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Backward inhibition and positive episodic priming coexist in ABA sequences

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PhD Thesis

Backward inhibition and positive episodic priming coexist in ABA sequences.

2010

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Backward inhibition and positive episodic priming coexist in ABA sequences.

CONTENTS

Ph.D Abstract

It has been shown that the sooner individuals return to a task that they had previously stopped doing, the longer it will take them to complete that task again. This has been shown in experiments that have looked at the time it takes to do a task, while taking into consideration what task was undertaken two tasks prior to the present task. Such experiments have been designed around continual switching between three tasks, ensuring that a task never immediately repeats itself, giving a number of ABA and CBA sequences. In an ABA sequence, participants repeat what they were doing two tasks prior to the present task, a lag-2 repeat, where as in a CBA sequence they do not repeat what they were doing two tasks prior to the present task, a lag-2 non repeat sequence. Comparisons of these sequences have shown that reaction time to task A, in an ABA sequence, on average is longer than when task A is in a CBA sequence.

This difference in response times has been linked to a process of inhibition, where a new task is believed to make the components of a previous task that interfere with the correct response to that new task, less active. This means that the sooner individuals return to a previously inhibited task, the longer it will take them to complete it again. This difference in response times between trials in an ABA or CBA sequence has been labelled as a backward inhibition cost.

There is still a great deal of debate about what components of that task were previously made less active, and this may be because of the variety of methodologies that have been used to study this question. What has become apparent is that the cue and its relationship to the target, may play some part in the backward inhibition that occurs.

The experiments in this study have sought to simplify previous experiments, in order to determine how much the relationship between the cue and target may be affecting backward inhibition. This simplification involved repeating the same task, which was to identify the position of the target on the screen, while only switching between three cues and targets that have a fixed one-to-one relationship with each other. The only difference between conditions and experiments was the transparency of the relationship between the cue and target. The transparency is linked to how obvious the cue's meaning is in relation to what task it specifies should be carried out on the target.

The overall results suggest that when we use this methodology, the increases we see in backward inhibition are linked to a combination of top down inhibition of a language label, and bottom up episodic negative or positive priming of the visual image. These results could give us further insights into how methodological changes, which have previously not been thought as important, may actually be altering backward inhibition.

Chapter 1

Introduction

Summary of the whole of the PhD

The following pages are a Summary of the whole PhD, hopefully giving an insight and introduction into the investigation.

Mayr and Keele (2000) carried out an experiment where they asked subjects to complete one of three tasks. These tasks involved identifying one of four objects on the screen that had a pre-specified characteristic. The tasks were to look for an object that was moving, coloured, or angled, differently from the other three objects. Subjects registered the object's position by pressing one of four keys on a keyboard. The experiment first involved the subject learning how three different words, which acted as cues, related to the set objects they were to look for. These words were 'movement', 'colour', or 'orientation'; if they first saw the word 'movement', they were to look for the object that was either moving up or down or from side to side; if the word was 'colour' they were to look for an object that was either pink or purple; and if the word was 'orientation' they were to look for an object that was either slanted to the left or the right of the perpendicular, refer to figure 1.

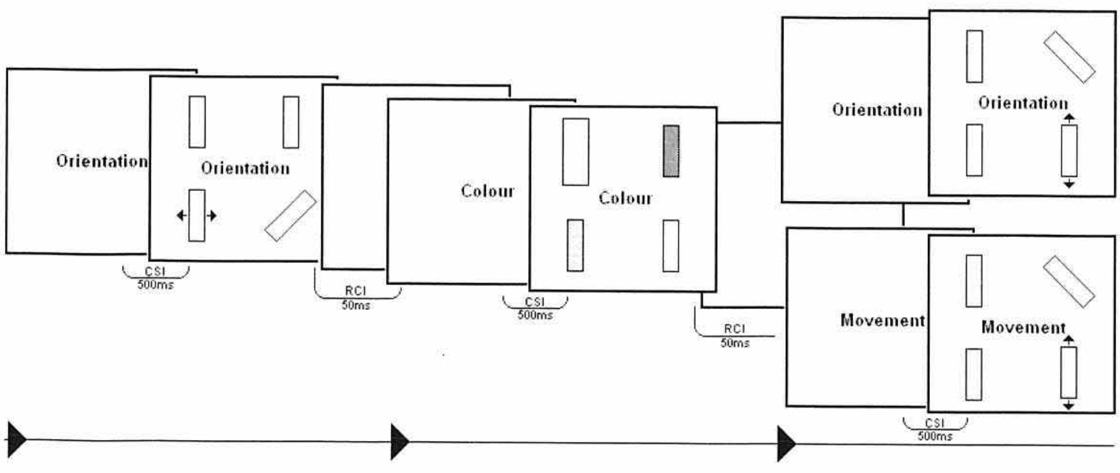


Figure 1: A comparison between an ABA and CBA sequential switch in task, from Mayr & Keele (2000).

The experiment (Mayr & Keele, 2000) involved subjects going through a sequence of continually changing tasks with the provision that no task would be immediately be repeated.

As a consequence of this there were two different sequences that could occur: one was where the task the subject was presently doing was also completed two tasks prior to that present task, a lag-2 repeat or ABA sequence; and one where the subject was not repeating the same task that occurred two tasks prior to the present task, a lag-2 non-repeat or CBA sequence. Subjects could therefore go, for example, from the orientation task, to the colour task, and finally return to the orientation task, in an ABA sequence, whereas in the CBA sequence they would go from the task movement, then move to the colour task, and finally change again to the orientation task.

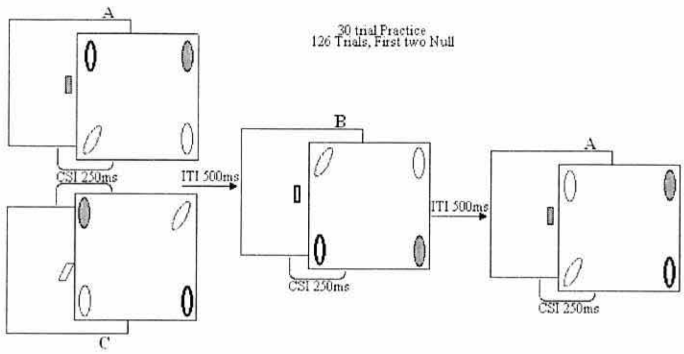
What Mayr and Keele (2000) identified was that if individuals were doing the same task that they were doing at lag-2, an ABA sequence, they would take longer to make the correct response than if they were not doing the same task that they were doing at lag-2, a CBA sequence.

Mayr and Keele (2000) suggested that this cost difference was linked to a process they believed occurred when individuals moved away from an old task and onto a new task; they termed this process inhibition (Houghton & Tipper, 1994; 1996). It is suggested that when a new task is begun, components of the previous task can interfere with the successful completion of the present task. To reduce the occurrence of this interference, components of the previous task, which interfere with the present task, are thought to be made less active by the new task. This process is known as backward inhibition. Mayr and Keele (2000) suggest that it is the task set of the previous task that is inhibited. They define the task set as the specifications for the "configuration of the perceptual, attentional, mnemonic, and motor processes critical for a particular task goal" (Mayr & Keele, 2000, p.5). Mayr and Keele (2000) believed that the task that is in position 'B', in an ABA sequence, inhibits the task-set that is in position 'A'. This means that if someone immediately returns to the task that was initially in position 'A' in the sequence, it will slow the process involved in the reconfiguration of the new task set.

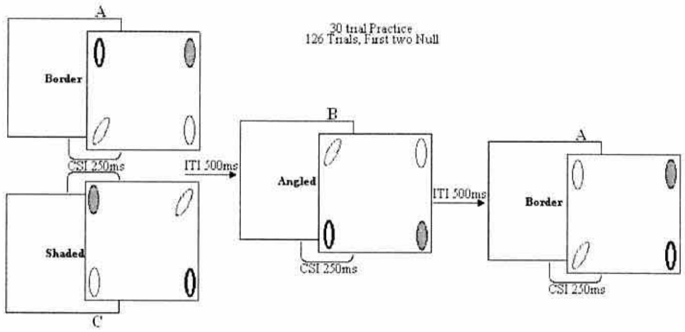
Since this study,, there has been a great deal of controversy about what exactly is being inhibited or if anything is being inhibited at all. Logan and Bundesen (2003) would suggest that all we are seeing is an anomaly linked to episodic priming, whereas other researchers, who believe in a process that involves inhibition, have suggested that the extra time required to do the task is linked to a reconfiguration cost, and that the cost is associated with the application stage, which is specifically linked to the relationship between the target and response (Gade & Koch, in press). The application stage is understood to be when the participant makes a response to the target. Others, like Altmann (2007), suggest that the semantic meaning held in the cue may be linked to where the cost originates from, whereas Mayr and Kliegl (2003) propose that it is to do with the new cue and stimulus reconfiguring, so that the correct stimulus response map can be extracted from the task set category. This debate is not helped by the variety of different methodologies used, where different cues, targets, response types, the times between the cue and targets appearance (cue-target interval, CTI) and the times between the response to a previous task and a new cue appearing for the next task (response-cue interval, RCI), have all differed from each other. This has made it difficult to reach conclusions about exactly what other researchers are seeing.

What has become apparent in some experiments is how the transparency of the relationship between a cue and its appropriate target (Logan & Schneider, 2006; Monsell & Mizon, 2006), and the language label associated with giving the task meaning (Altmann, 2007), may be influencing response times, with transparency being linked to how easily the cue's meaning can be interpreted in relation to it directing the individual to the right task to perform on the target. What is not clear is the mechanism that may be causing these costs and how it operates within explicitly cued task switching experiments.

This research has specifically focussed on the relationship between the cue and the target to see if this may be linked to some of the costs that have previously been associated with a switch in task set. The following experiments have tried to look more exclusively at this question of how the transparency of the relationship between the cue and target may be influencing these costs. In order to do this, an experiment was designed based on Mayr and Keele's (2000) experiment in that its objective was to "identify the position of the target"; however, in this experiment, unlike that of Mayr and Keele (2000), the task remained constant. It was hoped that this removal of the switch in task-set simplified the potential variables that may be in operation when there was a switch in cue and target. In all of the experimental conditions there was a one, or two, cued relationship to one specific target, where the relationship between the cue and target remained constant. What switched as trials changed, within the condition, were the cue-target relationships and not the task, refer to figures 2 and 3.



(a) Icon condition in experiment 1



(b) Language cued condition in experiment 1

Figure 2: Switches of cue target relationships in an ABA and CBA sequence in the (a) Icon and (b) Language conditions in experiment 1.

The difference between conditions was linked to the transparency of the relationship between the cue and the target. This could be totally 'transparent' (where the cues and the targets were visually similar to each other), 'implicit' (where the cues had a language relationship to the target or only shared some of the visual features of the target) or 'abstract' (where the relationship between the cue and target had no immediately obvious visual or language features that linked it to the target).

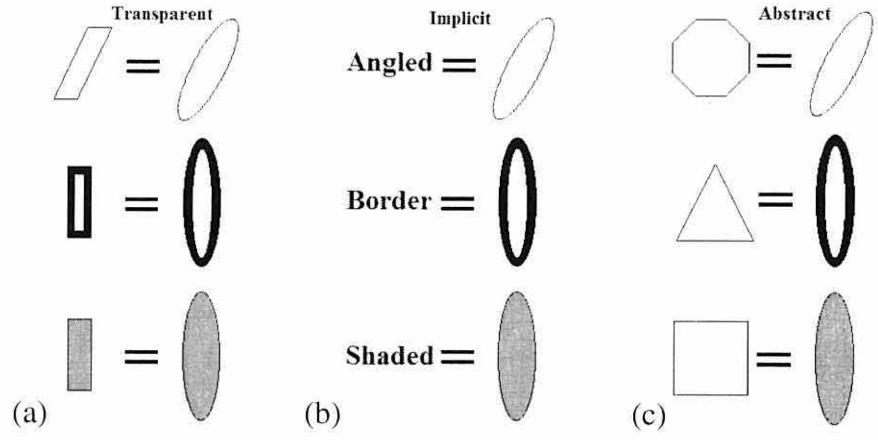


Figure 3: Cue-target relationships, (a) icon cues in experiment 1, (b) language cues condition in experiments 1 and 3, (c) abstract cues in experiment 3.

In all of the experimental conditions, subjects first learnt about which cue related to which target, then once they had understood this relationship, they were asked to sit in front of the computer screen and practise the task, which was to look for the cue then to look for its associated target and to register its position on the screen by pressing one of four keys. The keys were: D (representing top left of the screen); C (representing bottom left; and J (for the top right); and N (representing the bottom right).

The experiments in chapter 1 were designed to see if the same costs that had been found in the Mayr and Keele (2000) experiment could be replicated, when only switching between cue-target relationships and not task-sets, as found in their experiment. A trial was comprised of the following components: a cue, its target, then the response to the target, and it was hypothesized that as there was a change in the type of cue and target that was used between trials, this would cause conflict between trials and require a process of inhibition to occur. This conflict would subsequently cause the increase in response times when an ABA sequence was completed, in comparison to a CBA sequence. Experiment 1 was designed to establish if there was also a relationship between this increase in response times, as seen in an

ABA sequence, and the level of transparency of the relationship between the cue and target. This was investigated because of the results found by Logan and Schneider (2006) and Monsell and Mizon (2006), who had not looked at backward inhibition, but had found that there were potentially added costs when the transparency of the relationship altered. A further aspect of this study was that language cues were compared with icon cues as there was a suggestion by Arbuthnott and Woodward (2002) and Arbuthnott (2005) that the language label associated with the target plays an essential role in task switching costs. Altmann (2007) had also highlighted the importance of the semantic meaning of the cue and how this seemed to influence costs. Because of the above factors, experiment 1 had two conditions: one where the relationship between the cue and the target used a language cue, and the other where the cue was an icon that had almost matching features to that of the target. This led to a second hypothesis that was linked to Arbuthnott and Woodward (2002), Arbuthnott (2005), and Altmann's (2007) findings, which suggested that a top down language label was required to see any costs. If this were true then there should be no increase in the response times in the ABA sequence in the icon cued condition, only in the language condition.

The results of experiment 1 showed an increase in the overall response times in the ABA sequence in the language condition, and not in the icon condition. This suggested that the use of a top down language label was required to cause the cost difference in the ABA sequence when compared to a CBA sequence. The only problem was that the overall response time in the icon cued condition was also significantly greater than the language cued condition. It is suggested that this may be the reason why no backward inhibition was identified in the icon cued condition. Experiment 2 was designed to see if the overall response times of the language condition could be decreased and made to more closely mirror those of the icon condition. Again, there was a language and icon cued condition but this used colour targets: red, blue, and green. In the language condition, the associated language label for the colour was used, and in the icon condition the colour of the icon cue matched that of the target. It was hypothesized that there would be backward inhibition in the language condition and not in the icon cued condition. The results did show a speed up in overall response times so that they were similar to those in the icon condition in experiment 1. Backward inhibition in the language condition was again found, but was also apparent in the icon condition. This was concluded to be linked to individuals' automatic labelling of colours with a language label when they are required to search for them in the icon cued condition (Allport & Wylie, 2000).

The experiments in chapter 1 seemed to suggest that the use of a top down language label was being inhibited, on a change of trial, as it would interfere with the up and coming trial's top down language label. It also suggested that the bottom up characteristics of the previous trial's target, and the new trial's cue, were not being inhibited, as if they were, there would have been backward inhibition present in the icon condition in experiment 1.

Chapter 2 investigates whether it is the top down language label that is being inhibited by increasing the potential number of language labels occurring within a trial. Logan and Schneider (2006a) proposed that if there is no obvious relationship between the cue and target, so it that the relationship is not transparent, a mediator is required to link the cue to the goal of the task. If, for example, the letter 'G' was the cue for a task that requires individuals to identify whether a number is odd or even, the top down language label of 'G' would not tell them how to do the task. Another top down language label would be needed to be attached to the letter 'G' to direct them to the right task, such as the word 'Parity', which would then act as the mediator. The findings of Logan and Schneider (2006a) appeared to suggest that the cue is given first a top down language label linked to its recognition, followed by a new top down language label linked to the recognition of the target. If this were so then there would be a likely requirement for the first top down language label, associated with the cue's recognition, to be removed, as it would cause conflict with the up and coming top down language label associated with the target's recognition. If this were correct then our previous results would suggest that this may increase backward inhibition if the cue had a nontransparent abstract relationship to the target.

Experiment 3 was designed to investigate this hypothesis; there were two conditions that used the same stimuli that were in experiment 1. The language condition found in experiment 1 was also rerun. What was different in experiment 3 was the use of an icon condition where the icon cue had no obvious transparent relationship with the target's characteristics. The icon condition in experiment 3 used a triangle, square, and hexagon as cues. It was hypothesized that because of this, the cue would first be given a top down language label that was linked to the recognition of the cue's shape. This would than need to be inhibited, within the trial, to allow a new top down language label associated with the target to be used. The label associated with the target would then again need to be inhibited by the next trial's cue as appeared to be the case in the experiments described in chapter 1. This should in turn double the amount of cost associated with an ABA sequence, as both the language label associated with the cue and the target would potentially be inhibited in a trial.

The results of experiment 3 were as expected, and confirmed that there was a doubling in the cost associated with backward inhibition. The icon condition in experiment 3 had over double the backward inhibition cost. This suggested that we were seeing inhibition of the language label associated with the target in experiments 1 and 2. Furthermore, it seemed to highlight that inhibition could also occur within trial. Within trial inhibition seemed to be linked to a requirement to inhibit the top down language label required to recognize the cue, with that of the top down label that was linked to identifying the target. This within trial inhibition, if it is occurring, is important, as it may explain some of the results seen in previous experiments where the cue has had a non transparent relationship with the target (Mayr & Kliegl, 2003).

One of the concerns in all of the above experiments was that there seemed to be an increase in the backward inhibition costs as the overall response time increased. This may have highlighted a relationship between the two variables that was not necessarily linked to backward inhibition. Taking this into consideration, a post hoc test was carried out to see if there was any relationship between the orders of condition. The results highlighted that there was no effect on the backward inhibition cost, in the icon or language cued conditions, but that there was a significant over 100ms benefit in overall response times, in the icon cued condition, when the language condition was completed first. More importantly, there was no difference in the cost associated with backward inhibition. The results suggested that we were seeing a two stage model in operation, similar to the model proposed by Mayr and Kliegl (2003): a recovery stage, that seemed to benefit from the practice with the language cues, and an application stage where the language label was integrated with its associated icon target.

Experiment 4 was designed to examine some of the anomalies that had occurred in the previous experiments that might be influencing backward inhibition. All of the previous experimental conditions had used cues that had icon targets; they also may or may not have required a language label to be superimposed on them. There was also a switch of cue, but repeat of stimuli, when conditions changed, so changing the cue target relationships. Because of this experiment 4 used only language cues and targets. There were two separate conditions: one in which the cue and target had an abstract relationship to each other, and the other in which the cue and target matched. The experiment was also divided into two groups:

one in which the cues changed between conditions and the stimuli remained the same, as in all of the previous experiments, and the other in which the cues remained the same but the stimuli were different between conditions.

It was hypothesized that these changes should have little effect on the results. It was proposed that in the matching cue and target condition we should find similar results to those we found in the icon condition in experiment 1. This was because there was no need to apply a top down language label to recognize the target. On the other hand, the abstract condition should have similar results to those found in the abstract condition of experiment 3, as there would be a requirement to apply different top down language labels to the cue and to the target.

The results of experiment 4 showed that the above hypotheses were correct. Post hoc tests on the order of conditions also gave similar results to those found in experiment 3. The overall response time of the abstract condition decreased, when it was completed as the second condition, which had no effect on the backward inhibition costs.

The experiments described in Chapter 2 replicated the backward inhibition costs found in previous task switching experiments, while repeating the same task and only switching between cue-target relationships. The results seem to suggest that we were seeing inhibition of the top down language label, associated with the recognition of the target, by the up and coming top down language in the new trial. The experiments described in Chapter 3 seemed to confirm this, as when there was another top down label, linked to the recognition of the cue required, there was a doubling in backward inhibition. This suggested that inhibition could occur both within and between trials if the previous top down language label interfered with the ability of the new top down language labels relationship with the new bottom up visual image. There was also a suggestion that there is a two stage model in operation: firstly, a recovery stage that benefits from practice with a condition that has a more transparent relationship between the cue and target, followed by an application stage that is linked to applying the top down language label to the bottom up visual image.

Chapter 4 specifically focuses on the question of episodic priming. Episodic priming is one of the major counter arguments against the inhibition explanation for the costs associated with backward inhibition. It is suggested that when we do any task, there is a unique metaphoric picture taken of that event. This can involve factors such as the cue and the target used, and their shape, colour and size, as well as the response made to that target. If any of these components are repeated, there is likely to be a benefit to response time (positive priming) whereas changes in these components are likely to impede response time (negative priming). Based on this and other arguments, Logan and Bundesen (2003) and Schneider and Logan (2005) have hypothesised that, in explicitly cued experiments, the difference in response between a repeat or change in task can be linked to episodic priming and not to inhibition. They have suggested that there is a confounding variable in most explicitly cued experiments, and this is that there is only one cue used to identify a task. Because of this, when a task repeats, so does the cue. They propose that, as a result of this, the cue and the target can act as a compound and that this can create positive priming. To show that this may be what was actually occurring, Logan and Bundesen (2003) completed an experiment in which there were two cues for each task. They compared three different types of sequence: a change in task, a repeat in task with a change in cue, and a repeat in task with a repeat in task. They found that a change in task and a repeat in task, where the cue changed, took a similarly more lengthy time to complete in comparison to when there was a repeat in the cue and task. Mayr and Kliegl (2003) countered Logan and Bundesen's (2003) argument by carrying out an experiment that similarly used two cues for one task, but their results were different from those of Logan and Bundesen (2003): they found a hierarchy of costs, with the task switch taking longer than the task repeat where the cue changed, with the least time being taken when task and cue repeated. This position was countered by Logan and Bundesen (2004) who claimed that this cost difference in experiments was linked to the difference in the transparency of cues used in the two experiments. They hypothesised that the less transparent cues used in the Mayr and Kliegl (2003) experiment were causing the difference in results as a 'mediator' was being used.

All of the previous experiments would suggest that we are seeing inhibition occurring, in that if the cue-target relationship was not being inhibited, then the ABA sequence would be faster than the CBA sequence as task 'A' at lag-2 would prime task 'A' at lag-0.

What is not made totally clear in the previous experiments, because of the one-to-one relationship between cue and target, is whether any of the bottom up components linked to the cue are being inhibited, or if it is only the top down label that is inhibited. Having two cues to one target permitted investigation of whether the unique bottom up characteristics of the cue could influence the costs. All three experiments described in Chapter 4 had a condition where there were two cues to one target. Experiment 5 had one condition that was a slight alteration of the language condition found in experiments 1 and 3. In experiment 5, there were two language cues for each target; these were the cues' border or outline, shaded or filled, and angled or slanted. This meant that there were three different sequences. As in the previous experiments, there was an ABA sequence in which the cue and the target were the same at lag-2, a CBA sequence in which the cue and target were different at lag-2, and finally, differently from the previous experiments, there was an AB'A' sequence in which the target was the same as it was at lag-2, while the associated cue was different, refer to figure 4.

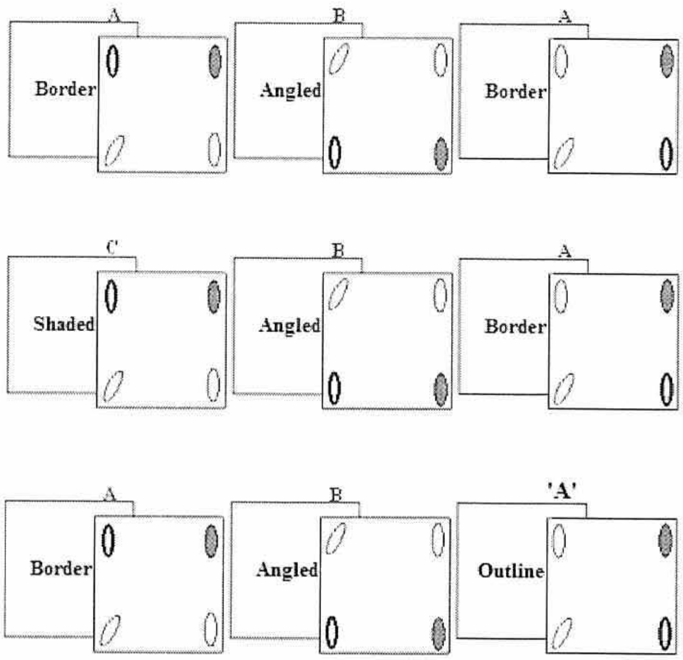


Figure 4: Experiment 5, two language cues to one target.

Experiment 6 had two conditions: the language condition found in experiments 1 and 3, as well as an icon condition that used two implicit icon cues for each target. The stimuli used for targets were the same in both conditions, refer to figure 5.

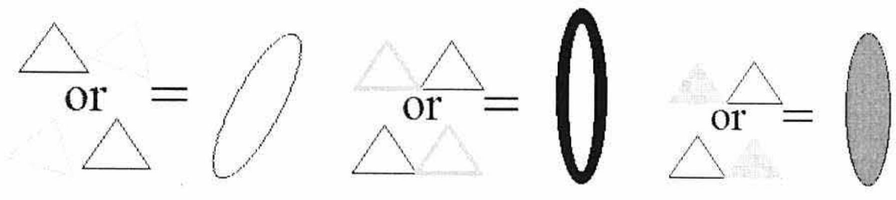


Figure 5: Experament 6, Implicit icon cues and relevant targets.

Finally experiment 7 had one condition that used two abstract icon cues for each target. There were also two groups that could either be given one language label for the two cues, or a separate language label for each of the two cues, refer to figure 6.

Square = 海 Or 路   Circle = 無 Or 雲   Triangle = 徑 Or 邊

Circle = 無   Dotted = 雲   Square = 海

Border = 路   Triangle = 徑   Filled = 邊

Figure 6: Experiment 7, one or two language labels associated with two cues.

There were also three target stimuli that had both internal and external features that could be used to identify them, refer to figure 7.

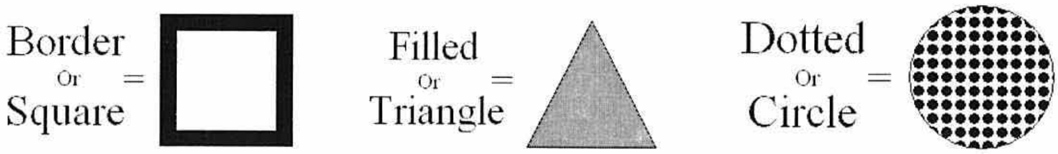


Figure 7: Experiment 7, language labels associated with targets.

These changes were made to investigate whether the uniqueness of the top down label could influence those potentially associated with the uniqueness of the bottom up visual image of the cue.

The results of the three experiments were directly linked to how many language labels were associated with the two cues. When there was only one shared language label for the two cues then the AB'A' sequence was the most costly. This result was reversed when the two cues had their own unique language label with the ABA sequence becoming the most costly sequence. The results from experiments 5, 6, and 7 were not totally conclusive, but there was a suggestion that we were seeing inhibition the top down language label associated with the bottom up image. Although there was also a indication that there may also be a unique cue code that comprised of both the bottom up and top down factors linked to the recognition of the cue.

The final experimental chapter attempts to answer the question of whether backward inhibition costs can be influenced by the types of cue-target relationships at lag-1 and lag-2. This was prompted by Gade and Koch's (2007) demonstration that backward inhibition was influenced by the subtleties linked to how the stimuli and response were represented at lag-1. A further aspect of the investigation was differing cue target interval (CTI) and response cue interval (RCI), as this too had been shown by Gade and Koch (2005) to influence backward inhibition costs. They had shown that the distance in time between the previous response to a target, at lag-2, in an ABA sequence, and the appearance of the next cue in the trial at lag-1, seemed to influence cost. Gade and Koch (2005) suggested that the level of activation of the task at lag-2 has a direct relationship on the amount of inhibition required by the task at lag-1.

Experiment 8 was designed to look at differing transparencies of cue target relationships within condition; the experiment was designed to include two cue-target relationships that were abstract, and non transparent, and one in which the cue and the target were matching in bottom up features, so were totally transparent. The abstract related cue-targets were labelled T trials, as the relationship between the cue and target may need translating. The matching cue-target relationship was known as an M trial as this was considered to be a simple, transparent, matching bottom up relationship. This gave us three ABA sequences: TTT, TMT, MTM, and three CBA sequences: TMT, MTT, and TTM. The experiment also had two different conditions, one using icon cues to icon targets, the other using language cues to language targets.

The results of experiment 8 suggest that when there is a switch from a T trial at lag-2 and to an M trial at lag-1, in the icon condition, both the language labels associated with the T trial and the mechanism associated with applying a language label are inhibited.

Finally, experiment 9 was designed to altering the response cue interval (RCI) and cue target interval (CTI), as both of these factors had previously influenced task switching costs. The results had suggested we were seeing inhibition of a top down language label associated with the recognition of a bottom up image. If this were so, it seemed that by returning to experiment 1 and altering these two factors, we might see an alteration in backward inhibition. Subjects were split into two separate groups: one that had a CTI of 50ms and RCI of 500ms, the other group having CTI of 500ms and RCI of 50ms. It was hypothesized that, because there was no conflict within trials in the language condition, between the language label used by the cue and the target, so the CTI should have little to no effect. Similarly, in the icon condition, no language label needed to be used so again the CTI should have little effect. The RCI, on the other hand, should affect backward inhibition in the language condition, as there would be conflict between trials: the shorter the RCI, the greater the conflict, the more requirements to inhibit the language label of the previous trial, so the longer a trial would take in an ABA sequence.

