Corr
Stimulus (Intercept) 0.0006478  0.02545
Subject  (Intercept) 0.0338674  0.18403
         condword    0.0024741  0.04974  -0.48
Residual             0.0712963  0.26701
Number of obs: 4133, groups:  Stimulus, 64; Subject, 24

Fixed effects:
                      Estimate  Std. Error  df          t value  Pr(>|t|)
(Intercept)            6.45961  0.04005     27.00000    161.294  <2e-16 ***
condword               0.04417  0.02008     19.00000      2.199  0.0401 *
prevcondword           0.02421  0.01090     4065.00000    2.221  0.0264 *
condword:prevcondword -0.00777  0.02246     4081.00000   -0.346  0.7294
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
            (Intr) cndwrd prvcnd
condword    -0.469
prevcondwrd -0.071  0.141
cndwrd:prvc  0.034 -0.284 -0.486
```