Thus, it was hypothesized that we would see little alteration in the icon condition, as there seemed to be no use of a top down language label. On the other hand, in the language condition, the different RCI should affect the backward inhibition cost, as this would affect the amount of activation in language label of the previous trial when the new trial cue appeared. This suggested that there would be significantly less backward inhibition in the language condition with a 500ms RCI in comparison to the 50ms RCI condition.

Findings were again inconclusive. There was no significant difference between the two groups with differing CTI and RCI. However, the icon condition had now developed a cost linked to backward inhibition, but it was not clear whether it was the alteration of the CTI or RCI that had created this. What may have occurred was that when the CTI was 500ms, a top down label may have become recruited to help the participant to remember which target to look for. This then in turn may have needed to be inhibited, as there was only a 50ms RCI before the new cue appeared, but again this could only be speculated about.

After all the experiments had been completed, the question still remained about the position of the target when the subject was making a response. Because of the randomness in the positioning of the target, in both the ABA and CBA sequences, in 75% of the trials the position of the target was repeated, and in 25% of the trials there were repeats of the position of where the target was at lag-2. Mayr and Keele (2000) had dismissed this as a problem and, because there was so little known at the time about the repeat of the position of a target, had removed these trials from their analysis. Arbuthnott and Woodward (2002) had also suggested that the position of an object may involve the use of different processes to those that affect backward inhibition costs.

Taking all of the above into consideration, it seemed useful to investigate how this may have affected cost in the previous experiments. Realizing that this analysis could only be done to see if there was a suggestion of a trend, as it had not been factored into the previous methodology, experiment 9 was re-examined, taking the position of the target into consideration. It appeared that the position of the target had significant interactions with the type of cue used, with backward inhibition costs, and with the two groups that had differing CTI and RCI. What was highlighted was that the language and icon cues' backward inhibition response times were completely opposite to each other when the factor of position was taken into consideration.

In the icon condition, when the CTI was 500ms and the RCI was 50ms, backward inhibition was present in the ABA sequence whether the position of the target response was repeated or not. This was not true in the 50ms CTI and 500ms RCI group, as backward inhibition was only present in the non repeat of position, whereas priming of the ABA sequence seemed to be occurring when the position was repeated.

The language cued condition had quite different results, it was in the group that had a 50ms CTI and RCI of 500ms that backward inhibition was present in both the repeat and non repeat of position. In the group that had a 500ms CTI and 50ms RCI, backward inhibition was only present when the subject changed the position, and priming again occurred in the ABA sequence when the position remained the same.

These results seem to suggest that the position of the target does not generally act as a prime, as, if it were to do so, both the ABA and CBA sequences should be quicker when the target position is repeated. This is not what occurs. This priming effect is only apparent in the ABA sequence, which suggests that the bottom up visual image of the target and its position are amalgamated into a related bottom up code. This bottom up amalgamated code seems not to be inhibited but to remain in working memory, acting to prime a repeat of the same target when it was in the same position as it was at lag-2.

This priming affect did not seem to occur in the 50ms CTI - 500ms RCI group in the language condition and in the 500ms CTI - 50ms RCI group in the icon condition. This suggests that another top down process may also be in operation, adding to the ABA sequences cost when the position is repeated. All the previous experiments suggest that this cost may be linked to the application of a previously inhibited language label to a bottom up visual image. If this is so, then this may explain why inhibition is seen in the repeat and non repeat of position in the 50ms CTI - 500ms RCI group's language condition and in the 500ms CTI - 50ms RCI group's icon condition. This is because the application of the top down language label would occur at different times in the two different cued conditions. In the language condition it would occur on the appearance of the target, so in the 50ms CTI - 500ms group there would be little time between the appearance of the cue and target. This quick recovery of an inhibited language code into working memory would make its application to the bottom up target visual representation more pressured and likely to cause more costs. In the icon condition, it seems that a language label is recruited in the 500ms CTI - 50ms RCI group because of the time between the appearance of the cue and target. The application of that language label would occur at a different time to that of the language cued condition. It would occur when the cue appears, not when the target appears, as in the language condition. This would explain why, in the icon 500ms CTI - 50ms RCI group, we see backward inhibition cost in both the repeat and non repeat of position because of the short time between the presenting of the target of the last trial and the requirement of the new cue for a language label.

Taking all of the above into consideration, the findings of the series of investigations in this study seem to show a two stage model in operation that explains backward inhibition cost. They also suggest that there are two processes in operation, one linked to episodic priming and the other to inhibition.

Firstly the processes involved with inhibition seem to be linked with a bottom up visual representation activating an associated top down language label, amalgamated into a common code. This amalgamated code is inhibited when it comes into conflict with a similar type of code which is linked to identifying a new bottom up image that requires a different top down language label. Inhibition seems to remove this amalgamated code from working memory (WM) and send it back to long term memory (LTM). Backward inhibition costs seem not to be linked with the recovery of this amalgamated code from LTM, but with the application of the language label, within this code, to a new bottom up visual image in working memory.

A second process also seems to be in operation, while this is occurring, that is linked to the visual representation of the target and the position of the associated response. These two factors also seem to become amalgamated into a unique code that is not inhibited. This code remains in WM and gradually dissipates over time, which suggests that the sooner the return to the task, the faster the response will be.

It is hoped that, in the following study, it will be demonstrated that this is what occurs in an ABA sequence, showing that backward inhibition and episodic priming can coexist.

Brief Summary of the research leading to this investigation

In 2000, Mayr and Keele designed an experiment comparing ABA and CBA task switching sequences, which they interpreted as reflecting inhibition of the task goal, linked to the task-set. Later on, using two cues to one target, Mayr and Kliegl (2003) identified two separate costs associated with a switch in task set: one linked to a change in cue and repeat of task set, and the other to greater costs linked to a change in cue and task set. Based on these findings, they proposed a two stage model of processing rule retrieval from long term memory (LTM), which was driven by the appearance of the cue, and a secondary application stage that automatically applied the rule to the target stimulus, enabling the correct response.

This interpretation of the results was challenged by Logan and Bundesen (2003;2004) and later developed into a model by Schneider and Logan (2005; 2007) and Logan and Schneider (2006a), which proposed that these costs were linked to episodic priming, based around the priming affects of a compound cue-target when there was a repeat of task set. In contrast to Mayr and Kliegl (2003), Logan and Bundesen (2003; 2004) had initially shown that a change in cue and repeat in task was equally as costly as a change in cue and task set, when they compared them to a repeat of cue and task. Logan and Bundesen proposed that the cue and target were acting as a compound and that cost differences in explicitly cued experiments were linked to episodic priming. Logan and Schneider (2006a) later suggested that the reason why Mayr and Kliegl (2003) had such discrepant results was due to the type of cue they had used. According to Schneider and Logan (2005), a "mediator" is attached to a cue when it does not hold a meaningful relationship to the rule, which identifies how response to a target should be made. Hence, the added retrieval of this mediator was the cause of the cost linked to a switch in cue and repeat of target in the Mayr and Kliegl (2003) paradigm.

Monsell and Mizon (2006) have suggested that it is not necessarily the actions of a mediator that cause these differences in results, but a methodological difference based on the probability of a task switch. They managed to replicate Logan and Bundesen's (2003) results, and then, in an experiment closely modelled on this, managed to achieve similar results to those of Mayr and Kliegl (2003) by simply lowering the probability of a switch in task. Monsell and Mizon concluded that when there is a low chance of a task switch, participants are discouraged from reconfiguring a switch in task unless a cue tells them to do so. When this occurs, there is a cost not linked to the anticipatory reconfiguration of the task-set. In their discussion, Monsell and Mizon repeat a concern, shared by Logan and Schneider (2006a), about the transparency of the cue, stating that some sort of mechanism of translation would be required when the cue cannot be immediately associated with the task. Logan and Schneider, as previously stated, hypothesised that a mediator may be used. Monsell and Mizon proposed that if the relationship between the cue and target is completely abstract, in comparison to transparent, then this translation, between the cue, target, and the appropriate response, is a task in itself. They also suggest that verbal and pictorial cues may be using different processing resources. This insight may be linked to mechanisms proposed thirty years previously by Baddeley and Hitch (1974), who hypothesised that working memory consists of two systems linked to visual and language processing. Of particular interest, Monsell and Mizon (2006) found that short cue target intervals (CTI) created higher error rates for pictorial cues than for language cues.

An effect of cue type had also been noted previously by Arbuthnott (2005) and Arbuthnott and Woodward (2002) on costs associated with an ABA sequence. They had shown that the nature of the cue had a direct effect upon the costs that were seen in all types of task switching sequences. Language, shape and location cues could lengthen or completely remove certain costs. Arbuthnott and Woodward (2002) had compared three different types of sequential switch of task: a single switch in task (BA); three consecutive switches in task (CBA); an alternating switch in task (ABA); and a repeat of task (AA). This highlighted that all of the sequences using a switch in task were more costly than a repeat of task, irrespective of the type of cue. Of particular significance was that the type of cue affected the costs linked to particular types of task switching sequence. Shape cues were the most costly overall in all types of sequence, while location cues were more costly than verbal cues when making 'BA' or 'CBA' switches in task. The most efficient sequence was when there was a repeat of task using the location-cues. Of particular interest, was the effect that cue type had on ABA costs; all three cue types had greater ABA costs than CBA costs, but this was only significant in the shape and language cues. Shape and language cue ABA costs were of similar magnitude to both the CBA and BA task sequences. This was not the same in the location cued tasks, where the ABA cost was less than the BA switch in task, although unlike the other two types of cued conditions, all three types of task switches in the location cued condition were very similar.

Another interesting finding came from Arbuthnott and Woodward (2002) who looked at the costs linked to the specific task type (e.g., identify the digit, symbol, or letter); the ABA cost was not apparent in the digit task. This may have fundamental importance in determining why the episodic compound cue-target priming experiments have different results to those of other experiments.

Arbuthnott (2005) extended these findings by looking at the effects of congruency and verbalisation of location cues. Her experiments were somewhat different to the experiments described above, as they used only language and location cues, and had only digit targets, which were multivalent in nature. Arbuthnott completed three separate experiments: firstly repeating her initial findings with Woodward, secondly looking at congruency, where she found classic cost associated effects within congruency and incongruency in all types of cue and sequential switch, although the findings overall were somewhat inconclusive. What stood out was Arbuthnott's third and final experiment, where she had two separate groups. One completed the language cued experiment, the other the location experiment. After they had completed these experimental blocks, they carried out two final blocks where they verbalised the meaning of the cue, i.e. stating, "parity", "size", or "prime", out loud. The results fell into two groups: what occurred prior to and post verbalisation. Both language and location cued groups repeated the findings of Experiment 1, with there being an ABA cost in the language cued group, but not in the location cued group, whereas after verbalisation, a similar ABA cost was found in both of the cued conditions. Costs linked to AA and AB sequences were also affected by naming: AB costs when compared to the AA sequence were substantially greater in the location cued condition, in comparison to the language cued condition, prior to participants naming the cue. This difference remained when participants named the cues, but was greatly decreased, as it made the location cued group far more efficient in the AB sequence.

Cue type therefore, may also play a subtle role in addition to probability when we see differences in experimental results. Marian and Neisser (2000) have shown how cue type can influence what is retrieved, as did Arbuthnott and Robinson (2005) who identified effects on performance linked to the nature of the cue, suggesting that the specific task set that is retrieved varies on the basis of the cue type (Arbuthnott, 2005).

Considering this, and Schneider and Logan's (2005; 2007) suggestion that abstract or implicit cues would require a language mediator, it appears that the cost difference that Monsell and Mizon (2006) found, between pictorial and language cues, could be linked to interplay between language and visual working memory. A pictorial cue would need some sort of top down language label in order to be understood, unless it looked exactly like the target, whereas a language cue would supply the necessary information to identify the target.

If the CTI is decreased, then the communication between these two systems would be more likely to cause greater costs. Baddeley (2003) gives a label to a system that may be similar to this, the "episodic buffer", a mechanism that combines visual and verbal top down language labels into a new top down language label which can then successfully access the multidimensional top down language labels represented in long term memory. The anatomy of the brain suggests that the use of language is integral to understanding of external and internal environments at any level of complexity (Baddeley 2003; Gruber & Goschke, 2004). A switch in task may require the use of some sort of language, not only to understand the goal of the task, but also to make decisions on how to react to the visual representations we are presented with.

Schneider and Logan's (2005; 2007) experiments suggest that a language mediator is attached to cues that do not immediately suggest the goal of the task. Monsell and Mizon (2006), although disagreeing with the compound cue target explanation for costs associated with explicitly cued experiments, propose that when there is an abstract relationship between the cue and the target, this in itself may become a separate task linked to translating the relationship between the cue and target.

Arbuthnott and Woodward's (2002) findings appear to confirm the importance of the role that language may play in the costs associated with an ABA switch. This seems to be confirmed by Arbuthnott (2005), who found an ABA cost using location cues that did not initially generate an ABA cost, until a language label was superimposed onto the location cues. These results appear to suggest that some of the cost associated with an ABA switch in task set may be linked to the way language is superimposed upon a target. However, the problem with most of the experiments detailed above is that the relationship between the cue and the target is complicated by the target which may have a multidimensional relationship to the cue, or may be presented with other targets associated with different tasks. The way in which the cue and target relate to each other is potentially masked by other factors linked to task-set, making an accurate interpretation of effects of language on cue and target relationships difficult.

This thesis attempts to clarify these issues by removing some of these factors in order to better understand the relationship between a cue and target, and how language may influence the costs associated with an ABA switch in task set. An attempt has been made to simplify the relationship between the cue and target so that it is a one-to-one relationship. Cue-target relationships are switched within task-set, and not between task-set, so any ABA costs are more likely to be a consequence of a switch in cue-target relationship, and not between a switch in task set. Findings suggest that some of the ABA cost is linked to a mechanism of translation that creates a top down language label that links the cue and target type together into an understandable relationship, so that an appropriate response is enabled. It appears that we may be seeing the inhibition of a system similar to that which Baddeley (2003) terms the episodic buffer.

Task switching

Mayr and Keele (2000) highlight the potential ambiguity of both our external and internal environments, in that these environments bombard us with a potential cacophony of sensory information. What we need to do is filter out unnecessary background information, and highlight what is important to us achieving our goals, so that we can successfully negotiate our way through these environments.

Various explanations have been given as to how we select, reject, order and move through our sensory environment. We are both surrounded by, and part of, potential confusion of external and internal sensory experiences. How we make sense of this information so that we are able to constructively interact with our environment is very much linked to the study of task switching. The questions we try to answer in this literature are linked to how we select, exclude, act upon, and move systematically through, this sensory information. It is suggested that because of the lack of clarity in our sensory environment, there is a high risk of leaping from one sensory experience to the next. Consequently, it is believed that constraints are placed upon this by our cognitive-neuro system (Mayr & Keele, 2000). As human beings, we tend to move from one task to another, driven normally by a specified goal that acts as a top down, high-level control setting, which limits and selects the sensory information that is important to the successful achievement of a specific goal (Houghton & Tipper, 1996; Monsell, 1996). Mayr and Keele (2000) define the task set as the configuration of the attentional, motor processes, mnemonic, and perceptual criteria, which are critical in successfully achieving a set goal.

Houghton and Tipper (1996) propose that we do this by inhibiting extraneous information and activating relevant stimuli, using bottom up, low level inhibitory loops. This process is generated as a consequence of a neutral state, which all potential environmental stimuli have up until the centrally generated goal acts to constrain the bottom up perceptual domain by altering the "object field states"(OFS). This is effected by the central generation of a goal, which operates a match/mismatch selection criterion, with objects that match the OFS causing a positive feedback loop, and objects that do not match causing a negative feedback loop.

Mayr and Keele (2000) hypothesize that a stable internal representation of the potentially chaotic world is created by what Rogers and Monsell (1995) call a "task set", which serves to limit the potential number of actions that we can apply to the sensory information we are receiving. Mayr and Keele (2000) also highlight the flexibility-stability paradox, linked to the problem when switching task set, as a lack of flexibility can cause problems with perseveration errors, whereas too much flexibility would make the system potentially chaotic.

Although they are not absolutely clear, Mayr and Keele (2000) seem to be suggesting that inhibition is occurring at the level of control settings. They suggest that a high level task goal creates a specific task set, which stipulates attentional, mnemonic, motor, and perceptual procedures required for its successful completion. It is this, they suggest, that is being inhibited, rather than low level, bottom up characteristics of the sensory stimuli. These two opinions about where inhibition originates will later become important in this thesis. This is because Houghton and Tipper's (1996) proposition that inhibition is at a low, bottom up level, which is fenced by top down, goal driven parameters, differs from Myer and Keele's (2000) top down explanation of inhibition.

The basis of research that examines the costs associated with the switch in task focuses on the 'task set' (Rogers & Monsell, 1995). The task set holds together a group of stimulus response mappings associated with a goal/rule, which some believe can be represented in the cue. How we study and interpret costs can be influenced by what experimenters believe is occurring, whether they are linked to a switch in task, or whether we are seeing subtle changes linked to a switch in stimulus response mapping (Gilbert & Shallice, 2002). A problem in previous research into the simple relationship between a cue and target type, is that cues may not have a natural or obvious relationship to the goal of the task, so may require a language label (Arbuthnott & Woodward, 2002; Arbuthnott, 2005; Monsell and Mizon, 2006; Schneider & Logan, 2005; 2007). This could also be said of the target, as this too may require a label to understand how one should respond to it. For example a right or left key press, when identifying the colour, shape, parity, or magnitude of a target, may require a language label that is secondarily superimposed onto the target, which may have no obvious relationship to the target's physical appearance. This is further complicated by the use of targets that are multidimensional (i.e. have different components of their representation that can be responded to, colour, shape, parity, magnitude, etc), or when all task target types (i.e. number, letter, and shape) that can be responded to are present on the screen in each trial. This confusion is compounded by the fact that some experiments keep the cue on the screen when the targets are present, whereas others remove the cue prior to the target's arrival. This makes comparisons between experiments extremely difficult and may obscure costs that are linked simply to how a cue and target relate to each other.

In the light of this confusion between, and complexities within, methodologies, this investigation set out to remove and simplify the cue-target relationship to its simplest, in the hope that this would make the effects on the cue-target relationship more precise.

History of task switching

Prior to the publication of Jersild's 1927 paper, most research into task 'set' ('Einstellung') was carried out in the nineteenth and twentieth centuries by German experimental psychologists. Until very recently, most of the English-language literature which discussed ideas on how task-sets worked was linked to the study of impairment of control in everyday circumstances and in individuals with neurological disorders (Monsell, 2003). The modern cognitive study of task switching started with Jersild in 1927, followed by Pinard (1932), and then by researchers such as Spector and Biederman (1976). Recently, a renaissance in the interest of this area of study has begun, as there is a suggestion by some researchers that it may be the key to understanding whether the elusive 'homunculus' exists.

Or, as Ian Robertson suggested, at the end of the Eighteenth International Symposium on Attention and Performance, they could declare the control homunculus extinct (Monsell & Diver 2000). Whatever the answer, the debate still continues, as the methodology that underpins the study of task switching is more critically examined. Presently, questions are being asked about whether explicitly cued experiments truly reflect top down control processes or only bottom up priming effects. The research here seems to suggest that Ian Robertson's declaration may have some credence to it, as if a top down language label that links the different elements of a task set exists, a complex homunculus may be less necessary than previously thought.

Task Switching Paradigms

Jersild's (1927) task switching study is considered by many to be one of the first influential studies (Lien & Ruthruff, 2004) because of its systematic approach (Yantis, 2005). Jersild (1927) found that switch costs were larger and less accurate than a repeat of a task, although this was only apparent when the switch was between task sets that were associated with the same stimulus. If the switch in task involved the identification of a characteristic of the target stimulus not associated with the previous task, then cost was dramatically reduced and, in some cases, completely removed (Mayr & Kliegl, 2000). Using a list paradigm, Jersild (1927) compared response times (RTs) of participants completing alternating blocks (task A then task B, e.g. ABABAB…), and pure blocks (e.g. AAAA…). Response times were mostly slower in alternating blocks compared to pure blocks (i.e. a switch cost). Moreover, costs were especially large when the two tasks operated on a common stimulus domain (e.g. odd-even judgments versus greater than-less than judgments on digits); however there were small negative switch costs when tasks were performed on separate sets of stimuli (Lien & Ruthruff, 2004). Subjects alternating between subtracting 3 from a 2-digit number and giving a common opposite word were faster than those repeating either task independently. In addition, switching between counting the number of digits in a digit string, or stating what number was present (for example 44444 = 5(count), or 4444 = 4 (figure), was very costly, whereas when switching task to state what colour ink was used for printing, for example red or black, cost was almost completely removed.

Spector and Biederman (1976) suggest that this was because the stimulus may be acting as a retrieval cue for the operation to be performed. They found that costs occurred when there were switches between uncommon domains if the subject had to keep track of the task switching sequence. These early results suggest how important the representation of the task is, in determining the kind of results obtained and how the representation of a target, and response to that target, may interfere with a previous image and response to a target earlier in the sequence.

From the initial task switching experiments, it was noted that there was negligible cost when subjects alternated between differing tasks, which had differing responses to classes of stimuli (Arrington, Logan, & Schneider, 2007). These initial and later findings suggested that costs were linked to cognitive processes that select the appropriate task set from others that are competing with it. Reconfiguration of the attentional, memory, motor, and perceptual processes was believed to be involved when selecting the task set, but not if there was a unique association with the stimulus type in a specific context (Arbuthnott & Frank, 2000). Mayr and Kliegl (2000) suggested that switch costs are linked to stimulus driven competition between the task sets and automatic activation of both task sets occurs on the presentation of a specific stimulus, with endogenous control required to determine which task set is relevant. Jersild (1927) and later, Rogers and Monsell (1995), also suggested that that practice may benefit executive process involved in task set selection, which subsequently reduces overall costs (Cepeda, Cepeda, & Kramer, 2000).

This type of list paradigm comparison was later questioned by researchers such as Fagot (1994), who saw problems with the "mixed-list cost" (Yantis, 2004). A combination of increased memory load and keeping track of tasks was suggested as potentially confounding results. Alternating blocks imposed greater working memory load, as the participants kept track of two tasks and maintained knowledge of where they were in the task sequence. The level of arousal and effort were also considered to be potentially problematic (Monsell, 2003). To counteract these particular problems, Rogers and Monsell (1995) developed the *alternating-runs paradigm.* Here, the task alternates every N trials, where N is predictable and constant, and this allows for comparison of task-switch and task-repetition trials within the block (Monsell, 2003). Participants alternate between short runs of different tasks (e.g. AABBAABB), with repetitions occurring within runs (e.g., AA, BB) and alternations occurring between runs (e.g., AB, BA) (Schneider & Logan, 2005). Because subjects keep both tasks in mind throughout the runs, with repetitions and alternations requiring the same monitoring, memory load is considered to be the same for both types of task sequences (Schneider & Logan, 2005). The benefit of this methodology is that it enables the comparison of repeat or switch tasks in the same block, with no requirement for the participant to remember the sequence of the forthcoming tasks (Rogers & Monsell, 1995).

Rogers and Monsell's (1995) results supported the idea that switch costs reflect the duration of executive processes, as they too found large switch costs when using their procedure. A cost was found that was not totally eliminated, even when sufficient time had been given to prepare for the shift in task. Although some reduction in the shift costs was found, this cost was called *residual shift cost.* Monsell (2003) and Meiran and Marciano

(2002) have suggested that this cost reflects the operation of executive processes, whereas Schneider and Logan (2005) hypothesise it is linked to compound cue stimulus priming, and Mayr and Keele (2000) suggest it is linked to task set inhibition.

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An alternative approach was the *pre specified task sequence* (e.g. shape-colour-shape), as seen in Allport, Styles and Hsieh's (1994) experiments and in experiment 5 of Mayr and Keele's (2000) paper, with subjects being given short sequences of trials (Monsell, Sumner, & Waters, 2003). There was an added advantage to both of these methodologies, as the available preparation time could be altered by changing the stimulus-response interval. This also altered the time available for any passive dissipation of the previous task.

The next development of the experimental methodologies was the *task-cueing paradigm* initially introduced by Spector and Biederman (1978) and Meiran (1996) (Grange, 2010; Monsell, 2003) or *explicit task-cueing procedure* (Schneider & Logan, 2005). Here the cue appears either before, or with the stimulus. Because of this, the task sequence can be made unpredictable. Effects such as active preparation and passive dissipation may be independently manipulated, which may have an effect on the task costs by altering the cue-stimulus interval, or response-stimulus interval respectively (Monsell, 2003). Using this methodology it is possible to study *residual switch costs,* defined by De Jong (2000) as, "*switch costs* at *long preparation intervals*, that *should provide ample time for advance* preparation to be complete" (Monsell & Driver, pp 357, 2000). A cue allowed for unpredictability in the sequence of task. Meiran (1996) was one of the first to develop this approach, using a similar grid system to Rogers and Monsell (1995). Meiran placed a target in one of four quadrants, and through the use of either vertical or horizontal arrows, which acted as cues, the task was to state whether the target appeared above or below the central line, or to the right or left of the mid way line (Gilbert & Shallice, 2002)

An alternative to this paradigm is the *intermittent-instruction paradigm* (Altmann, 2007). When this methodology is used, there is an occasional interruption to a series of trials which indicates the task that should be followed. Using this method, cost is observed, even when the cue informs the subject to continue with the present task; however, there is again, a larger cost associated with a switch in task (Monsell, 2003).

A development on all of these methodologies was that used by Mayr and Keele (2000). They suggested that the cause of some of the residual switch costs did not occur because of the relationship between N-1 and N, but originated at N-2 and was related to the activation of the task-set at N-2 and the subsequent need for the task at N-1 to inhibit it. They hypothesized that when there was a switch from one task to another, there would be a need to inhibit the previous task goal, which they suggested was represented as an abstract task-set. To test this hypothesis Mayr and Keele devised an experiment that used three separate tasks, which were explicitly cued, and could be presented in either an ABA or CBA task sequence. They found that an ABA task sequence, in which the same task that occurred at Lag-2 is repeated, was more costly than a CBA task sequence, in which the same task at Lag-2 is not repeated. They also presented four stimuli on the screen on each trial, with three acting as distracters to one target. The position of the target was randomly selected so it could repeat or change its position from the previous trial. This meant that in 25% of trials there was a repeat of position of the target. It was important to analyse this effect as Mayr and Keele hypothesised that they were seeing inhibition of a top down goal, and not inhibition of the bottom up physical characteristics of the stimulus-response in the previous trial. The methodology also allowed them to make sure the stimulus at lag-2 could be different to the present trial. Their analysis suggested that there was slightly more cost when there was a repeat of position, but this was in addition to cost of a non repeat of position. Because of this they proposed that the majority of cost, when using this methodology, was linked to the inhibition of the top down goal, not of the bottom up representation of the previous trial's stimulus-response map at lag-2.

Theoretical accounts of the switch cost

In the task switching literature, there were initially two main theories attempting to explain the cost associated with a switch in task-set: preparation and interference theories. The preparation theory emphasised the need for active preparation to carry out an upcoming task. DeJong (2000) argues that a failure to prepare on a subset of trials is the origin of the residual switch costs. In contrast, others argue that an optimal level of response preparation cannot be reached (Meiran, 2000), or that it is as a consequence of incomplete preparation, as not all acts of control can be completed prior to the arrival of the target (Mayr & Keele, 2000; Rogers & Monsell, 1995). Finally, Allport et al. (1994) and Goschke (2000) conclude that the costs are evidence that an act of endogenous control is not in operation (Logan & Schneider, 2006).

In the classic task switching experiments, the debate linked to where costs originate continues to centre around how much bottom up and top down processes are involved, specifically, which process is causing the cost.

According to Gilbert and Shallice (2002), there are two main explanations of the costs associated with a switch in task set: ''task carryover'' and "Exogenous Control Process". The "task carryover" account, proposed by Allport and his colleagues (e.g., Allport et al., 1994; Allport & Wylie, 2000), suggests that costs are linked to a combination of carry over effects from the previous task set, combined with potential inhibition of previous components of the earlier task set that are now required. This account, although not denying their existence, hypothesises that switch costs are not linked to high level cognitive control process, but are simply a form of priming. Costs are a consequence of greater competition between the present task set and the previous one (Gilbert & Shallice, 2002).

A different explanation for these costs has been proposed by Monsell and colleagues (Monsell, Young, & Azuma, 2000; Rogers & Monsell, 1995). They suggest a two stage process that first involves top down, endogenous control, which prepares the system for the arrival of the new stimulus. This is followed by a second stage, which is said to drive the process, which occurs when the stimulus is presented as the reconfiguration cannot be completed until its arrival (Gilbert & Shallice, 2002). An important assumption made by supporters of this account is that once a task set has been activated, it remains at that level of activation until there is a requirement to switch task set (Schneider & Logan, 2006).

Task set inertia

The task carry over effect is based on Allport et al.'s (1994) theory of task set inertia, and is said to be a mechanism that is not necessarily associated with endogenous processes. It reflects a form of proactive interference from a previous stimulus response map, which had the same stimuli, and persists from the preceding instructional set (Meiran, Chorev, & Sapir, 2000). It was also believed to have an effect that could last for up to several minutes, due to it only slowly dissipating. The primary problem with this explanation of cost is that Allport et al.'s and Rogers and Monsell's (1995) experimental designs cannot differentiate between passive dissipation of an older task set and preparatory reconfiguration of an upcoming task set (Meiran, Chorev, & Sapir, 2000). Meiran et al., (2000) conclude that through the use of explicit cues, these design problems can be overcome.

Another result identified in Allport et al.'s (1994) experiments, was the *Asymmetric Switch Costs* between identifying the colour of the word in comparison to reading the word. Participants switched between word reading and identifying the colour of the ink that the word was printed in. Interestingly, it was more costly to return to the well practised word reading task in comparison to switching back to the more difficult task of identifying the colour of the ink that the word was printed in. Initially, there was little to no cost when switching back to identifying the colour of the word, but in later experiments (Allport & Wylie, 2000; Wylie & Allport, 2000), a cost was identified, but this was still substantially slower than switching back to the word reading task. This result is difficult to explain if cost is linked specifically to reconfiguration, as returning to a well practised task should take less time than returning to a less practised and more difficult task (Gilbert & Shallice, 2002). Allport et al. explain this as a consequence of the more dominant task of word reading needing a greater degree of inhibition when switching away from it, which means that when it returns, there is a greater cost in reactivation of the task. Mayr and Keele (2000) offer evidence in favour of this explanation by showing that an ABA sequence takes longer than a CBA task switching sequence. Unlike Allport et al., they see it as inhibition of the goal and subsequently, of all of the previous stimulus-response maps, not necessarily a specific relationship between a previous stimulus and the present stimulus. Gade and Koch (2005) suggest that there is a basis for this argument, as they showed that the more active a task that is to be abandoned, the greater the cost when wishing to reactivate it later on in a task switching sequence. To counter this argument, Monsell et al. (2000) managed to reverse this asymmetry of cost.

Another anomaly identified by Allport and Wylie (2000) was "item specific costs", based on the requirement for a previous stimulus, with an incongruent relationship to the present stimulus, to have been present before, for cost to be seen (Gilbert & Shallice, 2002).

Schneider and Verbruggen (2008) examined switching within the same task category, rather than between task categories, using a repeat and non repeat of response set at lag-2. As Mayr and Keele (2000) hypothesised that any cost difference between these sequences was linked to inhibition of the task set, it was suggested that cost differences should not be seen when the category does not change. Schneider and Verbruggen showed that cost variation occurred when response sets differ across sets, but not when they stay the same within category. Their results suggest that lag-2 costs are linked to the inhibition of irrelevant category response mappings. Cognitive control is seen as essential when there is a requirement to efficiently switch task. How we do this is still a matter of debate. One of the prominent theories is that we inhibit irrelevant task sets in order to facilitate the relevant task set. In their paper, Schneider and Verbruggen highlight how components of each task set will overlap with other task sets; inhibiting the whole task set would only act to inhibit subcomponents of a relevant task set. Because of this, they suggest that only certain components of an irrelevant task set would need to be inhibited rather than the whole. They specify that it is irrelevant "category response mappings", that are inhibited, which they say are associations between a specific category stimulus to responses.

Koch's recent work suggests that the components of a task set associated with the response are inhibited (Gade & Koch, 2007). Participants performed a Go/NoGo trials, where they either pressed the two response keys at the same time, in the 'NoGo trials', or one of two keys, in the 'Go' trials, which specified the appropriate response to a target They found no ABA costs when a NoGo trial was completed at trial B. It was suggested that irrelevant response maps are inhibited. Gade and Koch (2007) also ran an experiment using trivalent (T) tasks, and a univalent (U) task, in a TTT and TUT sequence, comparing ABA and CBA task switching sequences. They found that there was always a cost in the ABA, TTT sequences, but only in the TUT sequences when there was a complete response set overlap. They concluded that when response sets overlap, they can induce task-set inhibition. Schneider and Vebruggen (2008) highlight another potential confound present in many experiments, which is that different tasks are associated with different stimulus categories. This means that even when there are the same or different responses to a category of task, there is always an irrelevant category response map present. The question arises as to whether the switch in category in itself causes the associated ABA cost, or whether a similar cost will be found when remaining in category but only switching the stimulus response map. This investigation may answer this question, as although it does not use category judgments as a task, it does maintain the same overall goal of the task, which is to identify the position of a target that has a one-to-one relationship to one cue.

Experiments using an ABA/CBA sequential switch

Mayr and Keele's (2000) initial premise, linked to their experimental design, was connected to their belief that previous task switching experiments had not revealed inhibitory processes that were due to inhibition of the abstract task set. Subsequently, concerns about the episodic priming account for these costs were also forwarded, and these have become the primary counter argument to the inhibition explanation for why a switch in task set was more costly than a repeat in task set (Logan & Bundesen, 2004). Logan and Bundesen (2004) suggested that the episodic priming explanation was a real challenge to previous experiments using the AABBAA design, especially where the target contained both a "prime" and a "probe". Their methodology required the participant to identify a previously cued deviant object from a display of four objects, which were each placed centrally in one of the four quadrants of the screen. Initially, the appearance of each of the four objects could change in three different ways: "orientation"; "colour"; and "movement". There were said to be two deviant states and one neutral state for these objects: for colour these were pink or purple, and blue; for motion they were left to right, up and down, or stationary; in the orientation state, objects could lean to the right or left and vertically in the neutral state, respectively.

Another manipulation was linked to the interval between the cue's presentation and the target stimulus appearance, the "cue stimulus interval" (CSI) and the time between the response and the appearance of the new cue, the "response cue interval" (RCI). This manipulation was carried out because of the potential for an expectancy violation being the cause of the ABA cost. Participants are said to develop a sequential expectation that there will be a continual change in task from trial to trial, which biases against a lag-2 repeat of task. This means that an ABA sequence is perceived as a violation of their expectation and could subsequently cause the cost. The manipulation of the CSI is said to correct for this and directly checks if the origin of the cost is linked to this phenomena. A short CSI is far more likely to create this potential confound, whereas a 500ms interval is said to allow time to prepare for a change.

Mayr and Keele's (2000) overall results showed an ABA cost in comparison to the CBA sequence. There was no significant effect linked to this cost when either the CSI or RCI were lengthened in Experiment 1a, where as in 1b there was a reduction of cost when the RCI was lengthened, which was not the case when the CSI was increased. These results suggested that an expectancy violation was not the cause of the ABA cost. The decrease in the costs when the RCI was lengthened suggests that the change in task set and its closeness to a recently abandoned task set may require less inhibition.

Gade and Koch's (2005) paper implies that these conclusions are correct, as when the time between the task at lag-1 and lag-2 was extended, the cost of an ABA sequence was dramatically decreased in comparison to when the time between the task at lag-1 and lag-0 was increased. Cost seemed to be linked to the requirement of the task at lag-1 inhibiting the task at lag-2, rather than the task at lag-1 interfering with the task at lag-0.

A further finding in Mayr and Keele's (2000) study was that the temporal position and colour of the target seemed to have little to no effect upon overall costs, which suggested that the exogenous components of the target were not causing the cost. In their second experiment, they were concerned about a methodological issue in their first design, which caused a previous target to become a distracter from trial to trial. This concerned them, as they hypothesised that the costs they were seeing were linked to the endogenous nature of the goal changing and not to the inhibition of distracter top down language labels, or perseveration of a previous external stimuli. Based on these concerns, Experiment 2 used four, rather than three dimensions: colour, movement, orientation, and size, refer to figure 8. They also changed the design so that only two of the dimensions could be present at any one time, with the identified target dimension having one object acting as a target and another as a distracter, with the two other non-specified objects acting as distracters.

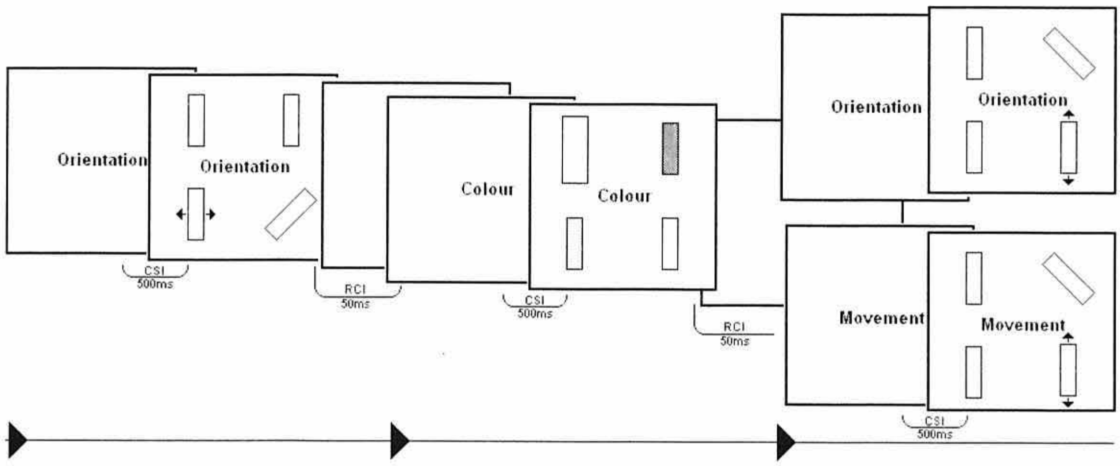


Figure 8: Experiment 2 Mayr and Keele (2000).

In Experiment 3, Mayr and Keele (2000) clarified their thinking about where they believed inhibition to originate, and hypothesised that it originates as a consequence of top down, executive processes rather than bottom-up lateral inhibition where perceptual modules compete to manage action.

Mayr and Keele (2000) concluded that inhibition should only occur as a consequence of a shift in related perceptual dimensions, which are controlled by an endogenous process, and not when these dimensional changes are singularly controlled by exogenous processes. Because of this, they compared two conditions, one that used cues and another which had a neutral line of Xs. In both conditions there was only one deviant target presented on the screen of four stimuli, which meant that in the neutrally cued condition, the participant would be able to identify and use bottom up processes to determine the correct stimulus to respond to. In this experiment, they found an ABA cost only in the cued condition, suggesting the ABA cost was a originating from a top down process, refer to Figure 9.

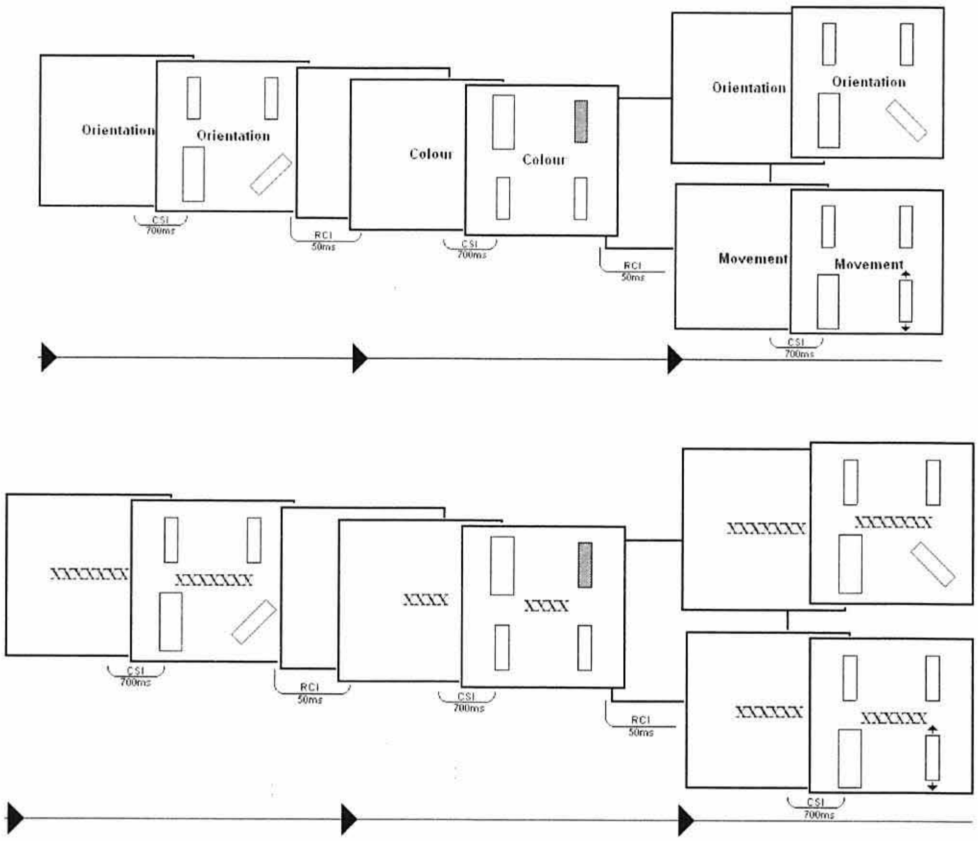


Figure 9: Mayr and Keele (2000) last two experiments.

Schuch and Koch (2003) used a go/no-go methodology, where participants always prepared for the arrival of a stimulus, but upon its arrival, were given a signal informing them whether or not to respond to the target. In their first experiment, no shift costs were found after a no-go trial, suggesting that a response was required for a shift cost to be apparent. Schuch and Koch's (2003) second experiment highlighted the absence of inhibition after a no-go trial. In their third and fourth experiments they showed that the selection of a response, rather than its completion, was the cause of backward inhibition. In their conclusions, they reemphasised the apparent advanced preparation benefits in all of the go trials, which suggested that this process of preparation was similarly occurring in the no-go trials. Because of this, they concluded that the inhibition of a previous task set occurs when the participant selects a response to a target, not when the cue first appears on the screen. The findings of the present study suggest that it is the related top down language label that links the cue to target that is inhibited. This, however, may not actually be required to be inhibited until a response is made.

Hübner, Dreisbach, Haider, and Kluwe (2003) found that backward inhibition helps to work against tendencies to perseverate responses to previous trials, selectively reducing the level of interference between trials. This did not occur if the cue had no relevance to the preceding task, or if the participant was not allowed to prepare for the next task. Endogenously preparing for the next task was a prerequisite for inhibition to be apparent.

Koch, Gade, and Philipp's (2004) experiment again showed the importance of the relationship between task inhibition and the response related component of a trial. It also suggested that inhibition had a time base release to its appearance. In their experiments, they had three different tasks, one of which required a double press of both response keys, whereas the other two tasks required a choice to be made between pressing one of two keys. Their two experiments involved either altering the CSI or the RCI. They found that in both experiments a cost was apparent in the ABA sequence in comparison to a CBA sequence, even in the double press condition, suggesting that inhibition is linked to the response mode of a trial. Their results also suggested a time based release of inhibition, as there was a difference between the way the task types were affected when there was either a change in the RCI or CSI. A prolonged CSI was shown to affect only the double press task and not the single choice tasks, reducing the level of inhibition apparent in the ABA sequence in the double press task. This was different for the prolonged RCI, where all three types of tasks had a reduction in the level of inhibition when the RCI was lengthened.

As previously stated, Arbuthnott (2005) replicated the findings of Arbuthnott and Woodward (2002) that location cues removed the cost associated with inhibition, also showing that location cues are more affected by response congruency than verbal cues, which they suggest is consistent with a lateral model of inhibition. Arbuthnott proposes that this effect may be linked to one's ability to differentiate location cues more accurately, which may reduce the likelihood of competition with a previous category-response rule, lessening the effects of lateral inhibition. What was also shown was that if a language label was attached to the location, cue inhibition again became apparent. This implied that the verbalisation of a cue created more interference with the previous trial, even when the remaining cue had a location element to it.

Gade and Koch (2005) asked whether a general decrease in the level of activation causes a reduction in the costs associated with an ABA task switch, when there is an increase in the RCI. Alternatively, this might be linked to a decrease in the level of activation of a competing task set reducing the level of interference between task-sets, which creates this reduction in cost. By manipulating the RCI, Gade and Koch (2005) came to the conclusion that the reduction in the activation of a competing task set is the important factor in the reduction in cost associated with the lengthening of the RCI.

In a study by Philipp and Koch (2005), the task was defined as the modality used to make a response, i.e. a vocal, finger, or foot response. There was only one stimulus categorisation task, which was to determine if a digit was odd or even. Their results, which showed a backward inhibition cost when switching modalities, suggested that the switch in modality for the response was inhibited, as in previous experiments, where the stimulus category seemed to be inhibited.

Gade and Koch (2007) conducted another experiment with four different tasks. Three of these overlapped in stimulus and response set, which they called "T" tasks, while a fourth task did not overlap with stimulus set, but could be altered to overlap in response set. They called this latter task, a "U" task. "T" tasks had two types of stimuli, A or 4, which could be in two different colours or sizes, refer to figure 10.

Stimulus = 1cm(4, A, 4, A, 0.5cm(4 , A, 4, or A.

Figure 10: Stimuli for Gade and Koch's (2007) experiment.

These are presented in a rectangle, which has one of three symbols on each of the four sides which act as a cue, refer to figure 11.

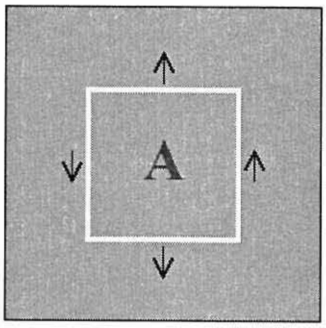
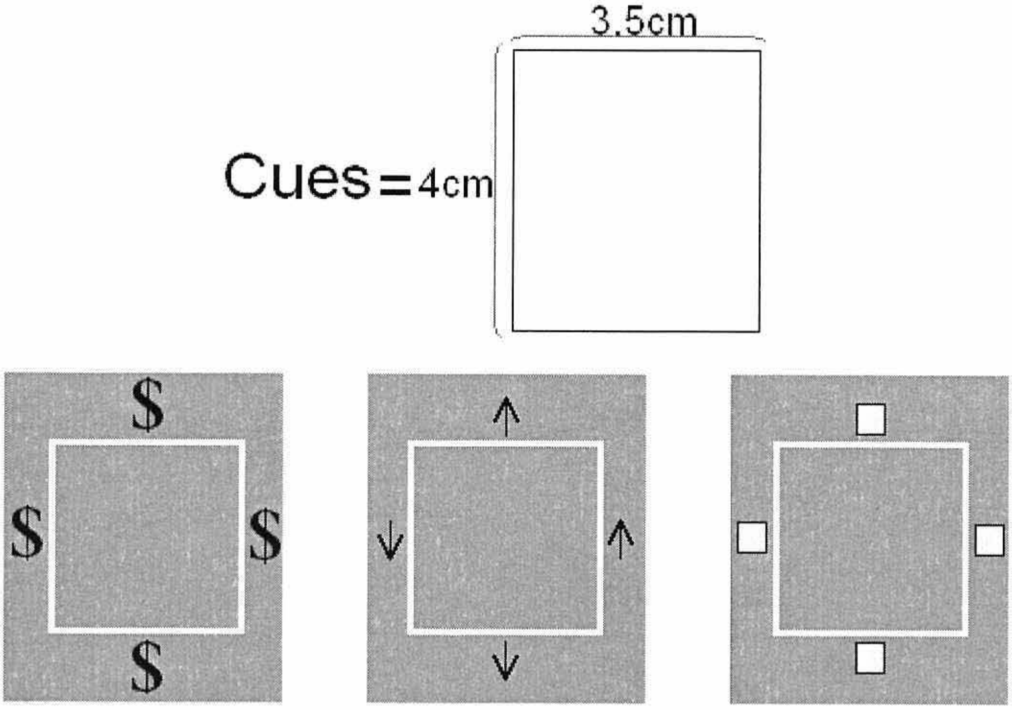


Figure 11: Cue and Stimuli for Gade and Koch's (2007) experiment.

"T" trials had three different cues that were presented around the four sides of the rectangle; dollar signs were related to identifying the form of a target (number or letter), arrows related to its size (big or small), and yellow squares were linked to identifying the target's colour, (blue or red), refer to figure 12. Responses were verbalised, and were left or right, i.e. left = red, right = blue, left = big, right = small, and left = letter, and right = number. These were counterbalanced across subjects.



$ = Form ↑ or ↓ = Size □ = Colour

Figure 12: Cues used to identify "T" targets from Gade and Koch (2007).

The "U" task on the other hand, was represented by a smaller rectangle, which could be filled or empty and this would have "£" signs on all four sides, refer figure 13.

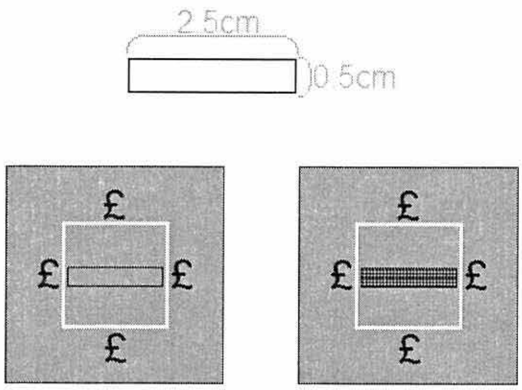


Figure 13: "U" trials cue and target from Gade and Koch (2007).

Subjects responded in the "U" trials by saying "empty or filled" in the first experiment, or "up or down" in the second experiment, while in the third experiment, responses were "left or right", as in the "T" task. Responses in the "U" trials, in the first two experiments, were said not to match the responses of the other three "T" trials, but in the third experiment, responses to "U" and "T" trials were said to map onto each other.

In ABA sequences, when there was a run of TTT tasks, there was an ABA cost. However, when there was an ABA sequence with a "TUT" run of tasks, there was no ABA cost unless the "U" task had a similar response to the "T" tasks , refer to figures 14 and 15.

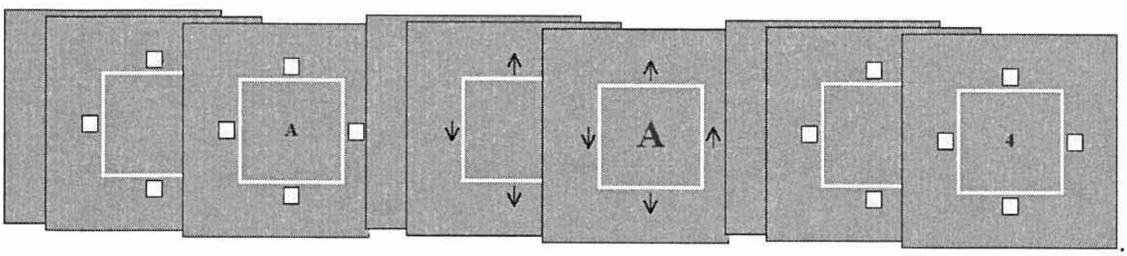


Figure 14: "TTT" run in an ABA sequence from Gade and Koch (2007).

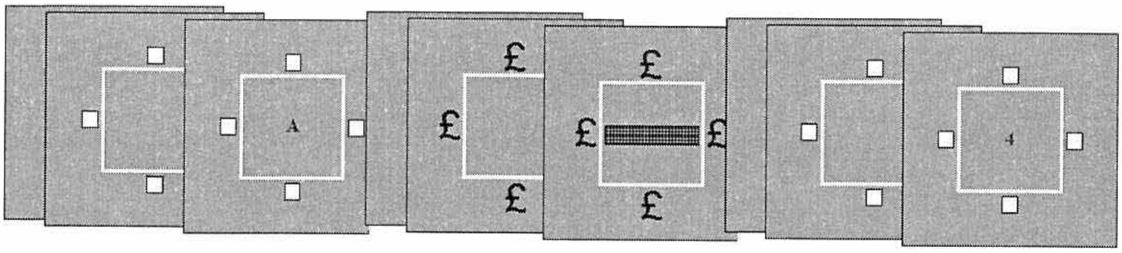


Figure 15: "TUT" run in an ABA sequence from Gade and Koch (2007).

These results are interesting as they suggest that it is not necessarily the bottom up physical representation of the cue or target that is being inhibited, or simply the verbalisation of the response, but that of the shared relationship of response and differing targets. Again, as in previous experiments, this suggests that the language element and its relationship to a target is inhibited.

Using a similar methodology, Gade and Koch (in press) also developed Mayr and Kliegl's (2003) experiment that used two cues to one target, specifically looking at an ABA sequence. They found very similar results to Mayr and Kliegl's (2003) findings countering Logan and Bundersen's (2003) "compound cue-target model", which is discussed in more depth later on in this study.

The evidence reviewed so far suggests that language plays a part in how the correct target, or target feature, is identified when an ABA cost is apparent, whereas a target can be identified without the use of language, i.e. when there is only one obvious deviant target (as in Mayr and Keele's (2000) experiment 3), or when location is the cue (as in Arbuthnott's (2005) experiments), there is no ABA cost. Similarly, in keeping with Gade and Koch (2007), the shared element of the language response to differing targets seems to be an important factor in the emergence of the ABA cost . However, further clarification is needed as to the locus of the language element that causes this cost.

In contrast to the above ABA experiments, Mayr and Bryck (2005) carried out experiments looking at the effects of priming. They were able to independently manipulate the relationship between the cue (which they termed the rule), target, and response, while comparing a repeat or change in any one of these three factors while keeping the other two factors constant. This experiment, although unlike the above ABA experiments, may shed some light on the importance of language and how it plays an integral role in the costs we see in task switching experiments. Mayr and Bryck's (2005) experiment highlights how the language label associated with the rule, represented in the cue, may bind together all of the subcomponents of any trial or task, refer to figure 16. They found that the greatest cost was associated with the repeat of the position of the stimulus and directional response linked to the position of that stimulus, combined with a change in rule (cue). It suggested that all of the components that make up a trial are bound together by the associated rule of the task, which was represented as a language cue.

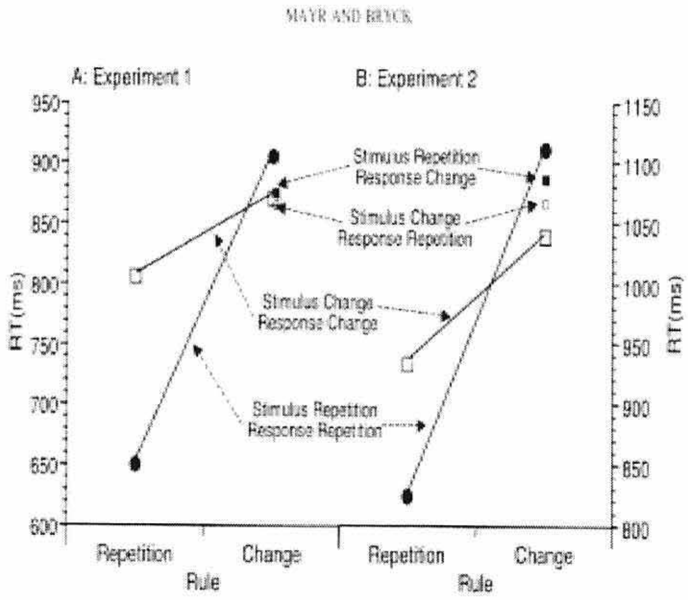


Figure 16: Results graph from Mayr and Bryck's (2005) paper.

If one were to look at the Mayr and Bryck (2005) and consider ABA sequences that may have occurred within the sequences and treat each cue, target, and response as a unique trial, this observed cost could be interpreted as a form of episodic priming (Logan & Bundesen, 2003; 2004; Schneider & Logan, 2005; 2007), or it could be linked to the need to inhibit the language label associated with the target and response more actively than the other elements that make up the trial. Whatever the answer, common to all of these experiments is the importance of language in the observed costs. When the language label is shared by the target and response, then an ABA cost is apparent, and Mayr and Bryck's (2005) experiment suggests that it is the language element that acts as the binding agent between the target and the appropriate response.

A counter argument to inhibition in explicitly cued experiments

Episodic priming

Mayr (2002) stated that Instance-Based episodic priming was the most challenging account of inhibition but it could not fully explain backward inhibition costs. Its origins lie in theories of attention and memory and how they may interact (Logan, 1988). The basis of the theory is that each time an action is seected, a "memory snapshot" is taken, and this is a top down language label into a "specific instance". Dimensions, such as the location, values of distracter objects, target features, and how we respond, are all taken into account. When, later on in a block of trials, a similar component of the previous snapshot appears, such as the cue, target stimuli, or one other of the previous snapshot dimensions reappear, this triggers the earlier memory trace. If they match, then this assists the recovery of the snapshot, but if they differ, then there is an associated cost. It is also suggested that if there are components of a previous target that had to be ignored in an earlier trial, then these may be given a no-go tag, which interferes with the present trial, if the ignored target feature now requires acting upon. Mayr (2002) suggests that the episodic account of why negative priming occurs has made it difficult to study inhibition using sequences that use AABBAABB methodology. It is proposed that lag-2 priming accounts are more resistant to this criticism, as they believe that it is the task set that is being inhibited.

One of the main problems with explicitly cued experiments is the confound that when a task switches so does the cue type, leaving the question: is the cost difference between different sequences or task types linked to the change in cue, change in task, or an amalgamation of the two? Researchers have attempted to determine the effect of the cue by using two cues to one target; this has given three types of sequence: a task switch; a task repeat where the cue switches; and a task repeat, where the cue repeats. Mayr and Kliegl (2003), and Gade and Koch's (in press) recent experiments, suggest that cost is not linked to episodic priming and the actions of a compound cue-target (Logan & Bundesen, 2003)

Mayr and Kliegl (2003) and Logan and Bundesen (2003) have carried out two different experiments, examining how much cost is linked to a switch in cue, in comparison to a switch in task, which have had contradictory results. These have generated different explanations as to where costs may be originating from. In chapter 4, these experiments are discussed in greater depth. However, the difficultly with making comparisons between these experiments is that they did not use similar methodologies. Cues, targets, tasks, and contingencies were different and may have played greater or lesser parts in the cost differences. The primary difference in these experiments was linked to the costs associated with a sequence, where the cue changed and the task repeated. Logan and Bundesen (2003) found little difference in cost between this type of sequence and a switch in task, when compared to a repeat of task. They concluded that cost was linked as much to a switch in cue as it was to a switch in task. Mayr and Kliegl (2003) found differing results, with a switch in task having a significantly greater cost than both a switch in cue and a repeat of cue. Unlike Logan and Bundesen (2003), the switch in cue was less costly to a switch in task, but more costly than a repeat in task. Two models of costs originated from these findings.

Because of this difference in results, Mayr and Kliegl (2003) concluded that costs were caused by the operation of an executive, which inhibited a previous task set from working memory. Where as Schneider and Logan (2005) proposed that costs were seen, in a switch of cue or task, because of the benefits that occurred when there was a repeat of cue and target, these acted as "cue-target" compound priming repeats of the task. Schneider and Logan (2005) propose that there are two mechanisms involved in processing the cue: residual activation in short term memory of primed cue, and the retrieval of the compound cue response categories from long term memory. Compound cue retrieval is said to explain the costs linked to congruency, while priming of the cue encoding accounts for differences in transitions.

Schneider and Logan (2005) suggest that the processing of the cue is linked to a race between short (STM) and long term (LTM) memory processing, where the perceptual representation of the cue can be compared with its transient representation in STM and its permanent representation in LTM. The rate of processing - and subsequent cost - is linked to the perceptual representation of the presented cue, making a comparison with its transient representation in STM, and its permanent representation in LTM. Differences in transition times are linked to different rates of comparison to short term memory.

According to Schneider and Logan (2005), this is because the rate of comparison to LTM is constant, whereas the rate of comparison to STM is determined by the sequence of transition. Schneider and Logan's experimental methodology used two separate tasks. One task required the subject to determine if a number was odd or even, while the other task asked them to determine whether a number was below or above five. Four types of cue were used: "Odd", "Even", "High", and "Low". Schneider and Logan (2005) present a mathematical model to explain how these different cues and tasks interact.

Logan and Schneider (2006) suggest that underlying the explicitly cued methodology is a potential confounding variable, as whenever there is a repeat or switch of task set, there is also a repeat or switch of cue. They suggest that the costs observed are not necessarily linked to the inhibition of the task goal, but could be linked to a mismatch between the cue and stimulus of the previous trial and those of the present trial.

Logan and Schneider's (2006) model assumes that there are two mechanisms involved in an explicitly cued experiment: a short term memory of the cue, which through residual activation acts as a prime, and a compound cue-target, which acts to retrieve response categories from long term memory. The instance view of episodic memory assumes that each set-selection episode creates a "snap-shot" (memory trace) of all of the relevant information required to retrieve the correct response top down language label (Logan, 1988). This would include the cue and stimulus. Any priming or costs would be linked to a respective match or mismatch between episodes.

In both models, there is a suggestion that there is a requirement to retrieve from LTM a component, or all of a task set. Mayr and Keele (2000) suggest that this cost is linked to the retrieval of the whole task set rather than a specific task set. They further suggest that the disengagement from a no longer relevant task set is caused by inhibition, and the requirement to re-engage a new task set from LTM is the basis of the cost.

Logan and Bundesen (2003; 2004) suggest that a cue is first used to access working memory, prior to it being used to retrieve responses from long term memory. Cue encoding is suggested to be similar to a race between working memory and long-term memory, where they compete to see which one can select the correct response category from long-term memory. A matching comparison is made, between the visual representation of the present cue and target, to its previous representation in working memory, and its more concrete representation in long term memory. The cue and target act as a compound: the more matching similarities between the present visual representation of the cue and target, the quicker it is able to access the correct response category from long term memory; the more mismatches between the cue and the target and its previous representation in working memory, the slower it is to recover the correct response categories, and the more likely that the long term memory cue encoding system will carry out the process of recovering the correct response category. The long term memory route of recovery, Logan suggests, is fairly constant, whereas the working memory route fluctuates in speed. This fluctuation is directly linked to the transition of the previous working memory's representation of the compound cue-target and the present visual representation of the cue and target.

In summary, the compound cue-target model suggests that a cue first acquires a top down language label in short term memory, prior to its use in retrieving responses from long term memory. Cue encoding, is suggested to be similar, again, to a race, between working memory and long-term memory, so that it can acquire the correct top down language label for the cue, and then select the correct response category from long-term memory. A matching comparison is made, between the visual representation of the present cue and target to its previous representation in working memory, and its more concrete representation in long term memory. The cue and target act as a compound; the more matching similarities between the present visual representation of the cue and target, the quicker it is able to access the correct response category from long term memory, refer to figure 17.

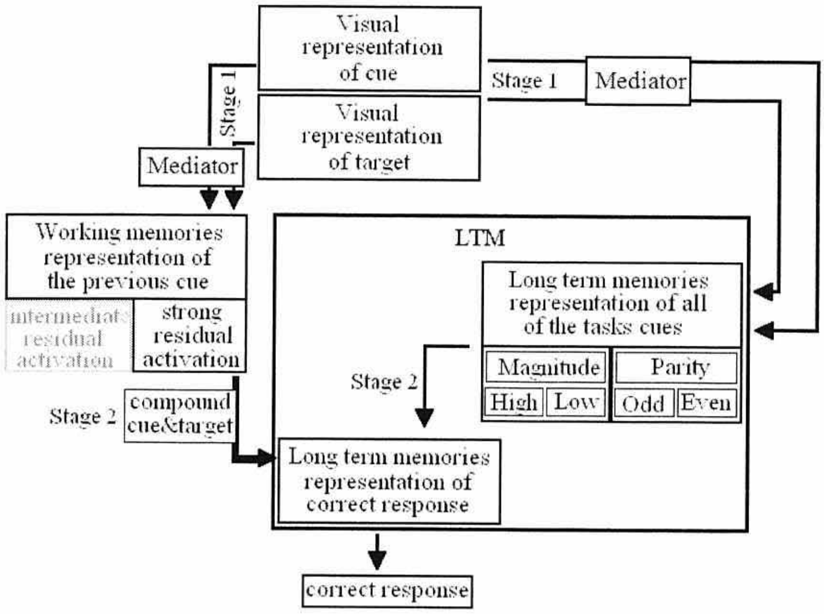


Figure 17: A graphical representation of the compound cue-target model (Logan and Schneider's (2006).

The more mismatches between the cue and the target and its previous representation in working memory, the slower it is to recover the correct response categories, and the more likely that the long term memory cue encoding system will carry out the process of recovering the correct response category. The long term memory route of recovery, Logan suggests, is fairly constant, whereas the working memory route fluctuates in speed. This fluctuation is directly linked to the transition of the previous working memory representation of the compound cue-target, and the present visual representation of the cue and target. Later, it was suggested that a mediator can also be attached to the cue stimulus relationship (Schneider & Logan, 2006) that can also assist in the process of recovering the correct response (Logan & Bundesen, 2003; 2004; Schneider & Logan, 2006; 2007).

Mayr and Kliegl (2000; 2003) on the other hand, suggested a different way to explain the costs in an ABA switch of task; they are linked to inhibition of the previous task set in working memory. They suggested a two stage model to explain the costs associated with a switch of task: a retrieval stage on the presentation of the cue, and an application stage, when the stimulus appears, refer to figure 18.

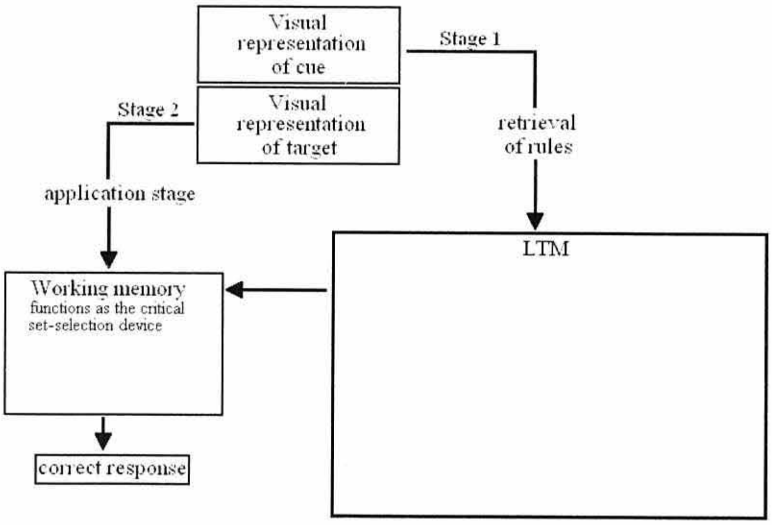


Figure 18: Graphical representation of the Mayr and Kliegl (2003) model.

On the presentation of the cue for the next task, working memory is cleared of the previous task set by inhibition. This allows the present cue to recover the "action rules" for the new task set from long term memory, to be placed into working memory. Cost, they suggested, was associated with the recovery of a recently inhibited task set, which was previously in working memory, and then for its retrieval from long term memory. Mayr and Keele (2000) propose that if one were simply instructed to look for a red object, a "simple action", then an ABA cost would not be evident, as a previous action rule based on a task set would not need to be recovered. Our methodology, where we were switching between single cue-target relationships, could, in certain conditions, be seen as "simple actions", so using

Mayr and Keele's model should not cause an ABA cost. Our findings suggest that costs do occur in an ABA sequence, even when there is a simple switch of cue stimulus relationships,

Mayr and Keele (2000) suggested that the costs incurred in an ABA switch of task were linked to inhibition of the previous task set in working memory. They suggested a two stage model to explain the costs associated with a switch of task: a retrieval stage on the presentation of the cue, and an application stage, when the stimulus appears.

Mayr and Kliegl's (2003) explanation for their model is based on Rogers and Monsell's (1995) suggestion that there is a requirement to restrict the possible sensory influences in our external and internal environment. This is because we are continually bombarded by a multitude of differing cues and stimuli, which can be responded to in numerous ways. They suggest that the cognitive filtering system that creates stability in our environment is linked to our higher cognitive ability to formulate behavioural goals. This can both restrict, link, and order what we select to act upon, and what we decide to reject. Cognitive goals are said to have special status in specific models of cognitive control (Anderson, 1983; 1993), and are also believed to be linked to specific "neuronal clusters" in the frontal cortex (Dehaene & Changeux, 1989). Neural networks suggest that task-sets are represented in the brain as a group of neurons acting together with a shared and common top down language label. These top down language labels are believed to compete with each other, with the most activated of the top down language labels winning and being acted upon (Houghton & Tipper, 1994). It is proposed that these top down language labels have a limited level of activation, causing a ceiling effect. This means that when a new task-set wishes to replace the present task-set, it is not able to become more active than the presently most active task-set. This problem is believed to be overcome by the new task-set inhibiting the present task-set, causing the presently most active task-set to become less active, so allowing a switch of task-set

(Houghton & Tipper, 1994). Recently, Gade and Koch's (2005) results have suggested that the level of activation of the to-be-replaced task-set determines the amount of inhibition required to remove it from working memory. Behaviourally, this is reflected in sequential task switching experiments, where the sooner one returns to a recently abandoned task-set, the greater the cost.

Mayr and Kliegl (2003) suggest a two stage model, with firstly, a retrieval stage that is cue driven, then an application stage, created by the target stimulus. The cue first acts to retrieve the relevant task sets from long term memory associated with the task goal; these are then placed into working memory. On the presentation of the cue for the next task, working memory is cleared of the previous task set, by it being inhibited; this allows the present cue to recover the "action rules" for the new task-set from long term memory and for it to then be placed into working memory. Cost, they suggested, was associated with the recovery of a recently inhibited task set, which was previously in working memory, and then its retrieval from long term memory. Mayr and Keele (2000) propose that if one were simply instructed to look for a red object, a "simple action", then an ABA cost would not be evident, as a previous action rule, based on a task set, would not need to be recovered. Our methodology, where we were switching between single task sets, could, in certain conditions, be seen as "simple actions", so using Mayr and Keel's model should not cause an ABA cost. Our findings suggest that costs do occur, in an ABA sequence, even when there is a simple switch of cue stimulus relationships.

In the experiments described in the present study, in Chapter 4, two cues to one target were used; these two experiments will be considered in more depth, taking into consideration some of the counter arguments to the compound cue-target model.

Monsell and Mizon (2006) were concerned about Logan and Bundesen's (2003 & 2004) and Schneider and Logan's (2006 & 200) findings, as the compound cue-target theorists were attributing this effect to all previous explicitly cued experiments. Monsell and Mizon proposed that the difference in the two groups may be a result of methodological differences. This was demonstrated when they both managed to reproduce the same results found in both experimental groups, then alter the results of the compound cue priming so that they were similar to the other group's results, by altering the probability of a task change. When the probability of a change is kept low, discouraging the participant from preparing or reconfiguring in advance of a change, the results suggest an act of endogenous processing in all of the above conditions. This will be considered in more depth in Chapter 4.

Other models that explain cost associated with a switch in task

Task switching models

The basis for much of the debate in the task switching literature is whether we are measuring costs associated with executive processes, or we are seeing costs that are linked to the priming effects of the cue and stimulus acting on responses as a compound.

Much of the debate originates around Allport, Styles and Hsieh's (1994) experiment, which used an alternating runs procedure, switching between word reading and colour naming. They found larger switch costs when returning to a well practised task after completing a less practised task (e.g. switching from colour naming to word reading), than when the switch in task was in the opposite direction (e.g. from word reading to colour naming). This cost was named by Allport (1994) as an *asymmetric switch cost* linked to *task-set inertia,* which is believed to reflect the "persisting activation suppression of competing task sets, or task processing pathways" (Wylie & Allport 2000. p515).

Another hypothesis developed by Wylie and Allport (2000) was a "*retrieval hypothesis*". Between-task interference is explained as a consequence of stimulus-triggered retrieval of competing stimulus-response associations, which are acquired or strengthened in early trials. Costs were considered to be linked to the characteristics of the previous task's stimulus response characteristics, not to the upcoming task. Logan and Bundesen (2003) suggest that because of these results, and the asymmetry of the switch costs (being the opposite to what would be expected if switch costs only reflected the burden on executive process), it would be wrong to suggest that we were only measuring costs associated with executive processing. Monsell, Yeung and Azuma (2000) countered this argument after surveying the available literature and carrying out three manipulations on task strength. They proposed that it was not universally true that it is easier to switch to a weaker task, suggesting that inhibition of a stronger task may be linked to a strategy used when tasks are extremely unequal in strength, or caused by post-stimulus masking of control operations for more complex tasks. They also concluded that inhibitory priming may be stimulus specific. Rogers and Monsell's (1995) primary argument proposes an exogenous control process, that is not solely based on priming accounts (Gilbert & Shallice, 2002).

There are two pieces of evidence for Rogers and Monsell's (1995) argument: firstly, Monsell, Azuma, Eimer, Le Pelley, and Safford (1998) showed that even after allowing for 600ms RCI to elapse, a residual switch cost still remains. Secondly, in experiments where there are more than two trials of a particular task, costs should not be limited to the first trial of a task switch. Rather, if they originate from the effects of the previous trial, they should instead dissipate gradually (Gilbert & Shallice, 2002). De Jong (2000) gives a further, all or nothing, explanation, proposing that there are two possible causes of residual switch costs: a failure to take advantage of opportunities for advance preparation, and restrictions to the completeness of task-set reconfiguration achievable by entirely endogenous processes.

Meiran (2000) postulates that we are unlikely to succeed when we attempt to categorize general switching processes, suggesting instead, that we concentrate our research on situational constraints and their effects on the choice of control strategies. He comes to this conclusion because of his findings that challenge the control strategy that he proposed in his earlier model (Meiran, 2000), which directed attention to a relevant stimulus dimension. His later results appear to suggest that this strategy is unlikely to be used in conditions where two dimensions are relatively limited, making its redirection difficult and taxing. In these conditions, he believes, participants will choose relatively less taxing and bottom up strategies for stimulus-cued reconfiguration.

Meiran's (2000) model has an important underlying concept: the task-set. The task set is said to control how a mental representation of a task is formed. He proposes that there are three types of task set: stimulus, previous response and alternative response sets. The function of these task-sets is to successfully process the information held in bivalent components of the task. He suggests that this is effected by biasing one of the mental representations in favour of one dimension.

Mayr and Keele (2000) suggest that part of the switch cost is linked to the inhibition of an abstract task-set that represents the goal of the task. They state that inhibition, in this case, cannot be considered simply as a component of negative priming and it is a top down process that reflects executive processes

As is clear from these accounts, the process of inhibition is frequently discussed. Houghton and Tipper's (1996) explanation of this process is presented in a neuro-cognitive model, which attempts to explain how inhibition works as a mechanism of selection and sequencing of cognitive states, rather than an independent top down system. It is suggested that many cognitive states can be active in parallel at any given moment in time, but only the selected representations can control actions and thought processes.

Houghton and Tipper (1996) state that selection and de-selection of competing cognitive states is controlled by mechanisms reliant on activating selective inhibitory processes. These inhibitory processes cause a lessening of activation of potentially disruptive representations, which may interfere with the selected representation. They suggest that, to understand how these dynamic systems work, it is important to appreciate the biological constraints that affect how such mechanisms may work.

Pyramidal cells, which are thought to exist in all layers of the cortex except for layer 1, act in an excitatory manner, feeding information both forward to activate new layers and backwards to previously active layers. Because of the "hard wired" nature of these connections, positive feedback loops could cause instability in the mechanism, creating perseveration errors linked to an insensitivity to input variations. Lateral inhibition is believed to exist when competition between cognitive representations compete by attempting to inhibit other cognitive representations. This type of inhibition has been seen within the visual cortex and has been linked to edge or orientation of an object. GABAergic neurons are also believed to affect the cortical plasticity of the receptor fields.

Houghton and Tipper (1996) suggest that the cue word acts in a top down manner to constrain the bottom up perceptual domain, "object field states" (OFS), using a matching process, "match-mismatch". Objects that match the OFS cause a positive feedback loop, whereas objects that do not match the OFS cause a negative feedback loop.

In their computational model of inhibition, Houghton and Tipper (1996) propose that bottom up input at the first level has both on and off switches within it, which counteract each other into either an excitatory or inhibitory loop when they initially perceive the stimulus. At the second level, a process of mismatch or match occurs, and matching components cause the on button to increase its level of action, overriding the off button, and creating a positive loop.

Houghton and Tipper (1996) do not propose a model that has a central inhibiter. They suggest that inhibition is distributed throughout the representational substrate and the central description of the target does not directly inhibit anything.

Houghton and Tipper (1996) have postulated that a top down process modulates activity. The matching function takes place in the basal ganglia, as it receives information from all areas of the brain and may allow anterior (attentional) and posterior (perceptual) systems to interact. They also suggest that early sensory perception occurs independently of the arousal state, and local selective modulation of inhibition may be linked to areas associated with coding for specific stimulus attributes. Houghton and Tipper go on to suggest that we inhibit extraneous information and activate relevant stimuli, using bottom up, low level inhibitory and excitery loops. This is generated as a consequence of a neutral state, which all potential environmental stimuli have, until the centrally generated goal acts to constrain the bottom up perceptual domain by altering the "object field states" (OFS). It does this by centrally generating a goal, which operates a match/mismatch selection criterion, with objects that match the OFS causing a positive feedback loop with objects that do not, causing a negative feedback loop.

Meiran (2002) describes a quantitative model of task switching. He suggests that it has relevance to task switching performance in general, but is designed around a specific task switching paradigm. Meiran points out that we have a variety of different ways that we can approach and act upon any specific stimuli; for example, when we approach a cup we can drink from it, or fill it with fluid, wash or dry it etc. Responses are said to be flexible and controllable, while task demands and situational constraints are said to determine our actions on any particular stimuli. Both stimulus and response are rarely acted upon without a predetermined goal in mind, and that goal can only be understood by previous environmental cues that have been learnt from in previous encounters with that stimuli.

Meiran's (2002) experimental paradigm involved participants identifying the location of a target in a 2 x 2 grid. There were two tasks which were randomly ordered. One task was linked to identifying the position of the target on a horizontal dimension: was it on the left or right of the screen? The other task was to identify the target's position in relation to its vertical dimension: was it at the top or bottom of the screen? Participants were told how to react to the stimuli by means of a symbolic cue, which appeared prior to the presentation of the stimuli. Meiran makes the point that both stimuli and response were bivalent, in that the target and the response had relevance for both tasks. This quality of bivalence is essential to almost all of the models explained here, as accounts of costs are concerned with explaining how this conflict, between these two potential goals of a task, are resolved.

Meiran's (2002) model examines four variables: the switch in task N-1 to N; response repetition; preparedness (alteration n of cue-target interval (CTI)); and congruency of response. He tested these relationships because the switch cost had been shown to be affected by the time allowed to prepare a task (CTI), which reduced, but did not remove cost as the CTI was increased. This was questioned by Wylie, Javitt and Foxe (2004), who removed this cost completely. Congruency had also been shown to have a main effect and an interaction with switch costs. Finally, Meiran wished to test whether there was an interaction between these three variables, as there had been little evidence for an interaction between congruency, task switching and the CTI. He suggested that this is because preparedness has little effect on activation or suppression of stimulus-response translation rules. He also mentions response repetition, with task switching causing slowing of responses. The model assumes that stimuli and responses are bivalent, and that a change in stimulus classification requires a change in how we interpret the stimuli, response or both.

The Meiran (2002) model also assumes that these two changes are independent and take place at different times. It assumes that the physical target stimulus and the two physical responses are associated with mental representations. The model uses the concept of task-set to explain how it works. The task-set is defined as a concept which governs how mental representations are formed. Meiran suggests that we can identify three potential task sets: a stimulus, previous response and alternative response set. The task sets' function is to deal with the bivalent components of the task, which is achieved by biasing the mental representations in favour of one dimension.

Task sets are said to use four processes: reconfiguration, application, stimulus matching, (where comparisons between the target stimulus and response representations are made), and finally a response decision. The model is said to explain a specific control strategy that is used in task-switching experiments, where speeded classification is required. It is proposed that we direct our attention to the relevant dimension in the target stimulus (Meiran & Hadas, 2002).

Response selection and activation are said to be related to an interaction between a representation of the target stimuli, as well as possible responses. They are believed to have a common representation domain because of the similarity between the abstract representation of stimuli and response top down language labels. Meiran and Hadas (2002) suggest that there is an asymmetry in this strategy, and that selective attention is not believed to filter out irrelevant response information, while filtering relevant stimulus information. Because of this, responses are said to become equally associated with their two possible interpretations. Hence, it is believed that there is a filtering out of irrelevant information from the stimulus in a task switching experiment that involves switching, for example, between "shape recognition" or "size discrimination"; a stimulus may be considered mostly "square" in comparison to "small", in the shape condition task, whereas it would be mostly "large" in comparison to "circle" in the size recognition task.

The filtering out of irrelevant information allows an individual to make a correct response. It is proposed that this process can be carried out prior to the arrival of the target stimulus, if enough time is added to the preparation time. This redirecting is only required in a switch of task and this is why we see the added cost.

Meiran's (2002) model argues that this time for preparation does not involve the retrieval of a relevant stimulus response, and that speeded classification of tasks does not involve the retrieval of the relevant stimulus-response maps. The premise is used to explain why preparation does not reduce task congruity effects. The model also assumes that efficient response selection can be achieved if the target stimulus does not contain irrelevant information. This allows for a single attribute to be directly mapped onto the correct key. The model states that the preparatory switch cost reflects the duration of a stimulus set biasing strategy. This is only required when the stimulus is bivalent and not when it is univalent.

Switching costs, when univalent target stimuli are presented, are entirely comprised of residual components. As response sets are said to be completely biased in one direction, they therefore need no readjustment.

The preparatory component of the task switch is linked to a biasing stage of the stimulus set. Error is based on this biasing stage; the longer the preparatory time allowed, the fewer the errors. Meiran's (2000b) experiment highlighted that when the switch was between bivalent stimuli, preparation time reduced costs. However, when the stimuli were univalent, the cost of a task switch was greatly reduced and preparation time had little effect on costs.

Reductions of switch costs are linked to the advanced preparation and redirection of selective attention to relevant stimuli (Meiran, 2000b). The stimulus task set can adjust relatively easily in the preparation time. If this adjustment does not occur, accuracy is affected. The response sets are, however, not readjusted during preparation time.

The Meiran (2002) model makes the critical assumption that stimulus set is easily adjusted during the cue task interval. This adjustment needs to occur before stimulus identification, for accuracy to be emphasized. The stimulus-task set has to have reached its maximum bias in favour of the task relevant dimension in trial N, whereas the response sets represent bias in favour the dimension that was task relevant in Trial N-1. Participants do not adjust the R-Sets during the CTI; the R-Sets are barely different in configuration, making costs less likely. To account for task set inertia (Allport et al., 1994), both S-Set and R-Sets maintain their value from the previous trial.

Language in task switching

The use of language (articulation) has traditionally been regarded as a non-executive slave system of working memory (Emerson & Miyake, 2003). Recent studies have changed this view, recognizing the important role that language may play during executive processing of the task, although there is still debate about whether it is exclusively used for task selection, or task sequencing (serial order control), or if there is a subtle relationship between these two processes (Bryck & Mayr, 2005).

Mayr and Keele (2000) make reference to the use of language in task switching experiments, using MacKay (1969 & 1987) as an example of inhibition of language. It is suggested to be the means by which rapid transitions can be made between sequential elements. MacKay's (1969 & 1987) model of top down language labels being inhibited after reaching an "above-threshold of activation" is given as an example.

The ''Competitive Queuing'' (CQ) framework models of Houghton (1990; Houghton et al., 1994), have also been used to show how inhibition of language can play a part in the articulatory loop (Burgess & Hitch, 1992). It suggested that language may be playing an underlying part in the costs associated with the switch in task set.

Mayr and Keele (2000) hypothesise that the costs seen are linked to inhibition of task sets in working memory, associated with a specified task goal. This task goal is represented in the cue, and is used specifically as a means to recover its associated task sets from long term memory. The task goal in itself is highly likely to require a language translation to be understood when selecting the task sets required to achieve the correct responses to the target stimuli.

Gruber and Goschke (2004) hypothesize that there are two systems involved in working memory, a "phylogenetically older" and "phylogenetically younger system", refer to figure 19. It is proposed that because of how the two systems evolved, the older system is completely enmeshed into the younger system, so that it is questionable whether the systems are able to act totally independently, especially when goal maintenance or retrieval is required. The older system is considered to be responsible for the maintenance of the location and feature based information about the visual and auditory systems. The younger system acts to record, through rehearsal, the cognitive information in the older system into a cohesive, goal driven relationship. Cortical regions underlying verbal rehearsal are said to be used during the advance preparation of task switches, which may also be involved in the retrieval of a verbal goal representation into working memory, and may modulate activity in prefrontal areas responsible for attentional selection (Gruber & von Cramon, 2003).

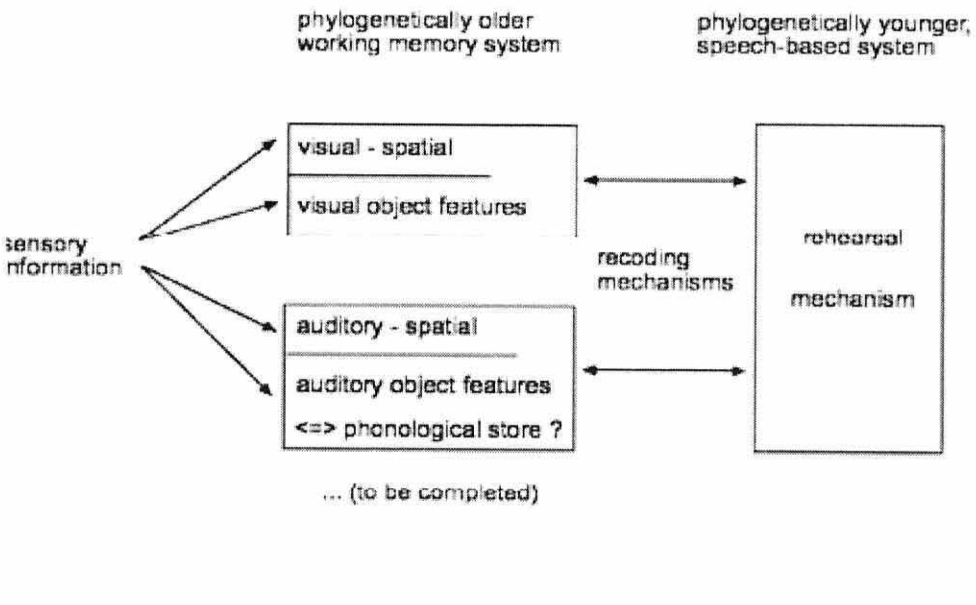


Figure 19: Taken from Gruber and Goschke (2004) who hypothesize that there are two systems involved: a phylogenetically older system, and a younger system.

Bunge (2004), in a review of evidence from cognitive neuroscience on how rules are used to select actions, highlights the importance of the use of top down language associations in this process. The post medial temporal gyrus and other regions in the lateral temporal cortex are said to be involved in storing top down language associations for visual cues, although they are not linked to activating the correct response representations, refer to figure 20.

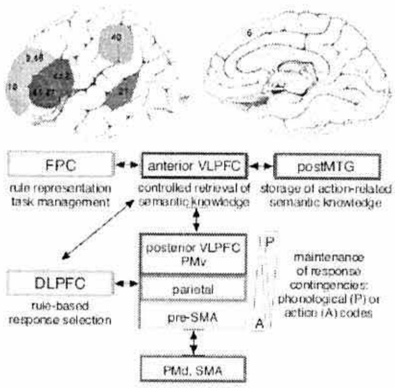


Figure 20: Graphical representation of Bunge's (2004) model.

Miyake, Emerson, Padilla and Ahn (2004) carried out a dual-task study, using a random task cuing paradigm, performing colour or shape judgments. They used explicit word cues (COLOR or SHAPE) or more obscure letter cues (C for the colour task and S for the shape task). It was shown that the letter and not word cues significantly increased the switch cost in the articulatory suppression condition when compared to the control condition. Articulatory suppression is believed to impede the participant's ability to use a top down label associated with the task while doing the task. Articulatory suppression is normally achieved by making the participant repeat a nonsense word or word unrelated to the task while completing the experiment. The results of Miyake et al.'s study suggested that inner speech could be used as a means to retrieve and activate appropriate task goals when the task cue was not obvious and therefore, imposes greater retrieval demands. Bryck and Mayr's (2005) results suggest that verbalization may be used within the task switching process, but that it is more likely to be vital for endogenous maintenance and updating of a sequential plan of the switch in task. The perceptual ambiguity of the cue is also believed to be related to how much the use of a language label is required in an endogenously controlled task switching (Mayr, 2001; Rogers & Monsell, 1995). As previously stated, Arbuthnott (2005) found that the use of location cues to a specific task reduced the cost associated with a switch, although when the participant was required to verbalise the task based on the cue's position, the cost of the switch was reintroduced. This suggested that language may be underlying some of the costs associated with an ABA switching sequence.

The ambiguous nature of the cue seems to require the attachment of a language label, although this does not mean that a language label may not necessarily be attached to less ambiguous cues (Logan & Schneider, 2006).

Logan and Schneider (2006) proposed a model that includes a Mediator. The Mediator is expressed as a language label associated with the goal of the task, which is attached to the cue. The Mediator is believed to share a common pathway with both non-transparent and transparent cues and is thought to have a transparency equivalent to a transparent cue.

Logan discusses two models: Association Strength and Mediator Retrieval. The Mediator Retrieval model suggests that a label would be attached even to transparent cues. In Logan's "Associated Strength" model, it is assumed that the transparent and non-transparent cues go along differing strength routes, leading directly to the goal or task set. The non transparent cues are also said not to induce the use of a Mediator.

The "Mediator retrieval hypothesis" is said to be a central process in understanding instructions. It is proposed that the non-transparent cues are not directly associated with the goal or task set, whereas the transparent ones are. The transparent cue is said to be the mediator; it acts to connect the non-transparent cue to the goal or task set. Consequently, there is greater cost when a non-transparent cue is used, as there is an extra stage required before the task goal\set can be accessed.

To test this, Logan and Schneider (2006) repeated the Schneider and Logan (2005) experiment, where they used the cues EVEN, ODD, and HIGH, LOW, as well as having two other conditions where the cues were E, O, and H, L, the first letter of the language cues, or D, V, and G, W, the second or third letter of the language cues.

It was also shown that the congruency effects that had initially been present when using a non-transparent cue, that were associated with the Mediator, dissipated with practice. This lead to the conclusion that, after repeated instances, there was no need to access top down language memory of the Mediator, as the non-transparent cue had become directly associated with the correct response, and episodic memory could now be used. The congruency effect was interesting when using transparent and non-transparent cues, as there was a cost when an incongruent cue and target (HIGH-3) was used in comparison to a non-transparent relationship between the cue and target (HIGH-7). This congruency effect was also apparent in the condition where the cue was the first letter of the transparent cues, but not in the letter condition, where the relationship between the cue and target was not as obvious. However, the congruency effect did occur in this condition when the relationship was highlighted to the participant.

Logan and Schneider (2006) make clear that previous researchers had two different views on how the target is processed after the meaning of the cue was interpreted. The first group had proposed that the cost originated through the associated strength between the cue and the goal or task sets (Arbuthnott & Woodward, 2002; Miyake et al., 2004). In contrast, the proposal was that the use of a Mediator was causing the cost difference (Logan & Bundesen, 2004; Mayr & Kliegl, 2000). Logan and Schneider (2006) propose that in many task switching experiments "words" act as Mediators. These words are attached to targets, causing a compound retrieval cue, which pulls out from memory the correct response. They suggest that their experiments on the actions of a Mediator, show that participants understand what the cue means by relating it to previous knowledge they have about what to do. The cue word language label is seen as a lightning rod that links into more complex previously learned behaviour.

Unlike Logan and Schneider (2006), Arbuthnott and Woodward (2004) and Mayr and Kliegl (2003) hypothesise that the cue acts to retrieve the mapping rules that are integral in underpinning performance. Logan and Schneider (2006) propose that there is no reconfiguration, as was previously suggested by Arbuthnott and Woodward (2002) and Mayr and Kliegl (2000), as the task set remains the same, whether it is a repeat or a change of target, and compound cue-target accesses top down language memory, where the correct response is retrieved. In Logan and Schneider's (2006) opinion, the benefits of cue encoding in a task repeat are the cause of the cost difference. Logan and Schneider (2006) say that this is because cues are not considered to be used to retrieve mapping rules. They suggest that this was highlighted by the Schneider and Logan (2005) experiment, where cues either mapped onto the responses or did not, with no significant cost difference between them.

Mayr and Bryck's (2005) experiment suggests that all of the subcomponents of the instance are selected, including the position of the response, the cue, and stimulus. Any mismatch between episodes causes a cost, but it is most costly when the language cue associated with the goal switches, but the response and target position do not change. This suggests that the language label seems to become linked to both the position of the target and the response to the target. Language may act to bind together all of the subcomponents of a task, so that the goal of the task can be understood. Others' research, as well as this present investigation, suggests that abstract, or less specific explicit cues seem to attach orthographic phonological labels to the cue, to assist in the process of task switching (Emerson & Miyake, 2003).

This discussion does seem to imply there is some sort of cognitive interplay between our bottom up visual-location interpretation of the world, and the language system that equips us with goals that give us the ability to order and select how we react to our environment. This also suggests that there is biological evidence for these two processes to be in operation. How these systems may interact has been the subject of a great deal of debate, although Baddeley (2003) has an interesting hypothesis about how this may occur and his model, while not necessarily designed to explain the intricacies of task switching, may be an excellent way of understanding some of the observable costs of its proposed mechanisms.

For many years Baddeley proposed that working memory could be sub-divided into three systems: a central executive, and two sub-systems, a visual-location sketchpad, and phonological loop, that interacted with their long term memory representations of what was held in working memory, refer to figure 21.

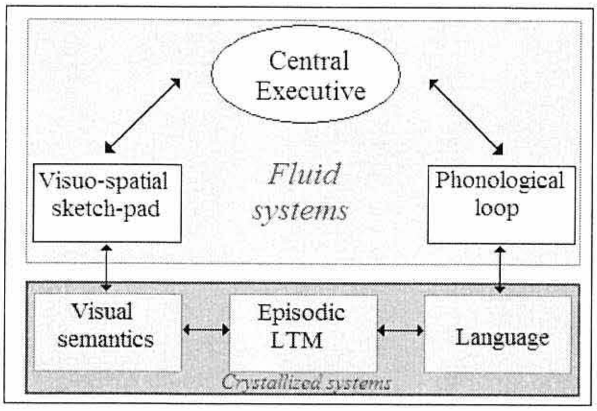


Figure 21: Baddeley (2003) model without episodic buffer.

A more recent advance on this model (Baddeley, 2003) has included what is called an episodic buffer, refer to figure 22. This resulted from Baddeley and Logie's (1999) decision that the central executive was singularly an attentional based control system that had no capacity to store information.

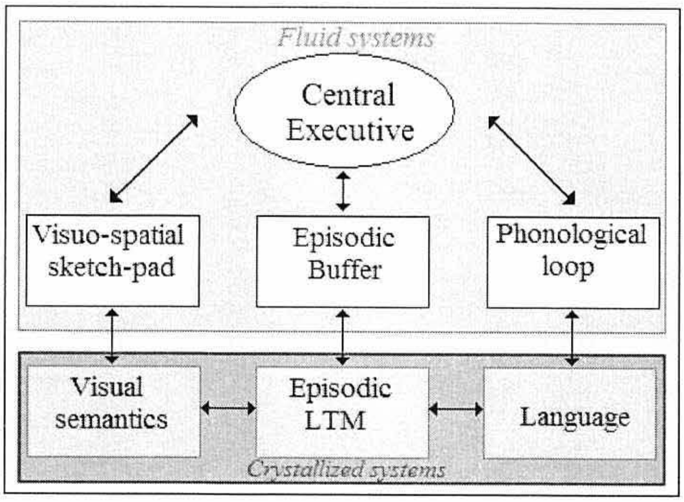


Figure 22: Baddeley (2003) model with episodic buffer.

Baddeley and Logie (1999) made this decision because it allowed them to divide the process of a hypothesised executive into smaller fractions. But it also caused them a problem with their model, as there was a need to identify a system in working memory that could amalgamate visual and verbal top down language labels. This system was important, as it needed to communicate and translate these simpler visual and verbal top down language labels in such a manner that the multi-dimensional representations in long term memory could be understood. The system would also need to be able to store information that they believed was in excess of the capacity of the visuo-location and phonological system. They had seen densely amnesiac patients with grossly impaired LTM, who could nevertheless remember for short periods of time, play cards, or immediately recall prose passages of over 20 or more idea units (Baddeley & Wilson, 2002).

Although these examples are not necessarily directly linked to the task switching literature, it is highly likely that there would be both a simple visual, location and language top down language label representation of any trial. These top down language labels would need to be amalgamated, so that a translated meaning can be given to them, which is highly likely to be linked to the goal of the task. Baddeley (2003) describes the episodic buffer as having the capacity to combine information from different modalities into a "multi-faceted top down language label". That "multi-faceted top down language label" could be the task set, or just the simple relationship between a cue and target. What seems to be important from the above, is that it is the combination of language as an expression of a response (Gade & Koch, 2007), or as a goal (Arbuthnott, 2005; Arbuthnott & Woodward, 2004) that is essential to this process when costs are witnessed. I would therefore suggest that we may be seeing inhibition of the top down language label created in a system similar to the episodic buffer, which takes the simple visual location and language components of a trial and combines them into an understandable more complex top down language label. This study aims to show that this is what may be the core of the costs that we see in the present task switching literature.

Rationale for following chapters and experiments

What seems to become increasingly apparent is that the language component of the task appears to be an important, if not integral element, which may be causing the cost in a switch of task. Houghton and Tipper (1996) suggest that inhibition and activation are constrained by the goal of the task. If this is so, then surely the goal of most tasks can only be accessed through a top down language label that represents, translates and links together the relationship between the cue, target and correct response. Arbuthnott and Woodward (2002) and Arbuthnott (2005), showed that even when a location cue is used, removing the classic switch cost, when a language label that reflected the goal of the task is attached to it, costs return. Gade and Koch's (2005) experiment seemed to add more weight to this idea about the language label, but unlike Arbuthnott and Woodward, suggested that it was not the abstract goal of the task that was the label, but that it was the correct response label. In their experiments, if the language label associated with the task response was the same at task B in the sequence, even though the cue, target, and goal of the task were different, then an ABA cost was identified. However, if all of the components of the task, including the response were different at task B, then no ABA cost was apparent. This suggests that it was not the bottom up representation of the cue, target and response that was being inhibited, but the language label associated with the correct response to the target. If it were simply the response label or the goal that was causing the cost associated with a switch in task, then the studies by Arbuthnott (2005) and Gade and Koch (2005) may have had differing results. Perhaps, when there is a requirement to use a label that has previously been associated with different bottom up representations of the cue, target and response, there is a new requirement to translate that relationship between each of these components.

Mayr and Bryck's (2005) experiment suggests that the language label associated with the goal seems to bind together all of the elements associated with a task, so that it becomes cohesive task-set. Logan and Schneider (2006) seem to show that language labels can also be attached to non-transparent cues, and that they in turn may underlie some of the costs associated with a task switch and ABA sequential switches. Monsell and Mizon (2006) have suggested that the relationship between the cue and the target is integral to the costs we may see in a switch of task. Although they have also shown that if participants seem to prepare in advance of the cue's arrival, when there is a high probability of a switch in task switch, costs are similarly removed. This suggests that a large proportion of the costs of a switch in task when the cue is used, are to concerned with the need to tie together the bottom up representation of the cue and target to the correct top down corresponding correct response based on the goal of the task. As reflected in Monsell and Mizon's (2006) experiment when the CTI was small, switching costs were greater than when the CTI was lengthened. This effect of the CTI is not apparent when the probability of a task switch is high and the cue is not used and suggests that the early endogenous preparations of the next task set, independent of the cue, are more efficient than when a cue is required. Monsell and Mizon (2006) propose that their results show the action of a two stage process, which is similar to Mayr and Kliegl's (2003) model when a cue is used. The cue firstly allows one to search in long term memory for the correct task-set, which is then placed into working memory, where the previous task-set was removed or made less active due to inhibition. Then, in the second stage, on the arrival of the target, a correct response can be made. This may be what is happening, but could there be something else occurring in addition to this?

Gade and Koch (2005) showed how the activation of a previous task set had a direct relationship to the costs of an ABA task switch. This was because the closer together two tasks were, the greater the level of inhibition required to remove the previous task-set from working memory.

When we look at the effect of the CTI, we could be seeing a similar mechanism, not necessarily linked to inhibition of a task set, but to inhibition of a language top down language label that links the cue to the target, and then correct response. If this is the case, then the CTI effects could be linked to activation levels of this top down language label from trial to trial. A long CTI would allow the activation time of the top down language label to dissipate, so that less inhibition would be required, therefore benefiting the time required to make a task switch. Comparatively, a short CTI would give little time for this top down language label to dissipate between trials and may need more inhibition for it to be removed from the previous trial, heightening the overall task switching response time. Cost may not singularly be linked to the need to retrieve a task set, but may also be linked to the inhibition of a language top down language label that translates the relationship between a cue, target and response into a cohesive goal. This present study examines this question in the attempt to determine whether or not that top down language label between a cue and target exists, and thus enables a correct response.

The biology of the brain would also suggest that almost all complex actions use language to understand the goal of a task (Gruber & von Cramon, 2003). Language seems integral to our understanding of our environment. Working memory is highly likely to hold both a visual representation of a cue, target and response and language labels that are associated with these. If this is correct, then surely there is also a need for a mechanism that translates all of these relationships into an understandable and organized goal. This mechanism in itself, it is suggested here, is perhaps best explained as similar to the episodic buffer, as described by Baddeley (2003).

Returning to the initial paper which inspired the present study, Mayr and Keele (2000) made it clear that the costs they observed were a consequence of a switch in task set, and that low level, bottom up processes have little to do with the costs associated with this type of sequential change. They make it clear in this paper, that a task-set can be distinguished from what they call a "simple action", by its ability to hold all of the high-level constraints of actions required to identify and respond to a specific target. For example, they highlight how the word "Colour", as a cue, represents the selection of all possibilities of a potential coloured target instead of the word "Red", which can only select one simple action to a specified target. It was the abstractness of the language cue and its ability to constrain and hold all of the necessary components of the task set, that is inhibited, and not necessarily the bottom up representation of the language cue. Because of this, they suggest that if one were to use the cue "Red" then no sequential cost would be apparent in an ABA sequence. I would question this interpretation on the following grounds. If costs are linked to a top down language label that represents the goal of a task that links together the cue, target and response into a cohesive representation of a task, then the word "Red" needs to be linked to a target and response, all of which will also needs to be translated and linked together.

A further question arising from the above is whether we are seeing inhibition of the top down language element of the task set that links a cue to a target, or whether it is the more complex elements of the whole task set that are being inhibited.

My primary concern about previous experiments that have tried to interpret the relationship between the cue and target is that a multitude of different factors, such as potential task set, and responses, and numerous different methodologies have been used. This may have hidden or confused findings that are linked to costs, specifically those linked to the cue target relationship. Because of this, throughout my investigation, I have tried, wherever possible, to reduce potential confounds to this cue-target relationship. I have done this by only having one goal for all of the experiments, to identify the location of the target that has a simple one-to-one relationship to the cue. I also used a very similar methodology to that of Mayr and Keele (2000): this seemed to reduce the effect of the response because of the random relationship it had to the cue and target. Mayr and Keele (2000) believed that this isolated the goal to some degree, from a specific response, as all four location responses could be correct.

All of my experiments therefore have the same goal: "identify the position of a target" that has a one to one relationship to a cue. Having this one-to-one relationship between the cue and target also reduced, if not removed, the effect of a task set that may be linked to a specified target's relationship to a cue. There is a question about each cue and target having four different potential responses, which may have a corresponding associated response task set. It is hoped that the random nature of the response positions will reduce these potential effects. This issue is discussed in more depth in the final chapter, where planned comparisons of my final experiment suggests some new insights into how response may affect the costs we see in this study.

A further question asked is whether the bottom up physical relationship between a cue and target can influence sequential costs, and whether this is linked to the requirement to link these two components of a task together, to enable successful completion of the goal of the task.

Chapter 2

Explicit and implicit cue target relationships

Chapter 2 Abstract

The experiments described here were designed to see if it was possible to replicate backward inhibition costs found in ABA sequences, when repeating the same task and only switching between one-to-one cue target relationships. I hypothesised that backward inhibition was a consequence of inhibition of the top down language label associated with the recognition of a bottom up visual image. It was proposed that if there were no need to use top down language labels to recognise and identify bottom up images, there would be no backward inhibition. Experiment 1 tested this with two conditions: one using implicit language cues to identify an icon target, the other using explicit icon cues. Results of the language cued condition replicated backward inhibition costs whereas no such costs were found in the icon condition. There were significantly faster responses in the icon condition. Experiment 2 was designed to see if the lack of backward inhibition cost in the icon condition was linked to its faster overall response times. It was designed to speed up overall response times, through the use coloured stimuli, with two conditions, one using the associated langue cue for the colour and another using explicit matching coloured icon cues. Results replicated backward inhibition costs at response times similar to those found in the experiment 1 icon condition. Unlike in experiment 1, the icon condition also had a backward inhibition cost. It was proposed that this was linked to the automatic top down labelling of colours when there is a need to search for a coloured target.

Chapter Summary

A variety of experiments have shown that a trial at the end of an ABA sequence takes longer to respond to than a trial at the end of a CBA sequence. This cost difference is known as a backward inhibition cost. The origins of this cost are believed to be linked to the inhibition of a component, or to components of a previous task set. It is also suggested that the increased response time is linked to reconstruction of the task set and not necessarily to the recovery of the inhibited component of the previous task set. Identifying exactly what is being inhibited has been difficult because of the variety of methodologies that have been used by previous experimenters. What has become apparent, in some experiments, is the importance of the transparency of the cue-target relationship and the top down language label or labels associated with this. The following two experiments sought to replicate this backward inhibition cost while simplifying the methodology used by repeating the same task and only switching between three, one to one, cue target relationships. The transparency of the cue-target relationship was also altered between conditions.

The backward inhibition costs seen in previous experiments were replicated when there was a top down language label associated with the target suggesting that backward inhibition was not linked to a change in bottom up factors when there was a switch in trials. It seems we are seeing inhibition of a top down language label associated with the target. Additionally, this does not seem to be linked to overall response times.

Chapter 1 explained the problem with identifying exactly what part language plays in relation to the costs associated with an ABA task switch. This arises because of the multitude of differing methodologies that have been used and has also been complicated by the complexity of cue and target types that can be multi-dimensional in their representation. This means that the potential action of a task set may cloud the intricacies of exactly how language may influence costs. What is interesting about many of the experiments reviewed in Chapter 1 is that variation of the Cue Target Intervals (CTI) has had differing effects upon associated task switching costs. This has been accounted for, by those who believe in a two stage model, as the time required for the appropriate new task-set to be retrieved from Long Term Memory (LTM) and placed in Working Memory, (WM) (Gade & Koch, 2005; Mayr & Kliegl, 2003; Monsell & Mizon, 2006). This may be what is actually happening, but it has been shown that a cost can also occur when switching within category (Schneider & Verbruggen, 2008) which may suggest that the cost associated with a CTI may not necessarily be exclusively linked to the recovery of the new task-set; it may also be related to the interaction between the cue and target. Monsell and Mizon (2006) make it clear that, when there is a complex relationship between a cue and target, this may become a task in itself. Because the cue, target, and response are often from different modalities, moving from one to the other may cause a competition cost within task-set, as it has been shown that a switch in modality between task set has caused costs (Philipp & Koch, 2005). If there is a competitive interaction between modality within task-set, this may also cause activation costs, similar to those identified by Gade and Koch (2005), when switching between task set and altering the Response Cue Interval (RCI).

It is suggested here that there may be a mechanism involved in this interaction between cue, target, and response that is concerned with competition between modalities. This mechanism may be linked to the need to translate the meaning that each modality has to an overall goal, which in itself is likely to be associated with a top down language label that identifies the goal in each trial. From the literature reviewed it is suggested that this mechanism is best described by the definition of the “episodic buffer” (Baddeley, 2003), which is not necessarily designed for explaining interactions within task-set, but has a defined purpose which would be similar to what may be happening in switches between modalities within task set. It is defined as a system that links the bottom up top down language labels of the language and visuo-spatial systems into a complex top down language label that can be identified and used in LTM. Previous experiments have suggested the importance of a top down language label in the costs associated with backward inhibition. It seems that the conflict that may occur between tasks, which leads to backward inhibition, may be linked to conflict between top down language labels associated with the goal of the task. If this is the case, then simply switching between top down language labels associated with a bottom up target may also cause similar costs.

Experiment 1 was designed to test this proposition by simplifying the relationship between the goal of the task and its associated cues, targets, and responses, so that the simple interaction between the cue and its associated target could be assessed. The experiment was designed around the methodology used by Mayr and Keele (2000), as it was proposed to isolate the goal of the task, and costs were said to be linked to the inhibition of a task-set, represented by a cue that had to be abstract in its relation to the appropriate response, which was made to a multi dimensional target. This was important because Mayr and Keele proposed that the cue which represented the goal needed to have the ability to hold the entire potential task-set, stimulus response maps, in its meaning. They also randomised the response positions, which had no relationship to the goal of the task, so that its costs were somewhat isolated from any other costs that might be found.

Experiment 1simplified the task by having only one goal, which was to identify the position of the appropriate target; the position related to a previous cue, which could appear in one of four quadrants on the screen. The target also only had a simple one-to-one relationship to a previously appearing cue. Mayr and Keele (2000) proposed that they were seeing inhibition of a task-set held in a cue that had an abstract relationship to the appropriate response. If this was so, then using their methodology, where the goal remains the same, and the cue and target have a one-to-one relationship to each other, there should be no backward inhibition, unless the cue and target have four stimulus response maps associated with them. These positional response maps in Mayr and Keele's (2000) experiment did cause a cost, but that was additional to the cost they were seeing that they linked to the goal.

Experiment 1 – Language and Icon cued

Experiment 1 attempts to remove all of the elements that Mayr and Keele (2000) suggested were causing these costs, by maintaining the same goal, and having only a simple one-to-one relationship between the cue and target. I hypothesised that Mayr and Keele (2000) were not simply seeing inhibition of a task set, but inhibition of the top down language label linked to the recognition of the target. Cost may be linked to the reapplication of that label to the target. Experiment 1 had two conditions, one using icon cues to icon targets, the other using language cues to icon targets. The icon condition used icon cues that had enough bottom up information in them not to require a language label, so no backward inhibition was expected. The language cue needed to be applied on a top down level to identify the appropriate target, so in turn should cause a backward inhibition cost.

Experiment 1 Method

All of the experiments described I this study used almost exactly the same methodology, apart from alterations to the cue and target types. Except for where changes are noted, other factors relating to the method and design remained constant throughout.

Participants

Thirty two participants were recruited via the School of Psychology Participation Panel, or from the University population, at Bangor. They all received course or printer credits. They were all naïve to the purpose of the study.

Design

The overall design was a repeated measures, with the factors cue type (words vs. icons), sequence type (ABA vs CBA) and order (words first vs. icons first).

Apparatus and stimuli.

The stimuli were presented to participants on a PC (800MHz, Pentium III processor) using E-Prime 1.0 experimental procedure software (Schneider, Eschman, & Zuccolotto, 2002). The monitor was set approximately 60cm from the participant. Responses were made manually on four keys, using the index or middle finger of both hands; the key positions topographically mirrored the positions of the stimuli on the screen (Top Left = D, Top Right = J, Bottom Right = N, Bottom Left = C). The response was spatially compatible with the target stimuli. The cue was centrally placed on the screen; stimuli were stretched, their size was:- Width 25%, Height 25%, and their position in the four quadrants of the screen :- X access 25%, Y access 25% (Top Left), X access 75%, Y access 25% (Top Right), X access 25%, Y access 75% (Bottom Left), X access 75%, Y access 75% (Bottom Right).

Verbal cues were: Angled, Border and Shaded; they were di-syllabic and contained 6 letters written in Times Roman 15 font. The three icon cues were 4cm in height, two were 1.5cm in width, and a third was 2cm. All four of the stimuli were 6cm in height, three were 2.3cm in width and the fourth was 3.5cm.

Procedure

In each condition there were 30 trials in the practice block, and 126 trials in the experimental block. In each trial, the interval between the cue appearing and the stimulus appearing was

250ms (Cue Stimulus Interval (CSI)), while the interval between making the response and the new cue appearing was 500ms (Response Cue Interval (RCI)).

Participants completed either the language or icon cued condition first, and this was counterbalanced across participants. There were two conditions, which had different cues but identical stimuli. There were three different cue-target relationships, which changed every trial, giving two types of sequential switch, ABA and CBA sequences, refer to figure 23. Participants completed each of the two conditions which were balanced for order between them.

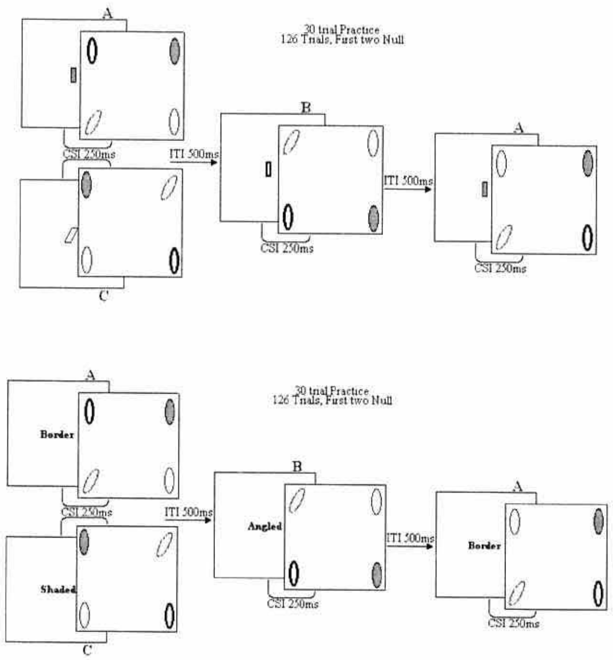


Figure 23: Examples of ABA and CBA sequences from experiment 1 for both iconic and language cues.

Cues, Stimuli, and Response

In experiment 1 there were two conditions, one using language cues (Border, Shaded, and Angled), and another using icon cues, refer to figure 24.

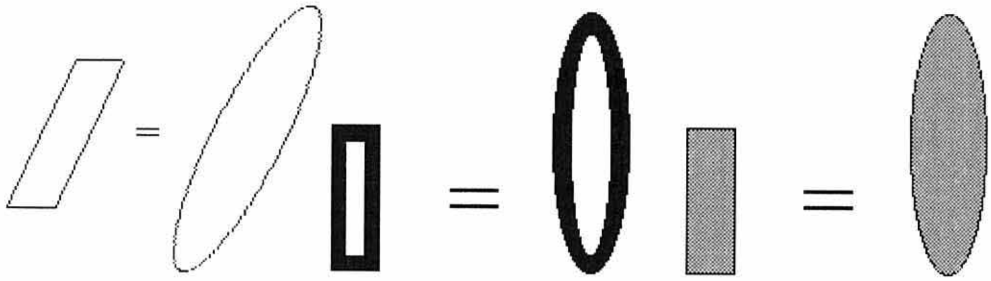


Figure 24: Experiment 1, Condition 2, explicit icon cue to icon target.

Each cue identified a specific feature in the target stimulus which corresponded with the cue, refer to figure 24. The stimuli remained the same in both conditions. There were four stimuli, three of which acted as potential targets. One of the stimuli always acted as a distracter as it was never cued, refer to figure 24.

The objective of each trial was to look at the cue, then identify the position of the related target stimulus, and respond accordingly by pressing one of four keys on the keyboard that corresponded with the position of the target stimulus.

In each condition, at the beginning of the block, a brief explanation of what participants would see on the screen appeared first, with instructions to touch any key when they were willing to continue. Then a cue appeared on the screen and remained there for 250ms, after which four stimuli would appear, one in each of the quadrants of the screen, remaining on the screen until the participant pressed one of the four previously identified keys.

Participants were first taken through an explanation sheet relating to one of the conditions, which showed the relationships between the cues and targets, and how to make an appropriate response based on the position of the target. They then completed a 30 trial practice block with the experimenter present. Once this had been completed, they were left alone to complete the experimental block of 125 trials. The second condition was then explained and completed in the same way as the first.

Experiment 1 Results

In experiment 1 there were initially 32 participants; 2 were removed because they had more than 10% errors, and 1 was removed because of a problem with the E-Prime program. Trials were trimmed using two different criteria, responses time and errors. Trials were removed if they were faster than 200ms or slower 2000ms. The first two trials in a block and all error trials were removed, as well as the two trials following any error trial.

All of the error bars on the graphs in this study are representative of the "Standard Error of the Mean" as expressed in the t tests "Paired Differences".

Error analysis of the data showed no significant differences. I therefore completed the following analysis on the response times. I initially carried out a 2x2 (within) x2 (between) Mixed ANOVA that compared Cue Type (Language Cue or Icon Cue) by Lag Type (ABA or CBA sequence) within, by the order in which participants completed the two conditions (Icon Cue or Language Cued condition first). The results showed a main effect of cue type, $F(1, 27) = 47.94$, $p < .001$, that interacted with the order of conditions, $F(1, 27) = 9.02$, $p = .006$, there was also a main effect of lag type, $F(1, 27) = 7.25$, $p = .012$, that interacted with the type of cue used, $F(1, 27) = 7.42$, $= p = .011$.

Planned comparisons, using pair wise t tests, compared the difference between the response times in the two conditions dependent on what cue type was used. The analysis showed that on average there was a 97ms (SD = 81.18, SEM = 15.07) cost when using the language cues in comparison to icon cues in an ABA sequence, t (28) = 6.42, p < .001, and that there was a similar 74ms (SD = 68.53, SEM = 12.73) cost, on average, in the CBA sequence when using the language cues instead of the icon cues, t(28) = 5.82, p < .001.

Similar planned comparisons, of the difference in lag type, in the two conditions showed that there was no significant difference between the ABA and CBA sequences in the icon condition (Mean difference = .319ms, SD = 23.05, SEM = 4.28), t(28) = 0.75, p = .941, whereas there was on average a significant 23ms (SD = 38.80, SEM = 7.20) cost difference, in the ABA sequence, when compared to the CBA sequence, in the language condition, t(28) = 3.20, p = .003, refer to tables 1 and 2 and figure 25.

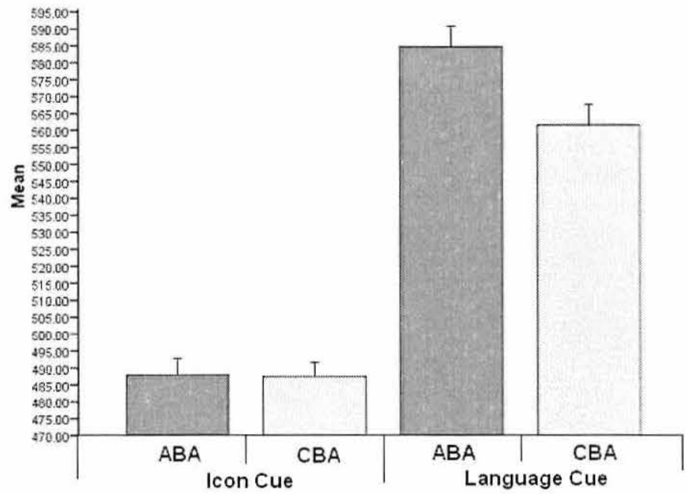


Figure 25: Mean Response Times (ms) for each condition by lag for Experiment 1. Error bars show the standard error of the mean.

Table 1: A comparison of mean Response Times (ms) of each condition, of subjects who carried out the Language condition first in Experiment 1.

Language Cue First

		Difference between ABA and CBA sequences			Mean Response Time				
Exp No	Condition	Mean Time difference	Std. Deviation	Std. Error Mean	ABA	CBA	t	df	Sig. (2-tailed)
1	LanguageCue	21.77ms	36.28	9.07	604.42ms	582.64ms	2.400	15	.030
	IconCueABA	1.18ms	22.32	5.58	476.86ms	475.68ms	.212	15	.835

Table 2: A comparison of mean Response Times (ms) of each condition, of subjects who carried out the Language condition first in Experiment 1.

Icon Cue First

		Difference between ABA and CBA sequences			Mean Response Time				
Exp No	Condition	Mean Time difference	Std. Deviation	Std. Error Mean	ABA	CBA	t	df	Sig. (2-tailed)
1	LanguageCue	24.66855	43.14681	11.96677	560.37ms	535.70ms	2.06	12	.062
	IconCueABA	-.74262	24.79157	6.87594	501.35ms	502.10ms	-.108	12	.916

Summary of results

The above results showed us that it took longer in time to complete a trial when using the language cues in comparison to the icon cues. It also seemed to confirm my initial hypothesis that the requirement of a top down language label was integral in seeing a backward inhibition costs. This was because there was no significant difference between the ABA and CBA sequences in the icon condition but there was a significant cost when doing the ABA sequence in the language condition. The order effect, related to which condition was completed first, seemed to be linked to the second completed condition taking less time than the first. This practice effect seemed to have no effect upon backward inhibition costs.

Experiment 1 Discussion

The above experimental results showed a backward inhibition cost in the language condition and no backward inhibition cost in the icon condition. This suggested that we were seeing inhibition of a top down language label that was associated with the recognition of the target. The order effect also suggested that we were seeing a two stage model in operation, similar to that proposed by Mayr and Kliegl (2003). This was because there was an order effect only in the language cued condition, which improved the overall response times when the icon cued condition was completed first, that had no significant effect on the backward inhibition cost. It suggested that there was first a recovery stage of the language label, as there was an improvement in the overall response time, which had no effect on the backward inhibition cost in the language condition. Practice seemed to help the response time: the backward inhibition seemed to be linked to an application stage not affected by practice.

Although there was an effect linked to the order of conditions, that suggested that the speed of the overall response times had no effect on backward inhibition costs, there were some concerns about how quickly individuals responded in the icon condition. . Could there have been a floor effect that stopped me seeing backward inhibition at very quick response times?

Giesbrecht, Dixon, and Kingstone (2001) had seen floor effects, in previous task switching experiments; this therefore raised the question that here there might be a floor effect linked to overall response times, that was hiding a backward inhibition cost. Experiment 2 attempted to answer this question. Another question which was also of concern was that we had only used 126 trials, so participants had little practice at this task, and that an increase in the number of trials might show a backward inhibition cost in the icon condition. Practice may affect costs, as it has been shown to decrease switch costs (Allport et al., 1994; Meiran, 1996); this has been linked to practice strengthening the links between an instructional cue and task-sets (Meiran, 1996). Arbuthnott and Frank (2000) showed that practice decreased response times in digit and letter tasks, but not in symbol tasks, concluding that experimental results were consistent with Meiran's (1996) hypothesis that practice had an effect on endogenous control processes, but did not decrease residual switch costs. Subsequently, Arbuthnott (2005) found that practice improves the retrieval of unfamiliar spatial cues in comparison to familiar language cues. Also, it was said to reduce switch costs and a difference was identified between the retrieval and application stages of task switching. Practice is said to increase the strength of a cue-task relationship and it was this that was influencing switch costs. The retrieval of a task-set is influenced by practice, not necessarily the response selection (Arbuthnott, 2005). Experiments that have alternated between well practised tasks and less practised tasks have identified an asymmetry in cost, with it being more costly to switch to a stronger task than to a weaker task (Allport et al., 1994). This effect has become known as the reverse Stroop effect and has been shown when tasks share similar response sets (Allport et al., 1994), and when they do not (Yeung & Monsell, 2002). All of the above suggests that a language label, expressed through the cue, may become more closely associated with the target with practice. If this were to occur, this may have an effect on the backward inhibition cost.

Experiment 2 therefore set out to see if there was a floor effect in overall response times that hid any backward inhibition cost. It also sought to see if there was a practice effect that may influence overall response times and backward inhibition.

To answer these questions, a similar methodology to that of experiment 1 was employed, but this time using coloured targets. There were similar language and icon conditions, which either labeled the colour to be identified, or had an icon cue with the same colour as the target. Colour was used as it seems to have a unique quality to it in that it may automatically generate a language label, when an attempt is being made to identify the actual physical colour of a target, which is reflected in the way costs are seen in the classic Stroop experiments (Allport & Wylie, 2000). Although the Stroop effect is caused by automaticity of word reading, not necessarily by the automatic application of a language label to a colour, the conflict between the name of the word for a colour and the opposing colour of the ink is unlikely to occur unless the colour of the ink is also automatically generating a top down language label.

This also gave me the opportunity to test one of Mayr and Keele's (2000) claims that they were seeing inhibition of a task-set and that this was linked to the abstract nature of their cues. Their cues were said to represent task-sets because of their abstract natures. The cue "colour", for example, could represent a variety of target colours, and similarly different responses, which could be made to a variety of targets. They also made clear that a simple one-to-one relationship between a cue and target, which they called a "representation of simple actions", was substantially different to cues that signified "high level constraints on action selection". They mention that the word "red", as a cue, was representative of a simple action; I would suggest that it also has a top down language representation, which is linked to a specific colour (Allport & Wylie, 2000). This is because the word 'Red' has no concrete natural bottom up relationship to the colour red, other than one which has been superimposed onto it by the language of a given society. There is nothing in the word red, if it is written in a different colour to the red target, which can assist on a bottom up level when identifying a target. Because of this, if I am correct and it is the top down language label for the bottom up visual image that is being inhibited, backward inhibition should be apparent when one switches from one colour label to the next, when using the word associated with a specific target. I would also suggest that because of the Stroop effect, this relationship between colour and its language label has become automatic, and that the colour generates its language label, when there is a requirement in a task to identify an associated coloured target (Allport & Wylie, 2000).

As noted, the conflict in the Stroop effect is based on the requirement to identify the colour the word is printed in; if this colour is incongruent with the colour that the word represents, a cost is apparent. This does not occur so dramatically if the word is neutral and does not represent a colour. This would suggest that when a person is identifying the colour that a word is printed in, they may simultaneously be generating a language label (Allport & Wylie, 2000). It is this label that comes into conflict with the written target that has a different colour label to the one being exogenously generated. Thus, I would suggest if one has to identify an icon's colour, to recognise a target of a similar colour, then a language label will be automatically generated. If this is so, then there is likely to be a backward inhibition cost in the coloured icon condition, because there will be a need to inhibit the previous language label generated, unless bottom up processes override the requirement to identify the target with a language label, so that it does not need to be inhibited.

Experiment 2, therefore, asked the following questions: Does the overall response speed have a floor effect on seeing backward inhibition? Is an automatic top down label given to coloured targets that will cause a backward inhibition cost in an icon cued condition? And does practice affect backward inhibition costs?

Experiment 2 – Colour Icon and Language cues

Experiment 2 Method

Participants

Eighteen participants were recruited from the same groups as in experiment 1 and were similarly rewarded for their participation.

Design

The methodology of experiment 2 is similar to that of experiment 1, except for the number of blocks of trials. Experiment 2, as in experiment 1, had two conditions, which had different cues but identical stimuli. There were three different cue-target relationships, which changed every trial, giving two types of sequential switch, an ABA and CBA sequence. Participants completed the first and second block of trials of one condition prior to moving on to the next condition. Each of the two conditions were balanced for order between them.

Apparatus & Stimuli

The language condition used the words; "Red", "Green", and "Blue, whereas the icon condition used coloured rectangles with the same colour as their appropriate target stimuli. The distracter stimuli was coloured orange. Cues, stimuli and responses had the same diameters as in experiment 1, refer to figures 26 and 27.

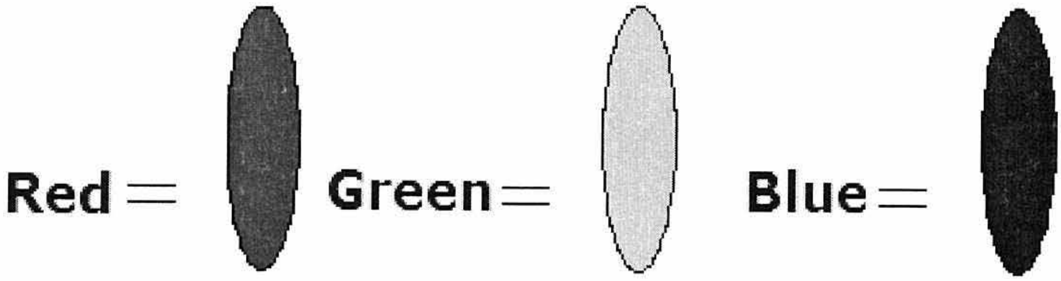


Figure 26: Experiment 2, Condition 1, implicit language cue to coloured icon target.

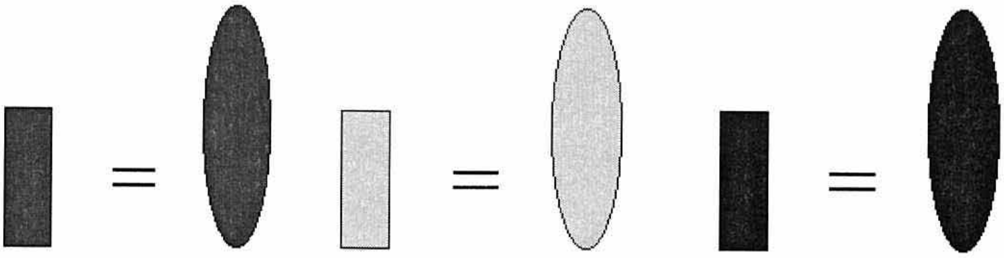


Figure 27: Experiment 2, Condition 2, explicit coloured icon cue to coloured icon target.

Unlike in experiment 1, there were two blocks of 126 trials that ran consecutively within conditions.

Procedure

As in experiment 1, participants completed one of the two conditions fully before completing the second. They had a chance to rest between blocks if they chose to, but none did. The conditions were explained and completed as in experiment 1.

Experiment 2 Results

Data trimming was completed as in the previous experiment; all errors were removed and the two trials in front of any error. The first two trials of each block were also removed. I also removed any trials that had a response time greater than 2000ms and less than 200ms. No participant needed to be removed for errors as no one made more than 10% of errors.

Error analysis showed no significant differences so I continued with response time analysis. I initially completed a 2x2x2 within, by 2x between, Mixed ANOVA, where I compared Cue Type (Language or Icon Cue), by Block Type (First or Second block of 126 trials), by Lag Type (ABA or CBA sequence) within, and between the order in which conditions were completed. The results showed a main effect of Cue Type, $F(1, 17) = 20.67$, $p < .001$, and Lag type, $F(1, 17) = 19.46$, $< .001$. Lag type was also shown to interact with the order of conditions, $F(1, 17) = 5.11$, $p = .037$. There was no main effect of Block Type or interactions with Block Type. There was no interaction between Cue Type and Lag Type, as seen in the previous experiment, but this interaction did interact with the order in which the conditions were completed, $F(1, 17) = 10.92$, $p = .004$. Finally there was a three way interaction between the Cue type, Block Type, and Lag Type, $F(1, 17) = 4.49$, $p = .049$.

Planned comparisons, using pair wise t tests, showed that the overall response times of each of the different type of cued conditions showed the following differences. There was a 21ms (SD = 37.49, SEM = 8.60) cost when using the language cue, in comparison to the icon cue, in the first block of the ABA sequence, $t(18) = 2.42$, $p = .026$, there was a similar 35ms (SD = 28.81, SEM = 6.61) cost in the first block of the CBA sequence, $t(18) = 5.37$, $p < .001$, and a 35ms (SD = 59.83, SEM = 13.73) cost in the second block of the ABA sequences, $t(18) = 2.54$, $p = .021$, and finally a 31ms (SD = 48.73, SEM = 11.18) cost when doing the language cued condition, in comparison to the icon cue condition, in the second blocks CBA sequences, $t(18) = 2.77$, $p = .013$, refer to table 3.

Table 3: Displays the differences in mean response times (ms) between the Icon and Language conditions, in relation to order and lag for Experiment 2.

Experiment 2

		Difference between Language and Icon conditions			Condition Type				
Exp No	Block and Lag Type	Mean	Std. Deviation	Std. Error Mean	Icon	Language	t	df	Sig. (2-tailed)
2	First Block ABA	20.81ms	37.49	8.60	449.84ms	470.66ms	2.420	18	.026
	First Block CBA	35.49ms	28.81	6.61	433.88ms	469.36ms	5.371	18	.000
	Second Block ABA	34.86ms	59.83	13.73	441.37ms	476.23ms	2.540	18	.021
	Second Block CBA	30.94ms	48.73	11.18	431.18ms	462.13ms	2.768	18	.013

I also compared the ABA and CBA sequences, using pair wise t tests, within conditions and found that there was a 16ms (SD = 16.04, SEM = 3.68) cost when doing the ABA sequence in the first block, t (18) = 4.34, $p < .001$, and similar 10ms (SD = 19.83, SEM = 4.55) cost in the second block of the icon condition, t (18) = 2.24, p = .038. This difference was not apparent in the language condition, in the first block, with the ABA and CBA sequences only having a 1ms difference between them. There was however a similar 14ms (SD = 28.85, SEM = 6.62) cost when doing the ABA sequence in the second block of the language condition, t (18) = 2. 23, p = .047, refer to table 4 and figure 28.

Table 4: Mean response times (ms) for Experiment 2, comparing lag with condition and order of condition.

Experiment 2

Exp No	Condition and block	Difference between ABA and CBA sequences: Mean Time difference	Std. Deviation	Std. Error Mean	Mean Response Time: ABA	CBA	t	df	Sig. (2-tailed)
2	Icon Cue First Block	15.96ms	16.04	3.68	449.84ms	433.88ms	4.339	18	.000
	Icon Cue Second Block	10.18ms	19.83	4.55	441.37ms	432.18ms	2.238	18	.038
	Language Cue First Bloc	1.29ms	24.45	5.61	470.66ms	469.37ms	.229	18	.821
	Language Cue Second Block	14.10ms	28.85	6.62	476.23ms	462.13ms	2.130	18	.047

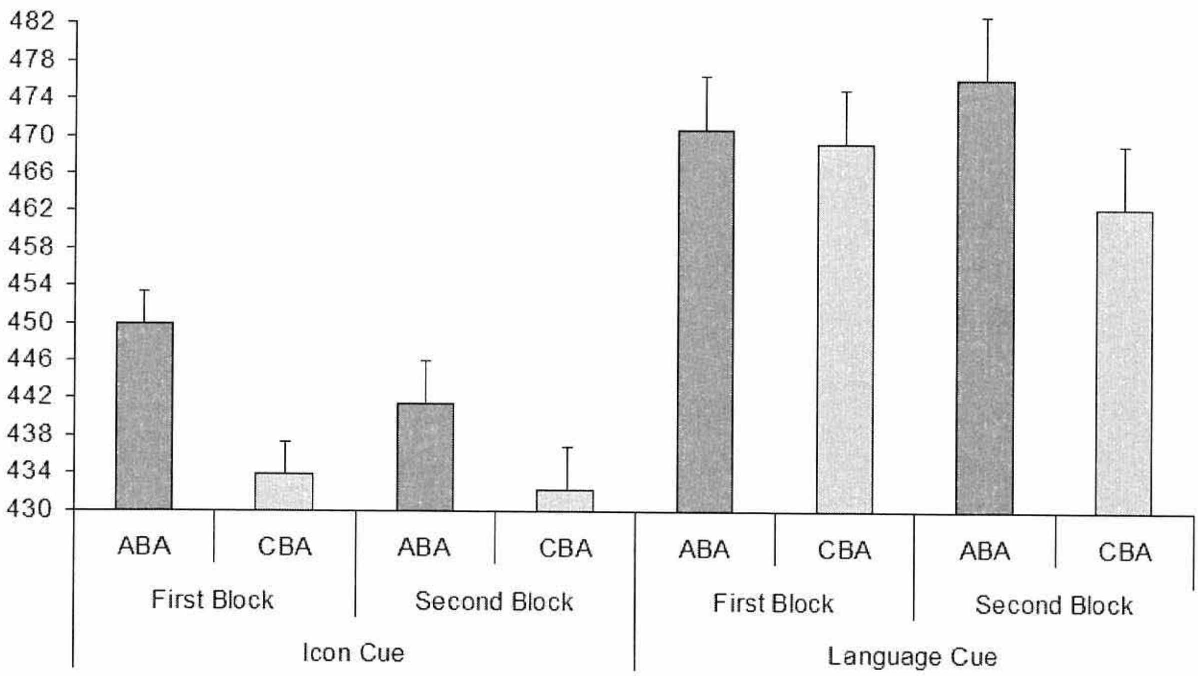


Figure 28: Graph of mean Response Times (ms) for each condition and the order in which the conditions were carried out in Experiment 2. Error bars show the standard error of the mean.

Summary of results

Experiment 2 set out to reduce the overall speed of response times so they were as fast as the icon condition in experiment 1. The above results did reduce the overall response times so they were similar to the icon condition in experiment 1. There was still a significant difference between the overall response times when the two conditions were compared but this was greatly reduced from the difference between these conditions in experiment 1. Analysis of the difference in response times of trials, which were in an ABA or CBA sequence, showed that trials in an ABA sequence took a greater amount of time in the first and second block of the icon condition than when they were in a CBA sequence. This cost difference was only apparent in the second block of language condition. The experiment showed that it is possible get a backward inhibition cost at response times less than 500ms as well as when there is enough bottom up information in a cue to identify a target as in the coloured icon condition.

Experiment 2 Discussion

The results would seem to suggest that an automatic language label is generated when using coloured icon cues which are then inhibited by the up and coming new trial's language label. Practice seemed to have little effect on overall response times but did seem to increase the backward inhibition costs when using language cues, but not when using icon cues. There was also an anomaly when in the language condition, in the ABA sequence, there was a reversal of cost to that of a benefit when the icon condition came first.

The overall response times were dramatically reduced in both conditions and were as fast if not faster than in the icon condition in experiment 1. Even so, there was backward inhibition in both of the cued conditions, showing that the speed of response was highly unlikely to have been the reason why there was no backward inhibition present in the icon condition in experiment 1.

The conclusions one can make on the practice effect cannot be conclusive, as there was also an order of blocks effect that was influencing our results. What was apparent was that practice had little to no effect on the ABA cost in the icon condition, but did seem to affect the language cued condition. There seemed to be an increase in the ABA cost in the second block of the language condition. This may be because the top down language label and bottom up visual image of the target were becoming more amalgamated. This may have heightened the level of activation and subsequently required a greater level of inhibition (Gade & Koch, 2005). Later on in this study, I suggest a model that links the backward inhibition cost to the deconstruction of an amalgamated cue code, which is made up of the bottom up representation of the cue and its associated top down language label, which occurs in working memory. This is so the top down language label, previously associated with the bottom up image of the cue, can now be reapplied to the new bottom up image of the target. If the amalgamated cue code has become more automated, perhaps this too would makes its disassembly more difficult and therefore increase backward inhibition costs? Arbuthnott and Frank (2000) suggested that practice improved response times by strengthening the links between the cue type and the task. This was consistent with Meiran's (1996) hypothesis that practice had an effect on endogenous control processes. The improvement in overall response times, which this would imply, was not significantly apparent, although the second block of the icon cued condition was marginally faster. What is interesting is that, if the top down language label and the associated task do have a strengthened relationship, this may in turn suggest a greater level of activation. Taking the above into consideration and Gade and Koch's (2005) results, which said that the level of activation of a task-set is directly linked to the level of inhibition required to remove it from working memory, this my explain why in the second block of the coloured language cued condition backward inhibition became apparent.

It could be suggested from these results that practice may have also caused the backward inhibition to become more apparent in the icon condition, as some of the participants would have completed two blocks of the language condition prior to the icon condition. This may have reinforced the requirement to use a language label for the task. This, however, cannot be the answer as there was a significant backward inhibition in the icon condition regardless of whether the language condition had been completed first or second. This would suggest that whatever was causing the cost in the icon cues was not being affected by the language cues. This was not the same for the language cues, which seemed, if anything, to be slightly primed in the ABA condition, when the icon cues were completed first. This result is difficult to interpret, as it may have been an anomaly that suggests that the top down language label was not being inhibited. This may have been a floor effect specifically linked to language cued conditions.

Finally I wanted to see if bottom up process were enough to remove backward inhibition. It was suggested by Mayr and Keele (2000) that if there is sufficient information in the target to identify the task, bottom up processes only are required, so there is no backward inhibition, as top down processes are not required. This was tested by the use of coloured icon cues that matched their icon targets colour exactly. This should have given enough bottom-up information to identify the target without the need for top down processes. As previously stated, it does seem likely that automatic processes, linked to practice, attach a language label to a colour when there is a requirement to identify it. This is best reflected in experiments that use Stroop stimuli, as even if bottom up information contradicts what one is trying to identify, costs are incurred, because, as noted earlier, there is a conflict between the colour label given to the colour that the ink of the target is printed in, and the actual colour that the language target states (Allport & Wylie, 2000). If this is the case then our cues and targets, which are not Stroop, would also have an automatic language label attached to them, matching their physical colour. Then, although there should have been enough bottom-up information in the cue to identify the target, as in the icon in experiment 1, there is likely to be a language label also more immediately available.

Our results suggest that bottom up information about the target does not automatically detach itself from a top down language label given to a target, as we see backward inhibition in the icon condition, whether it comes before or after the language condition.

Chapter 2 Discussion

The experiments described in Chapter 2 recreated the costs found in the Mayr and Keele (2000) paper. This occurred when a top down language label was either required to identify the correct target or was automatically generated. Order effects seem to suggest a two stage model: first a recovery stage of the top down language label, then secondly an application stage when it is attached to the target. This was because overall response times seemed to improve, when completing the second condition, which had little effect on backward inhibition costs in the language condition in experiment 1 and the icon condition in experiment 2. This was not true for the coloured language cued condition so caution was needed with this interpretation. Practice did seem to be having some effect on the language cued condition and may have suggested that the top down language label may have been becoming more amalgamated with the bottom up visual representation of the cue.

Chapter 3

Abstract, explicit and implicit cue target relationships

Chapter 3 Abstract

Results of experiments described in Chapter 2 suggested that the inhibition and subsequent reapplication of a top down language label was the cause of backward inhibition. This seemed to be linked to the conflict of two top down language labels between trials. Experiments described in Chapter 3 tried to increase the number of potential conflicting top down language labels by using a cue that had an abstract relationship to the target. Previous research suggested that in these cases both the cue and target would have differing top down language labels. I believed this may cause added potential conflict within-trial as well as between-trial conflict. It was hypothesised that the more language labels used, the larger the backward inhibition cost would be. Experiments 4 and 5 therefore had one condition that used a cue with an abstract relationship to the target. Experiment 4 used an icon cue to icon target and experiment 5 used a language cue to language target. The two conditions found in experiment 1 were duplicated, repeating the implicit language cued condition (experiment 4) and the matching cue target condition (experiment 5) using language cues instead of icon cues. Results confirmed the hypothesis: the abstract conditions had the largest backward inhibition cost, significantly slower than the implicit cued condition, with the explicit matching cue-target condition having no backward inhibition. Overall response times seemed to have no effect on the backward inhibition costs. These results also suggested a two stage model linked firstly to the inhibition of a top down language label then secondly to its reapplication to a bottom up visual image.

Chapter Summary

The experiments in Chapter 2 seemed to replicate the costs associated with backward inhibition. It also became apparent that these costs may be linked to inhibition of a top down language label and not to a change in bottom up features of the previous target. The experiments in Chapter 3 looked to test this by increasing the potential number of language labels used in each trial. Earlier experimenters' results have suggested that if a cue has a non transparent relationship to the goal of a task, both the cue and the target will have separate top down language labels. If this is true, then it would suggest that if cues with a non transparent abstract relationship to the target are used, both the cue and target may have different top down language labels. If this were the case, then conflict between the cue and targets labels, within trial, as well as the conflict between the previous target's label with the new trial cue's label, should double cost.

Chapter 3 therefore had two experiments, both of which had a condition that had an abstract relationship between the cue and target. One condition used icon cues and targets, while the other used language cues and targets. There was also an implicit language cued condition that had icon targets and an explicit matching language cue to target condition. It was hypothesised that we would see a doubling of backward inhibition costs in the abstract conditions. It was also believed that the language matching condition, like the icon condition in experiment 1, would show no backward inhibition cost as there was no requirement to inhibit a previous top down language label. My results were as hypothesised. Post hoc tests on the order of conditions also showed an overall increase in response times in the abstract conditions, when completed after the simpler condition. This increase in overall response times had no effect on the backward inhibition costs. These results hinted at a two stage model: first, recovery of the top down language labels, assisted by practice, and second, an application stage to the bottom up visual image, which is not helped by practice.

The experiments described in Chapter 2 suggested we were seeing inhibition of a top down language label that is applied to the bottom up visual representation of the target. Backward inhibition seems to be linked to the reapplication of a previously inhibited language label to the target. Inhibition seemed to be as a consequence of between trial conflicts that occur between the two top down language labels associated with the targets. If this is true then there may be an added backward inhibition cost if one were to increase the number of conflicting language labels that could occur in a trial.

Logan and Schneider (2006a) have proposed that there is a requirement to recruit a mediator, a top down language label associated with the goal of a task, when one uses a cue that has no obvious relationship to that goal. It seems that the cue has a label which is independent of that relating to the goal of the task. So, each trial has both a top down language label associated with the cue and also one with the task goal.

Taking this into consideration and looking at the methodology being used, I asked whether I could increase the level of backward inhibition if a trial had two language labels associated with it: one linked to the identification of the cue, that cannot be used to identify the target, and one specifically linked to identifying the correct target. This could be done if the cue had no obvious relationship to the target other than one that was used for the experiment. This would mean that the cue would require its own top down language label to be recognised, but this in turn would come into conflict with the language label for the target, so would need inhibiting within trial. This would then add to the level of inhibition, as both the language label for the cue and the separate language label for the target would have been previously inhibited in an ABA sequence. If this then doubled the cost of the backward inhibition, which was not affected by the previous order effect on overall response times found, it would suggest that I was seeing inhibition of a top down language label.

As previously noted, Logan and Schneider (2006a) have suggested that a "mediator" is used when a cue has no meaningful relationship to a task represented in the target. It is an additional process that is added to the action of determining which task-set in their experiments is required. The mediator has a direct relationship to the goal of the task, having a top down semantic link to the target which it identifies. The mediator, for example, will be used if the cue for a parity task was the word 'switch'. The word 'switch' would have its own top down language label, 'switch', which would have no natural relationship to the goal of a task. A mediating top down language label would then need to be recruited to identify the goal of the task such as the language label 'parity'. Logan and Schneider suggest that the mediator is similar to an explicit or implicit cue, in that it identifies the feature in the target being looked for. In our previous experiments, the cue and target could share a common top down language label. In the following experiments, I wanted to remove this commonality of a shared language label for the cue and target.

The target therefore normally has more than one physical characteristic, or way in which it can be interpreted, when the participant decides how to respond. Logan and Schneider (2007) gave a good example of this when they were using non-explicit transitional cues that told the participant to "REPEAT" and "SHIFT" task, when carrying out two tasks of parity or magnitude judgments of numbers. They suggested that if, for example, participants had previously been carrying out a magnitude judgment and the cue "SHIFT" were to appear, then they would first understand that this meant that a task change was about to occur. They would then recruit the task label parity, which would then allow them to select the right response of Odd or Even, depending on the target number.

Our methodology does not use a target that requires the participant to judge more than one feature of the target. This means that if there is a goal to the trial, in these experiments, then that goal would be to identify the targets position that shares a taught relationship to a previous cue. The top down language label associated with the target may then be seen as the goal, but this could be questioned. Logan and Schneider (2007) see the top down language label as associated with giving the target meaning. This means that in my experiments, the top down language labels, border, shaded, and angled, which give meaning to the targets, could equally be seen as mediators if the cue's top down language label does not automatically identify the target.

Because of this, experiments 3 and 4 were designed to use a cue which needed its own language label, so that it could be differentiated from the other cues, but had no obvious relationship to the target. This meant that both the cue and target would have different top down language labels. On the basis of this and the results of the previous experiments, where the between trial conflict of top down language labels seemed to be causing backward inhibition, I hypothesised that this, plus the inhibition of conflicting language labels within trial, would double the backward inhibition cost.

Experiment 3 was designed to use an icon cue which would be likely to attract an automatic top down label which was not associated with the recognition of the correct target. Because of this, the icon cues of a triangle, hexagon, and square were used, as they would first need to be labelled, so one could to recognise their shape, which differentiated them from the other cues. The cue's top down language label would then have no obvious relationship to the target's top down language label which would then need to be recruited when the target appears. This would mean that there would be an abstract relationship between the cue and the target. This icon condition was paired with the language condition that was used in experiment 1.

Experiment 4 used language cues and targets. There was one condition that, like the icon condition in Experiment 3, had an abstract relationship between the cues and targets, so two different words had no obvious relationship. There was also a second condition where the cue matched the target.

A by-product of this design was that there was no switching of modalities between a bottom up language cue and icon target. This was important, as it may have been seen as a potential confounding variable that could previously have been contributing to costs. I believed that this was highly unlikely and this remaining within modality would not decrease overall costs or backward inhibition.

The conditions of experiments 3 and 4 therefore had three potential levels of costs that may occur which were directly linked to the number of top down language labels in each trial. In the abstract condition there were two, one for the cue and one for the target, which would both need inhibiting so should be the most costly. The implicit language cued condition in experiment 3 only has one top down language label in a trial, which identifies the target, so should have less backward inhibition than the abstract conditions. Finally the matching cue-target words condition should have no backward inhibition cost, as there is enough bottom up information in the cue to identify the target, so there is no need to apply a top down language label to the target.

Experiment 3 – Abstract icon cues and language cues

Experiment 3 Method

Participants

There were 29 participants, recruited from the same population as the previous experiments.

Design

The design of the experiment was the same as in Experiment 1; the only alteration was the cue type used in the icon condition.

Apparatus & Stimuli

The only difference between Experiments 1 and 3 was the type of icon cues used; they had an abstract relationship to the target. They were 4cm in height and 4cm in width, refer to figure 29.

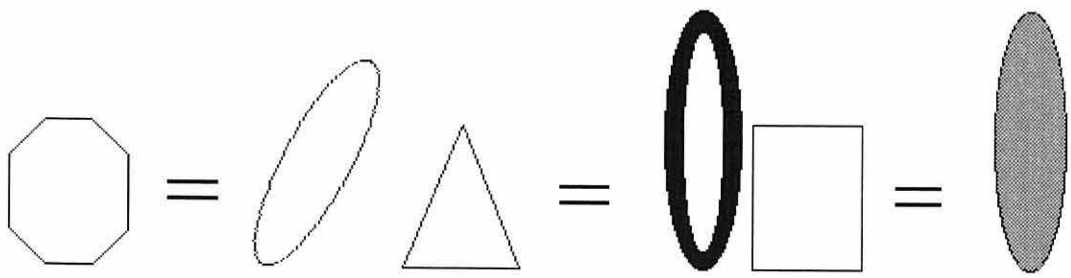


Figure 29: Experiment 3, Condition 2, abstract icon cue to icon target.

Procedure

The procedure remained the same as in experiment 1, although we did attempt to give the cues and their associated targets their obvious labels.

Experiment 3 Results

Data trimming was completed as in the previous experiments; all errors were removed and the two trials in front of any error. The first two trials of each block were removed. I also removed any trials that had a response time greater than 2000ms and less than 200ms. Three participants needed to be removed as over 10% of their responses were errors. One participant was also removed because of being an outlier. This meant that 25 participants were left out of an original 29 participants.

There was no main effect or interactions in the error data, so I focus on reaction time analysis only

I initially completed a 2x2 within x2 between mixed ANOVA that compared Cue Type (Abstract Icon or Language Cue), by Lag Type (ABA or CBA) within, and between the order that the conditions were carried out (Icon Cue or language Cued condition first).

The results identified a main effect of Cue Type, $F(1, 23) = 41.69$, $p < .001$, which interacted with the order of the conditions, $F(1, 23) = 16.63$, $p < .001$. There was also a main effect of Lag Type, $F(1, 23) = 18.13$, $p < .001$, that interacted with Cue Type, $F(1, 23) = 8.62$, $p = .007$. There was also an approaching between significant difference in the order in which the conditions were done, $F(1, 23) = 3.14$, $p < .089$.

I then completed planned comparisons of the results. I first carried out an independent samples t test, taking into consideration which condition had been completed first, while comparing ABA and CBA sequences. The results identified, in the icon condition, a significant 167ms (SED = 62.43) cost in the ABA sequences, t (23) = 2.67, p = .014, and 173ms (SED = 59.16) cost in the CBA sequences, t (23) = 2.93, p = .008, when the icon condition was completed first. This cost difference, that was dependent on the order of conditions, was not found in the language condition. There was also no significant effect on the backward inhibition cost in either of the conditions which was dependent on the order in which they were done, refer to figure 30 and table 5.

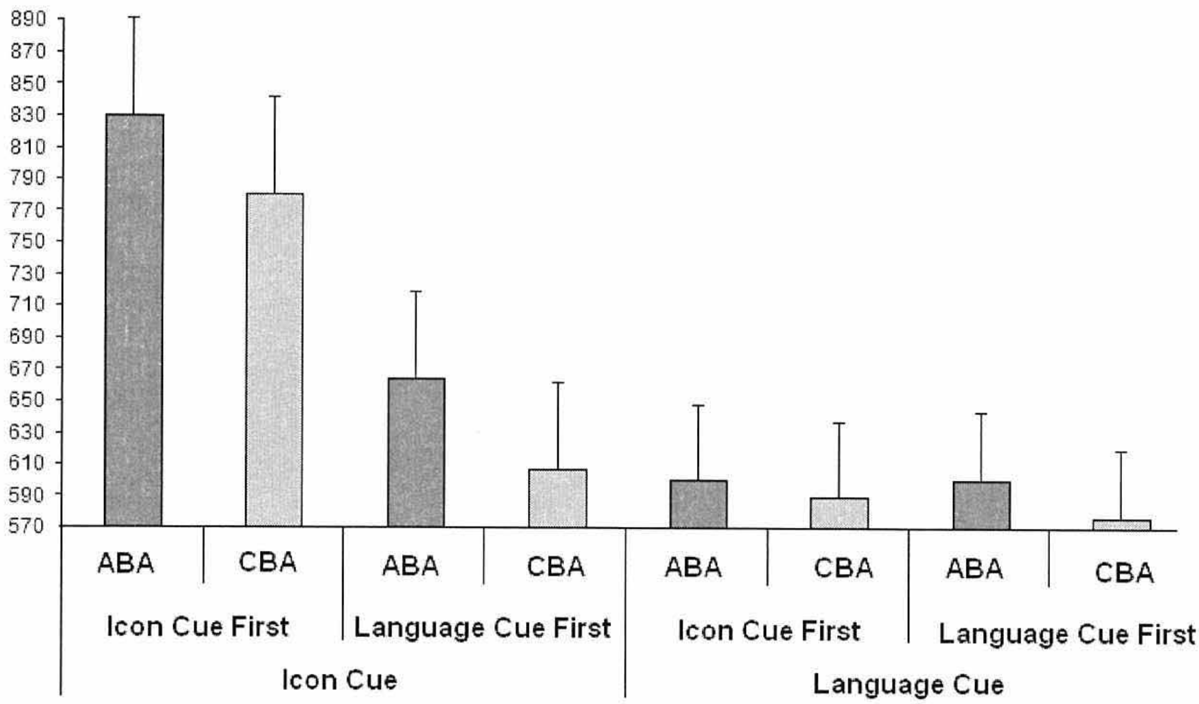


Figure 30: Mean Response Times (ms) across both conditions, order and lag type for Experiment 3. Error bars show the standard error of the mean.

Table 5: Illustrates the mean Response Times (ms) for Experiment 3, across both conditions, in relation to the order in which subjects carried out each condition.

Experiment 3, Independent Samples t test of order of conditions.

Exp No	Condition And Lag Type	Difference between Language and Icon conditions: Mean difference	Std. Error difference	Condition Type Completed First: Icon	Language	t	df	Sig. (2-tailed)
3	Icon Cue ABA	166.53ms	62.43	830.11ms	663.57ms	2.668	23	.014
	Icon Cue CBA	173.07ms	59.16	780.42ms	607.36ms	2.925	23	.008
	Language Cue ABA	0.55ms	48.56	600.06ms	599.50ms	-.011	23	.991
	Language Cue CBA	12.93ms	46.61	589.57ms	576.64ms	-.277	23	.784

Backward Inhibition:	Icon First	Lang First
Icon Condition	49.69ms	56.21ms
Language Condition	10.49ms	22.86ms

After the above independent t analysis, I carried out pair wise t tests that compared the ABA and CBA sequences within conditions and found the following. There was a significant 53ms (SD = 60.77, SEM = 12.15) cost when doing a trial in the ABA sequence in comparison to the CBA sequence in the icon condition, $t(24) = 4.34$, $p < .001$. There was also a significant 16ms (SD = 37.17, SEM = 7.43) cost when doing the ABA sequence in the language condition, $t(24) = 2.20$, $p = .037$. These two different backward inhibition costs could also be considered as significantly different from each other due to the interaction between lag type and cue type, which was previously identified in the Mixed ANOVA, $F(1, 23) = 8.62$, $p = .007$, refer to table 6 and figure 31.

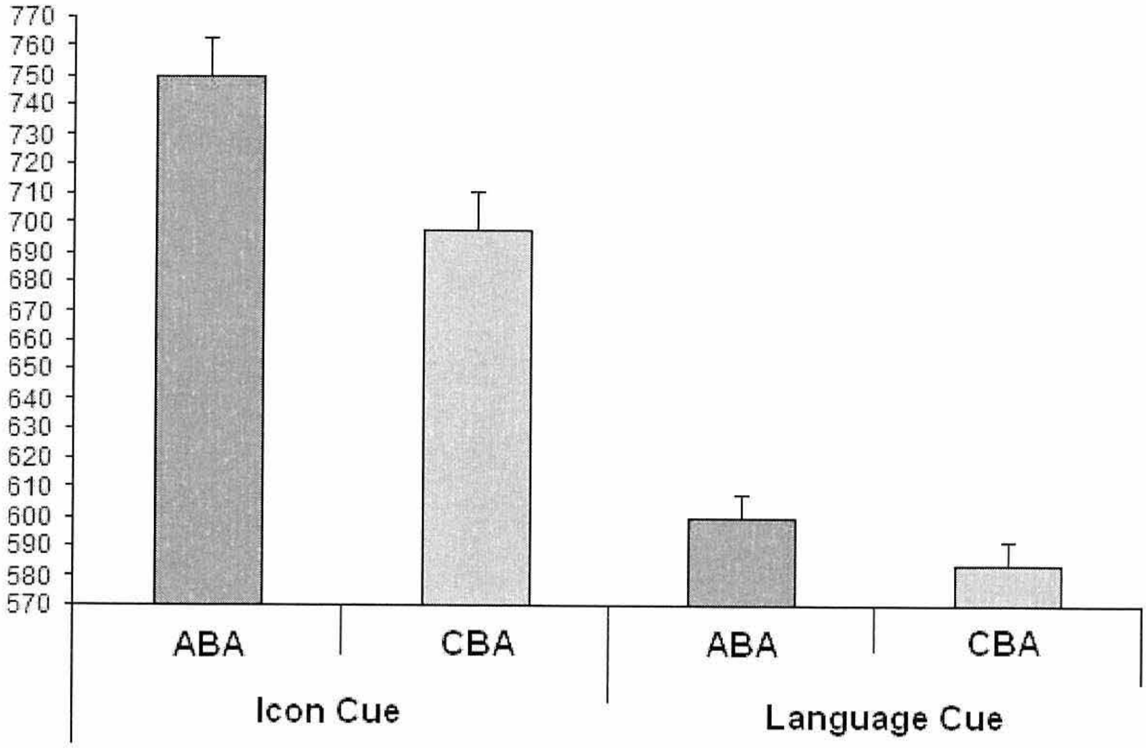


Figure 31: Mean Response Times (ms) for Experiment 3, by condition and lag. Error bars show the standard error of the mean.

Table 6: Mean Response Times (ms) for Experiment 3, across both conditions, comparing lag.

Experiment 3, Pair wise t test comparing ABA and CBA sequences.

		Difference between ABA and CBA sequences			Mean Response Time				
Exp No	Condition	Mean Time difference	Std. Deviation	Std. Error Mean	ABA	CBA	t	df	Sig. (2-tailed)
3	Icon Cue	52.82ms	60.77	12.15	750.17ms	697.35ms	4.34	24	.000
	Language Cue	16.43ms	37.17	7.43	599.79ms	583.37ms	2.20	24	.037

Summary of results

The above results showed the following. There was a trebling of the cost, associated with backward inhbition, in the abstract icon conditons ABA sequence, when compared to the backward inhibition cost in the implicit langage cued conditon. The backward inhibition seemd to be as a consequence of both within and between trial conflict between different language labels for the cue and taregt in the icon condition. Backward inhibition also seemed not to be linked to overall response times. This was because an order effect was identified in the icon conditon, which increased overall response times when the icon condition was carried out prior to the language conditon that did not significantly alter the backward inhibiton cost. This order effect was not significantly identified in the language condition.

Experiment 3 Discussion

The results of experiment 3 were as hypothesised. There was more than a doubling in costs associated with the number of potential top down language labels used in a trial. There seemed to be inhibition occurring both within trial and between trials in the abstract condition. In the implicit language cued condition, conflict between language labels only occurred between trials and over halved the backward inhibition cost. One obvious criticism which could be made of the above account of backward inhibition costs could be that the backward inhibition cost was directly linked to overall response times and not to the number of top down language labels in each trial. This would have some weight to it, if it were not for the order effect seen, where there was over a 100ms reduction in overall response times in the abstract condition when it was completed second to the language condition, which had no effect on backward inhibition cost. These results do seem to suggest that a two stage model was in operation, which firstly retrieves the top down language label, then secondly applies it to the bottom up image. They also seem to suggest that the physical act of responding to the bottom up image is not required for this cost to appear, as the cue did not need a physical response. What is also important is that later on in this study it became apparent that the bottom up image of the cue and its associated top down language label seem to become amalgamated into a shared common code. It seems that the process of deconstructing this code in working memory, so that the top down language label for the cue can now be used for the target, may be what is causing the cost. This, of course, does not happen in this scenario where the top down language code is not shared. Perhaps in this case we are seeing a general level of cost linked to the reactivation of two separate inhibited amalgamated codes linked to both the cues and targets having their own separate amalgamated language codes.

Experiment 4 – Abstract and matching language cues

In all of the previous experiments here, there have been two methodological constants which I wish address now: the first is that cue has always changed between conditions, and the stimuli have remained the same; the second is that all the stimuli have been iconic.

Mayr and Bryck (2005) showed how the goal of the task, as represented by a language cue, becomes associated with a specific target's position and the associated response to that target's position. It was suggested that the cue, target, and response, became amalgamated into the top down language label. Mayr and Bryck (2005) showed this by manipulating the cue, target, and responses separately, while keeping two of these components constant. What was interesting about their results was that the greatest cost was identified when the cue changed but the position of the target and its associated response remained constant. It seemed that the cue, which represented the top down language label for the bottom up visual image, became linked to the appropriate response to the target's position. Monsell and Mizon (2006) have also highlighted how the bottom up representation of all of the elements that make a task set can influence associated costs linked to top down processes. If this is so then a question that needed to be asked here was whether this could also be occurring in my experiments? Was the top down language label becoming amalgamated with the target, and was the change in this relationship between conditions having any effect on backward inhibition?

If this had been occurring then there should have been an order effect in all of the previous experiments, which increased the backward inhibition cost or overall response time in the second condition. This would be because relationship of the top down language label to the bottom up image would have changed. This is not what occurs. Any order effect that has been seen improves overall response times in the second condition, but has little to no effect on the backward inhibition cost. It also seems only to occur in the condition with the less transparent relationship with the cue and target and not in the condition with the more transparent relationship, in the experiment.

The target in all of the previous experiments appears on the screen at lag-2 in an ABA sequence but its bottom up characteristics seem to be playing little to no part in the costs. In the matching icon condition in experiment 1 and the implicit language cued conditions in experiments 1 and 3, as well as in the abstract condition in experiment 3, the icon target's bottom up characteristics remained the same to those at lag-2, except for its position, but backward inhibition costs were all different. This suggested that we are seeing inhibition of the top down language label associated with giving meaning to a bottom up image. Backward inhibition cost seemed to be linked to the reapplication of that top down language label to the new bottom up visual image. Even so, experiment 4 attempted to test the possibility that in the first condition the top down label becomes amalgamated with the bottom up image. This was achieved by having two groups of participants. One group completed the two conditions, as in the previous experiments, where the cues change between conditions but the stimuli remain the same, and for the second group, the cues remain the same between conditions and the targets change.

The second question is linked to the switch in modalities from a language cue, or from icon cue that seems to have an automatically acquired language label, to an iconic target. This was because previous experimenters had shown that a switch in modality can cause costs associated with response times and backward inhibition costs (Philipp & Koch, 2005). I wanted to see if this switch to an iconic target was integral to the costs we were seeing.

To answer the above questions, experiment 4 had two different conditions that had language cues and targets. One of the conditions had matching language cues and targets, and the other condition had a language cue and target with no obvious top down language relationship between them. I also split the experiment into two separate groups, one of which had the same cues in both conditions with the targets changing in the abstract condition, whereas for the second group, the cues were different between conditions but the stimuli remained the same.

I designed an experiment that used a language cue and targets, with the language cue having no obvious top down language relationship to the target, other than the one suggested by the experimenter. We also made sure that both the cue and target words had similar verbal and written frequencies, based on the "MRC Psycholinguistic Database", so there was less likelihood of these variables playing any part in cost. Please refer to Appendix 1.

It was hypothesised that the relationship between the conditions should have little to no effect on the backward inhibition cost. This was because there was the same number of top down language labels in both groups' conditions: two in the abstract condition and none in the matching cue target condition. I also believed that the switching of modalities, or the potential amalgamation of different top down language labels with the bottom up visual image, had little to nothing to do with the backward inhibition cost. On the other hand, overall response times may be affected, as not switching cues between conditions may assist in the process of recovery of the top down language label in the abstract condition.

Experiment 4 Method

Participants

There were 29 participants, recruited from the same population as in the previous experiments.

Design

The design of the experiment was the same as that for experiment 1, the only alteration being that in experiment 4 all of the cues and targets used language labels; in one of the conditions the language cues and targets matched each other, and in the other condition the relationship between the cue and the target was abstract in nature. All participants completed these two conditions, but half of the group experienced the cue changing between conditions, and the stimuli remaining the same, as in the previous experiments. The other group had the cues remain the same between conditions and the associated targets changed between conditions. The design was a mixed 2(Cue-Target relationship, matching or abstract) x 2(Lag type, ABA or CBA) within, x 2(Cue change or target change) between components to it.

Apparatus & Stimuli

In experiment 4 there were two language conditions, one in which the cue matched the target stimulus, and the other in which the relationship between the cue and target was abstract in nature. There were two separate groups; for one group the cue remained constant in both the matching and abstract conditions, and the target stimuli changed between conditions. For the other group, the stimuli remained the same between conditions and the cue changed. In the group where the target stimulus changed and cues remained constant between conditions, in the abstract condition, the cue to target stimulus relationships were, Milk-Disk, Coal-Seat, and Lake-Gate, and the distracter was Plug, refer to figure 32.

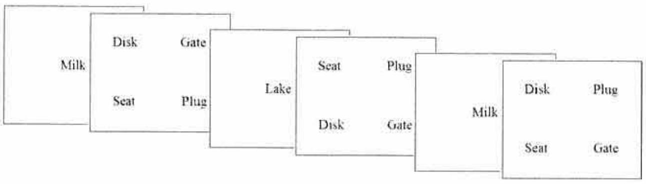


Figure 32: Experiment 4, Group where target changed and cue remained the same between conditions.

The matching condition relationships were the same in the two groups, Milk-Milk, Coal-Coal, Lake-Lake, except for the difference in the constant distracter stimulus, refer to figure 33.

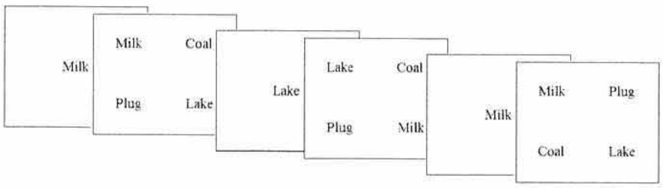


Figure 33: Experiment 4, matching cue to target, same condition in both groups.

In the group where the cues changed and the stimuli remained the same between conditions, the cue–stimulus relationships in the abstract condition were, Gate-Milk, Disk-Coal, Plug-Lake, and the distracter was Seat, refer to figure 34.

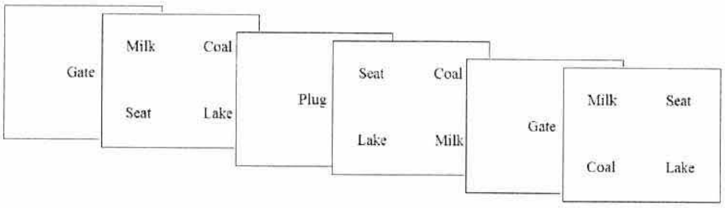


Figure 34: Experiment 4, group where cues change and targets remain the same between groups.

The words used were assessed for their frequency, both verbally and written, using the "MRC Psycholinguistic Database", see appendix 1.

Experiment 4 Results

Data trimming was completed and as in the previous experiments all errors were removed and the two trials in front of any error. The first two trials of each block were also removed. I also removed any trials that had a response time greater than 2000ms and less than 200ms. There were initially 29 participants; four participants needed to be removed as over 10% of their responses were errors. There was also one participant removed because of being an outlier and another whose data was mistakenly corrupted. This meant that 23 participants were left out of an original 29 participants.

Error analysis was completed and no main effects or interactions were identified.

In Experiment 4 I first completed a 2x2 (within)x2x2 (between) Mixed ANOVA, that compared Cue Type (Matching or Abstract cues) by Lag Type (ABA or CBA) within, in relation to the order in which the conditions were completed (Matching or Abstract condition first) by what changed between conditions (Cue change, stimulus repeat, or cue repeat stimulus change). There was a main effect Cue Type, $F(1, 19) = 80.42$, $p < .001$, that interacted with the order in which the conditions were completed in, $F(1, 19) = 7.47$, $p = .013$, and also interacted with what changed between conditions, the cue or stimuli, $F(1, 19) = 12.16$, $p = .002$. There was also a main effect of Lag Type, $(1, 19) = 10.72$, $p = .004$, which only interacted with the type of cue used, $F(1, 19) = 11.07$, $p = .004$. There was also an approaching significant three way interaction between the Cue Type, lag Type, and whether the cue or stimuli changed between conditions, $F(1, 19) = 3.91$, $p = .063$. There was also a between subjects effect relating to whether the cue or stimuli changed between conditions, $F(1, 19)$ 13.89, $p = .001$.

I then completed planned comparisons and first carried out pair wise t tests that compared the ABA and CBA sequences. I found that there was no significant difference in overall response times in the Matching cued condition, $t(23) = .026$, $p = .979$. There was however a significant 55ms (SD = 76.71, SEM = 16.00) cost when doing a trial in the ABA sequence when compared to the CBA sequence, $t(23) = 3.46$, $p = .002$, refer to table 7.

Table 7: Compares the mean Response Times (ms) by lag for each condition in Experiment 4.

Experiment 4, Pair wise t test comparing ABA and CBA sequences.

		Mean Response Time		Difference between ABA and CBA sequences					
Exp No	Condition	ABA	CBA	Mean Time difference	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
4	Matching Cue	653.16ms	652.98ms	.18ms	33.37	6.96	.026	22	.979
	Abstract Cue	855.89ms	800.58ms	55.31ms	76.71	16.00	3.458	22	.002

An independent samples t test was also carried out that looked at the difference between the response times when there was either a change in cue and repeat of stimuli between conditions or when there was a repeat of cue and a change of stimuli between conditions. It showed that there was a significant cost when there was a repeat of cue and a change in stimuli between conditions when compared to a change in cue and repeat of the stimuli. There was a 105ms (SED = 42.35) cost in the matching cued ABA sequences, t(21) = 2.47, p = .022, a 120ms (SED = 41.83) cost in the matching CBA sequence, t(21) = 2.87, p = .009), a 256ms (SED = 66.84) cost in the abstract cued ABA sequence, t(21) = 3.83, p = .001, and a 231ms (SED = 56.49) cost in the abstract cued CBA sequence, t(21) = 4.09, p = .001, refer to figure 35 and table 8.

Table 8: A comparison of the mean Response Times (ms) for all conditions by order for Experiment 4

Experiment 4, Independent Samples t test of order of conditions.

Exp No	Condition and Lag Type	Mean Response time: Stimulus Changes	Mean Response time: Cue Changes	Difference between Language and Icon conditions: Mean difference	Difference between Language and Icon conditions: Std. Error difference	t	df	Sig. (2-tailed)
4	Matching Cue ABA	703.18ms	598.58ms	104.60ms	42.35	2.470	21	.022
	Matching Cue CBA	710.39ms	590.35ms	120.04ms	41.83	2.870	21	.009
	Abstract Cue ABA	978.32ms	722.32ms	256.00ms	66.84	3.830	21	.001
	Abstract Cue CBA	911.09ms	680.03ms	231.06ms	56.49	4.090	21	.001

Backward Inhibition:	Stimulus Changes	Cue Changes
Matching Condition	-7.20ms	8.24ms
Abstract Condition	67.23ms	42.30ms

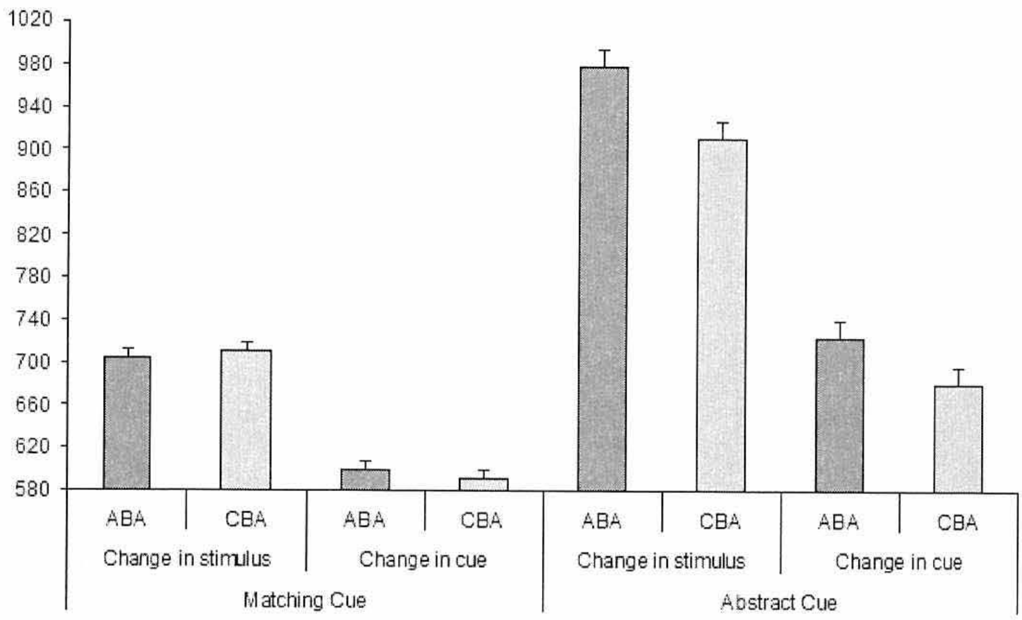


Figure 35: Mean Response Times (ms) across all conditions by lag, for Experiment 4. Error bars show the standard error of the mean.

Because of the above identified order affect I repeated the above analysis, while separating the two groups into those who did the matching cue target condition first and those who did the abstract cued condition first.

I first looked at the group that did the Matching cued condition first completing 2x2 within x 2 between mixed ANOVA comparing Cue type (Matching or Abstract) by Lag Type (ABA or CBA) within, by difference between the conditions (Cue changes or stimuli change between conditions). There was again a main effect of Cue type, $F(1, 11) = 33.85$, $p < .001$, which interacted with the type of difference between conditions, $F(1, 11) = 5.81$, $p = .035$, there was also an approaching significant main effect of Lag Type, $F(1, 11) = 3.63$, $p =.083$, that did not interact with anything else. Finally there was a main between subjects effect linked to what changed between conditions, the cue or target, $F(1, 11) = 12.60$, $p = .005$, refer to figure 36.

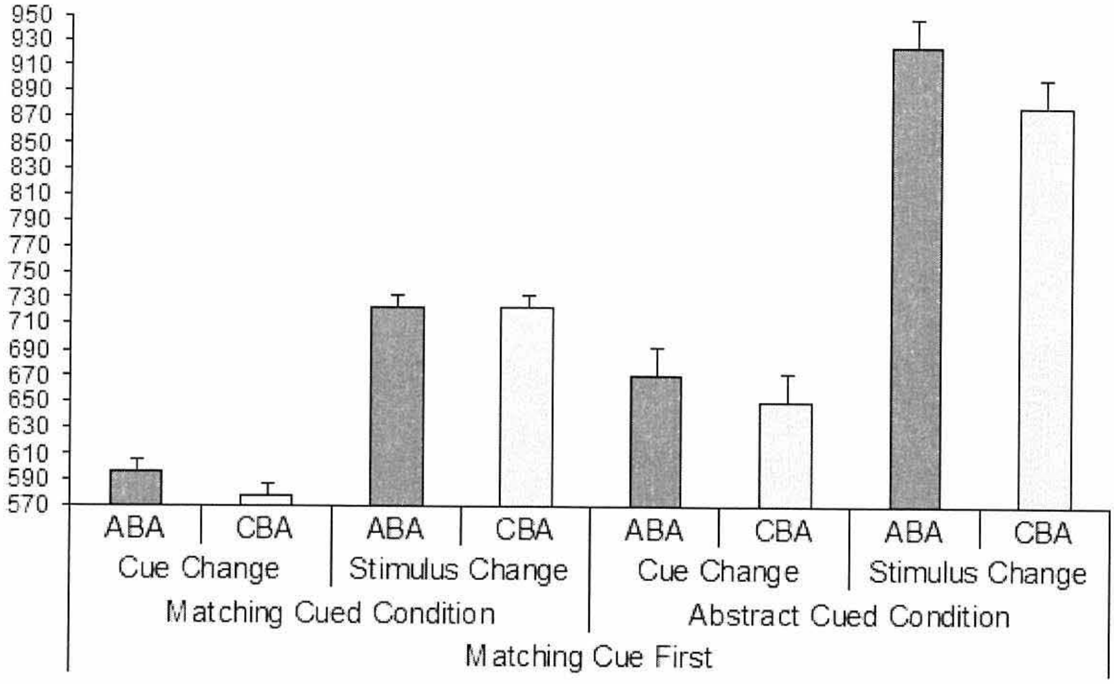


Figure 36: Mean Response Times (ms) for each condition and lag type, of the subject who carried out the Matching Cue condition first in Experiment 4. Error bars show the standard error of the mean.

I again did an independent t test comparing the difference between the response times when there was either a change in cue and repeat of stimuli between conditions or when there was a repeat of cue and a change of stimuli between conditions. It showed that there was a significant cost when there was a repeat of cue and a change in targets between conditions when compared to a change in cue and repeat of the stimuli. There was a 127ms (SED = 57.70) cost in the matching cued ABA sequences, $t(11) = 2.20$, $p = .050$, a 146ms (SED = 56.22) cost in the matching CBA sequence, $t(11) = 2.60$, $p = .025$, a 254ms (SED = 67.72) cost in the abstract cued ABA sequence, $t(11) = 3.75$, $p = .003$, and a 226ms (SED = 55.85) cost in the abstract cued CBA sequence, $t(11) = 4.05$, $p = .002$, refer to table 9.

Table 9: Mean Response Times (ms) of subject who carried out the Matching Cue condition first, by condition and lag, for Experiment 4.

Matching cued condition first: Experiment 4, Independent Samples t test of order of conditions.

Exp No	Condition and Lag Type	Mean Response time: Stimulus Changes	Mean Response time: Cue Changes	Difference between Language and Icon conditions: Mean difference	Difference between Language and Icon conditions: Std. Error difference	t	df	Sig. (2-tailed)
4	Matching Cue ABA	722.66ms	595.94ms	126.72ms	57.70	2.196	11	.050
	Matching Cue CBA	723.56ms	577.37ms	146.19ms	56.22	2.600	11	.025
	Abstract Cue ABA	923.36ms	669.42ms	253.94ms	67.72	3.750	11	.003
	Abstract Cue CBA	876.94ms	650.56ms	226.37ms	55.85	4.053	11	.002
		Backward Inhibition:	Stimulus Changes	Cue Changes				
		Matching Condition	-0.9ms	18.57ms				
		Abstract Condition	46.42ms	18.86ms				

I again completed pair wise t tests that compared the ABA and CBA sequences. I found that there was no significant difference in overall response times in the Matching cued condition, t(12) = .820, p = .428, or in the Abstract cued condition, t(12) = 1.64 , p = .127, refer to table 10.

Table 10: Mean Response Times (ms) of subject who carried out the Matching Cue condition first for both conditions by lag, for Experiment 4.

Matching cued condition first: Experiment 4, Pair wise t test comparing ABA and CBA sequences.

Exp No	Condition	Mean Response Time: ABA	Mean Response Time: CBA	Difference between ABA and CBA sequences: Mean Time difference	Difference between ABA and CBA sequences: Std. Deviation	Difference between ABA and CBA sequences: Std. Error Mean	t	df	Sig. (2-tailed)
4	Matching Cue	664.18ms	656.08ms	8.09ms	35.58	9.87	.820	12	.428
	Abstract Cue	806.16ms	772.46ms	33.70ms	74.01	20.53	1.642	12	.127

After this I repeated the above analysis on the group that had completed the Abstract cued condition first and found the following. There was again a main effect of Cue Type, F(1, 8) = 41,29, p < .001, which interacted with the type of change that occurred between conditions, F(1, 8) = 5.82, p = .042. There was also a main effect of Lag Type, F (1, 8) = 6.68, p = .032, that also interacted with Cue type, F(1, 8) = 15.18, p = .005. There was also an approaching significant between subjects effect linked to what changed between conditions, F (1, 8) = 3.90, p = .084.

Independent t tests on this occasion, comparing what changed between groups conditions, cue or stimuli, showed 74ms (SED = 67.62) cost in the ABA sequence, t(8) = 1.10, p = .305, and 86ms (SED = 68.33) cost in the CBA sequence, t(8) = 1.26, p = .244, in the matching cued condition, in the group where the stimuli changed in comparison to the cue between conditions. Both of which were not significant. A similar cost was found in the abstract cued condition but these were significant with a 120ms (SED = 119.97) cost in the ABA sequence, t(8) = 2.25, p = .055, and a 110ms (SED = 110.16) cost in the CBA sequence, t(8) = 2.21, p = .058, suggesting that the recovery of the target and the application of the language label may be impeded when the stimuli changes between conditions, refer to table 11.

Table 11: Mean Response Times (ms) of subject who carried out the Abstract Cue condition first for both conditions and lag type, for Experiment 4.

Abstract cued condition first: Experiment 4, Independent Samples t test of order of conditions.

		Mean Response time		Difference between Language and Icon conditions				
Exp No	Condition and Lag Type	Stimulus Changes	Cue Changes	Mean difference	Std. Error difference	T	df	Sig. (2-tailed)
4	Matching Cue ABA	675.91ms	601.76ms	74.16ms	67.62	1.097	8	.305
	Matching Cue CBA	691.94ms	605.93ms	86.01ms	68.33	1.259	8	.244
	Abstract Cue ABA	1055.26ms	785.81ms	269.45ms	119.97	2.246	8	.055
	Abstract Cue CBA	958.89ms	715.39ms	243.51ms	110.16	2.210	8	.058
		Backward Inhibition:	Stimulus Changes	Cue Changes				
		Matching Condition	-16.03ms	-4.1739				
		Abstract Condition	96.36ms	70.42ms				

This was reflected by there being a 74ms (SED = 67.62) cost in the matching cued ABA sequences, t(8) =1.10, p = .305, a 86ms (SED = 68.33) cost in the matching CBA sequence, t(8) = 1.26, p = .244, a 269ms (SED =119.97) cost in the abstract cued ABA sequence, t(8) = 2.25, p = .055, and a 244ms (SED = 110.16) cost in the abstract cued CBA sequence, t(8) = 2.21 , p = . 058, refer figure 37.

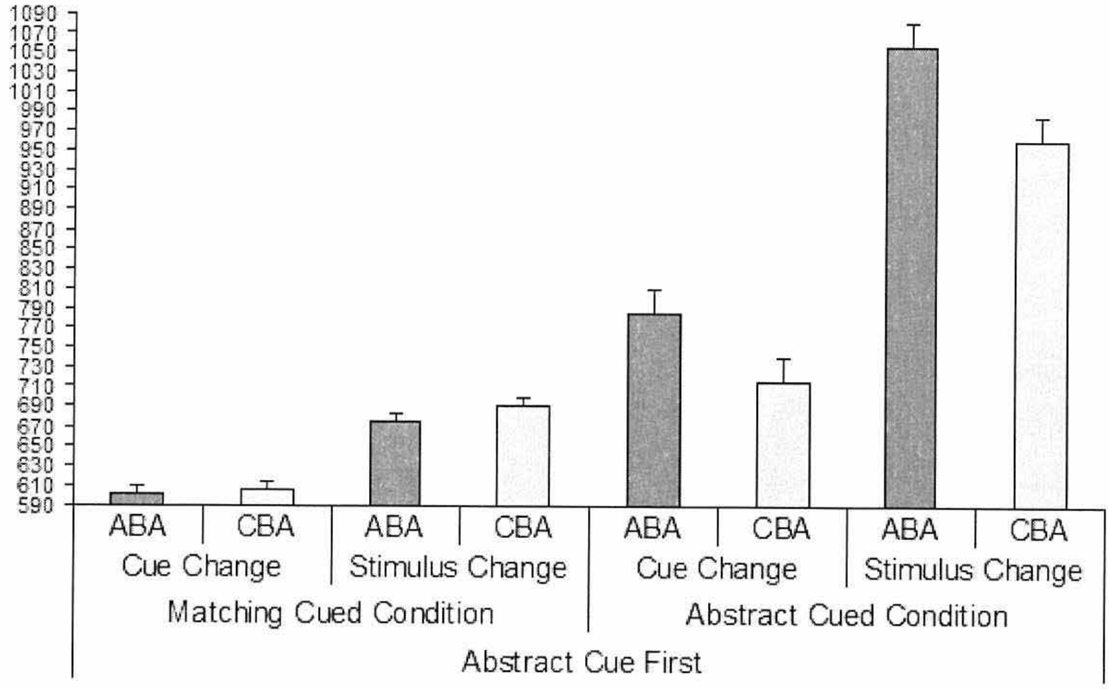


Figure 37: Mean Response Times (ms) for each condition and lag type, for subject who carried out the Matching Cue condition first in Experiment 4. Error bars show the standard error of the mean.

On this occasion when I completed pair wise t tests that compared the ABA and CBA sequences. I found that there was again no significant difference in overall response times in the Matching cued condition, $t(9) = 1.11.$, $p = .295$, although there was now again a significant 83ms (SD = 74.37, SEM = 23.52) cost when doing a trial in the ABA sequence when compared to the CBA sequence, $t(9) = 3.55$, $p = .006$, refer to table 12.

Table 12: Compares the mean response times (ms) for lag and cue type, in subjects who carried out the Abstract condition first.

Abstract cued condition first: Experiment 4, Pair wise t test comparing ABA and CBA sequences.

		Mean Response Time		Difference between ABA and CBA sequences					
Exp No	Condition	ABA	CBA	Mean Time difference	Std. Deviation	Std. Error Mean	T	df	Sig. (2-tailed)
4	Matching Cue	638.84ms	648.94ms	-10.10ms	28.75ms	9.09	-1.111	9	.295
	Abstract Cue	920.53ms	837.14ms	83.39ms	74.37ms	23.52	3.546	9	.006

Summary of results

The above results first and foremost identified that a trial in an ABA sequence, that involves the use of a language cue and has an abstract relationship to the target, takes longer to respond to than a trial that is in a CBA sequence. This does not occur when the target and the cue match each other when there is little to no difference in the response times in the two sequences. What was apparent was that the overall response time was greatly influenced by what condition was completed first, matching or abstract, or whether the cues or stimuli changed between sequences. In relation to the order effect it seemed to speed up overall response time in the second condition completed whether this was the matching or abstract cued conditions. This improvement in response times seemed to be far more apparent in the abstract cued condition when the matching condition was completed first than in the matching cued condition when the abstract condition was completed first, refer to figure 38.

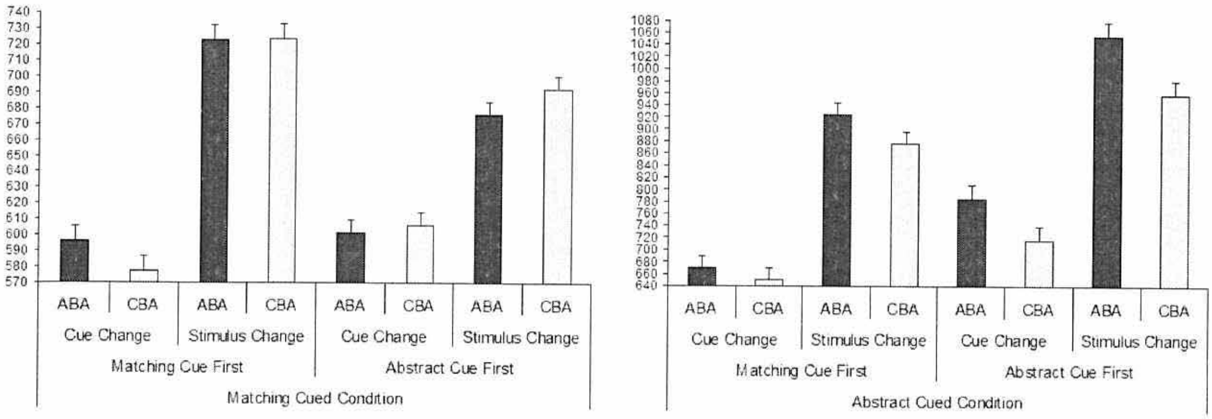


Figure 38: Mean Response Times (ms) for all conditions by lag, by order of condition, in Experiment 4. Error bars show the standard error of the mean.

A main effect that was also noted was dependant on whether the cue changed and the stimuli remained constant, or whether the cue remained constant and the stimuli changed. This was reflected in an increase in overall response times, in both conditions, when the cue remained constant and the stimuli changed. Both of these effects, linked to overall response times, that were affected by the order of conditions, or whether the cue or target changed between conditions, statistically seemed to have little to no effect on the backward inhibition costs. This however was not totally reliable as there did seem to be quadrupling in backward inhibition costs, in the abstractly cued condition, when it was completed prior to the matching cued condition. There was also a backward inhibition cost apparent in the matching cued condition when it was completed first and there was a cue change between sequences. These results did seem to suggest that in certain cases the overall response time may be influencing the backward inhibition costs. But it may also have been linked to the subtle changes in how the cue and target are reacting to each other that may also be influencing the backward inhibition cost. Even so there still seemed to be a suggestion that I may be seeing a two stage model in operation, one which is linked an initial recovery stage, of the correct top down language label, followed by a second stage where the reapplication of the language to a bottom up image occurs.

Experiment 4 Discussion

The above results seem to suggest that, if anything, the methodology we have been using in the previous experiments lessens both overall response times and backward inhibition costs. Contrary to my original hypothesis, the repeat of the same cues in the two conditions did not assist in the recovery of the language label associated with it. The repeat also seems to impede participants' ability to apply the language labels to the cue and target. Mayr and Bryck's (2005) study found that the greatest cost was associated with the repeat of the stimulus position, and directional response linked to the position of that stimulus, combined with a change in rule. Here we see the greatest cost when there is a repeat of the top down label associated with the cue and a change in the target associated with it. Perhaps in the condition where the cue changes between conditions this prepares the brain for a change in task. What could also be occurring is a heightening of the activation of the language label associated with the cue. If this is so, a higher level of inhibition may be needed to remove it by the up and coming language label for the target in the abstract condition.

Another answer for what may be occurring is linked to the model I suggest later in the study. I suggest that when a bottom up image first requires a top down language label to be identified these two separate codes become amalgamated. If this is so, perhaps when the cue is repeated in both condition this relationship becomes more automatic. This may make its level of activation levels higher and subsequently require more inhibiting by the target's different amalgamated code.

The results from this experiment showed that there was no significant difference in the ABA cost, whether there was a change of cue type, or a change in target type between conditions. However, the mean response times do seem to suggest that there is a cost difference linked to difficulty, as there was a doubling in the backward inhibition in the group that had a target change between conditions, in comparison to the group that had a cue change. In the group that had a target change the backward inhibition difference was 61ms in comparison to a 28ms cost in the group that had a cue change. Mayr and Bryck (2005) found in their experiments that if the cue, which represented the goal of the task, changed, but the position of the target and the direction of the response remained the same, this would cause the greatest cost. Bottom up representations of the target's position and the associated response seemed to become linked to the top down top down language representation of the goal of the task. These results would suggest that the bottom up relationship between the two conditions, may be playing some part in the costs we are seeing in the previous experiments, where there is a change of cue between conditions. Although Mayr and Bryck's (2005) experiments used a different methodology to that used here, as they compared switches and repeats of task, their cost may have been linked to an ABA cost that was derived from the previous time that the specific, cue, target position, and appropriate response, were last activated. Mayr and Bryck's (2005) results would have suggested that we should have a greater cost when the cue changes, but the associated targets remain constant, and a much reduced cost when the cue remains constant and the targets change, as the top down language label associated with the target, could be thought of as gluing the bottom up components together. This is not what occurred. These results would suggest that the change in cue between conditions, in the previous experiments, was not affecting the backward inhibition cost although it may have had some influence over the general response times.

Chapter 3 Discussion

Results from both the above experiments seem to suggest that there was inhibition of a top down language label and that cost was linked, not to the recovery of that label, but to its reapplication to the reappearance of its bottom up visual representation. Backward inhibition cost did seem to be linked to an incremental increase in the number of language labels in a trial and not to overall increases in response times. This seemed to be confirmed by the order effect that only improved overall response times in the abstract conditions, if they were done after the more transparent cue-target relationship condition, without it affecting backward inhibition costs. The results also seemed to confirm that we are seeing a two stage model of recovery, then application of the top down language label to the bottom up image.

The question about whether the language label does become amalgamated with the bottom up visual representation was not fully answered by experiment 4. There seems to be a suggestion that this does not occur and that the processes operate separately from each other. The following chapter sets out to examine this question more deeply.

Chapter 4

Two cues to one target

Chapter 4 Abstract

Chapter 4 explores the anomaly that when a trial switches so does the cue and the target. This could mean that we may not be seeing inhibition of a top down language label but the inhibition of the bottom up image of the cue or target. To address this issue, three experiments were run, each with a condition using two cues to one associated target. Experiment 5 used two implicit language cues; experiment 6 used two implicit icon cues, whereas experiment 7 used two abstract icon cues that could have one or two language labels associated to them. Experiment 6 also re-ran the language condition found in experiments 1 and 3. In the two cued conditions, it was hypothesised that if the cues' bottom up features were linked to backward inhibition, the AB'A sequence (cue switches and the target repeats), would be as fast as a CBA sequence in all of the experiments. If it were the language label being inhibited, the ABA (repeat of cue and target) and AB'A (change in cue and repeat of target) sequences would be the same when there was a shared language label for the two cues. Results showed that, in experiment 5, where the cue had a unique language label, the AB'A and CBA sequence had similar responses times which were both faster than the ABA sequence. In experiment 6, where the two cues had a shared common language label, the ABA and AB'A' sequences were similarly more costly than the CBA sequence. Experiment 7 mirrored experiments 5 and 6 results, as when the two cues sheared a common language label the AB'A' sequence was the most costly, and when each cue had its own unique language label the ABA sequence was the most costly. The results suggested it was the top down language label being inhibited and not the bottom up representation of the cue or target.

Chapter Summary

This chapter looks more closely at the question of what we are seeing being inhibited: is it the bottom up visual image of the target or the unique language label associated with it, or could it be an amalgamation of the two of them? Experiments carried out by Logan and Bundesen (2003; 2004) and Schneider and Logan (2005; 2007) have suggested that the cue and the target can be amalgamated into a compound that acts to prime task-set repeats. Although disagreeing with this account, Mayr and Bryck (2005) have also shown how task rules can become amalgamated with the stimulus response map. Taking these experiments into consideration the question I ask in Chapter 4 is are we seeing a similar process going on here? Or are we seeing inhibition of a specific component of the previous trail at lag -2. In the methodology I have used there are four components of the previous trial at lag -2 that can be repeated and one which may change. These are the bottom up representation of the cue and target, the associated top down language label or labels, and finally the position of the target, which can also change. The question of the position of the target I address later in the PhD but the following chapter looks more specifically at the cue, the target, and its associated top down language label. Any one of these three components of a trial may be where the cost is originating from or it could be linked to them being amalgamated into a common code, which is being inhibited. The following chapter tries to address this question by having two different cues associated with one target. This gave me three different lag-2 sequential switches in cue-target relationships: a repeat of cue and target (an ABA sequence), a switch of cue but repeat of target (an AB'A' sequence), and a switch in cue and target (a CBA sequence). Experiment 5 had two implicit language cues to one target which meant that in the AB'A' sequence the language label changed. Experiment 6 had two implicit icon cues to each target, which meant the bottom up image of the cue changed but the language label for the target remained the same in the AB'A' sequence. In Experiment 7 there were two different groups; each had two abstract cues to each target, but one group were taught to associate one language label with two of the cue-target relationships, and the other group were taught to associate one language label with one cue so each cue target relationship had a unique language label. The results of all three experiments differed and this seemed to be linked to the number of language labels used. Backward inhibition was found in both the ABA and AB'A' sequences in experiment 6, and only in the AB'A' sequence in experiment 7, when the cues shared a common language label. Where as there was only backward inhibition found in the ABA sequence, when the cues all had unique language labels, as in experiment 5 and in the two language cued condition in experiment 7. The findings suggested that the bottom up representation of the cue and target are independently inhibited. They also do not seem to be inhibited as part of an amalgamated code with their associated top down language label. Although this amalgamated code cannot be totally excluded. What does seem to be the most likely explanation is that the top down language label is being independently inhibited and backward inhibition is as a consequence of its reapplication?

One of the main problems associated with explicitly cued task switching experiments is that, when a task changes, so too does the cue. This has been perceived by some researchers as a potential confound, with the suggestion that the related cost difference may be linked to the cue change and not necessarily to the task switch (Arrington & Logan, 2004; Logan & Bundesen, 2003, 2004; Logan & Schneider, 2006; Schneider & Logan, 2005, 2007).

Because of the methodology used in this PhD this question is particularly important as not only is the cue repeated at lag-2, in an ABA sequence, so is the target and in 25% of cases so is the position of the response. Therefore backward inhibition costs could be linked to the repeat of the cue, target, or to the position of the response. This chapter concentrates predominantly on the costs linked to a repeat of the cue and target at lag-2, in an ABA sequence, where as the question of the position of the response is addressed latter on in the PhD.

A debate has been ignited by this concern, about what is repeated in previously explicitly cued experiments, with some researchers linking cost differences to exogenous priming when a cue repeats, whereas others see cost differences being linked to endogenous task-set reconfiguration (Arbuthnott, 2005; Gade & Koch, 2005, in press; Hubner, Dreisbach, Haider, & Kluwe, 2003; Koch, Philipp, & Gade, 2006; Mayr, 2002; Mayr & Keele, 2000; Schuch & Koch, 2003).

My experiments so far suggest that we were not seeing any episodic priming; if we were, the ABA sequence would be quicker than the CBA sequence. Cost in a lag-2 repeat sequence does seem to be linked to the inhibition of the top down language label and not to the inhibition of any of the bottom up characteristics associated with the cue or target. However, there are two potential confounding variables in my methodology that make my conclusions unsafe; these are linked to the cue and target. In all the previous experiments in this study, not only is the top down language label repeated from that at lag-2, so too are the cue and targets associated with it. When the target repeats, so too does the cue and target associated with it. This problem however can be partially rectified by using two cues to each target as was done in the past by Logan and Bundesen (2003) and Mayr and Kliegl (2003). In contrast to the present study, they compared task repeats and task switches, which gave three types of sequence: a task and cue repeat, a task repeat and cue change, and a task change and cue change. Even so, by utilising two cues to one target, I hoped to be able to see whether the bottom up image of the cue can become amalgamated with the bottom up language label associated with it. This might also shed some light on why the methodological differences between Logan and Bundesen's (2003) and Mayr and Kliegl's (2003) experiments may have yielded such different results.

The researchers involved in this debate have designed experiments that have used two cues to one task, although this is the only part of their designs that is the same (Altmann, 2007). Cues, targets, cue target intervals, response cue intervals, and frequency of task switches have all been different from each other, and these differences have been linked to why they seem to be getting different results from each other (Altmann 2007; Gade & Koch, in press; Monsell & Mizon, 2006). Except for the experiments of Altmann (2007) and Gade and Koch (in press), which will be discussed in more depth later, experimenters have not used an ABA-CBA comparison, but have used an AABBAABB sequence of tasks.

This type of methodology has given rise to three types of sequential comparison: a repeat in cue and task (AA or BB), a change in cue and repeat in task (A'A or B'B), and a change in cue and change in task (AB or BA). The two main groups of researchers involved in these investigations gained different results from these comparisons. The group that suggested an exogenous compound cue-target priming effect in the AA or BB sequence, found little to no cost difference between an A'A or B'B sequence and the AB or BA sequences which were both equally more costly than the repeat of task sequences (Arrington & Logan, 2004; Logan & Bundesen, 2003, 2004; Logan & Schneider, 2006; Schneider & Logan, 2005, 2007). They also suggested that the differences between their own experiment and the other group's results were linked to the ambiguity of the other group's cues (Logan & Bundesen, 2004). This was because the other group used less explicit cues and had found that the cue and task switching sequences were more costly than the cue switching task repeat sequences, although these sequences were still more costly than the cue and task repeat sequences (Mayr & Kliegl, 2003). They proposed that a mediator was being used to associate the two different cues with the target, and this was what was giving rise to the difference in costs between the cue switch/task repeat sequences and task switch sequences. The mediator is said to be attached to the task; this means that one mediator is given to each task, so on cue switch trials the mediator acts to prime the sequence, and not the cue, as in cue repeat sequences (Altmann, 2007).

Logan and Bundesen's (2003) results could be used to challenge the premise that inhibition is occurring in explicitly cued task switching experiments. They believed that cost was linked to the change in cue as much as the change in task. They tested this by designing a set of experiments that used two cues to one target, and proposed three different models that would test their hypothesis. The first model hypothesised that there was an act of endogenous processing in a task switch and cost was linked to this. Set switching is said only to occur when there is a change in cue, which only happens when the previous cue is different from the present cue; this would also change any potential top down language label associated with the goal. They proposed that if this model was correct, factors that influence cue-encoding, i.e. masking the cue, should not affect task switching times.

In their second model, Logan and Bundesen (2003) propose that explicitly cued experiments have the ability to present enough information on a single trial to enable the appropriate response. They propose that the cue and the target act as a compound that is unique to a specific response. They give as an example of this how the cue Odd-Even and the target 7 map uniquely onto the key 4. Because of this, they suggest that there would be benefit that is specifically linked to repeating the cue, which is part of a stimulus, onto a task repetition. They suggest that top down language label encoding is linked to making a memory comparison between working memory and long term memory. This is pictured as a race, with the rate of comparison to working memory being quicker than to long term memory when the cue repeats itself. It is proposed that the longer a cue is not used, the more requirement there is to access long term memory to retrieve a top down language label. They predicted faster speeds on cue and task repetition trials. This benefit should be more apparent in short CTI than in longer CTI when cue encoding is complete. They predict an "underadditive" interaction between repetitions versus alteration and the masking of the task found in their first two experiments. The mask was believed in this model to affect task repeats, disrupting the cue's representation in working memory, but to have little effect on task switches as the working memory representation of the cue was already different. The mask is supposed to have this effect as the cue's representation is believed to degrade randomly over time in WM and not in LTM; the random masking effect is suggested to be similar to what occurs in WM making task repeats even more troublesome. They hypothesised that model 1, which represented a exogenous process going on would not have an underadditive interaction between repetition and masking, whereas the compound cue-target, model 2, would. They finally had a third model which combined models 1 and 2.

In their first experiment Logan and Bundesen (2003) used three participants who completed the experiment over 16 experimental sessions. They had three cues: High-Low, Digit-Word, and Even-Odd, which could be masked with five pound ("£") signs. The masks changed randomly, with 5 of the 10 characters of the cue being masked at any one time. The targets were either a number or a word representing a number, and the numbers they used were 1,2,3,4,6,7,8, and 9. The time between trials was 500ms (RCI) and the time between the cue and the target appearing went up in increments of 50ms (CTI), starting at 50ms and going up to 950ms, changing randomly. Responses were made on one of six keys that corresponded with one of two answers that the participant could give corresponding with the goal of the task, refer to figure 39.

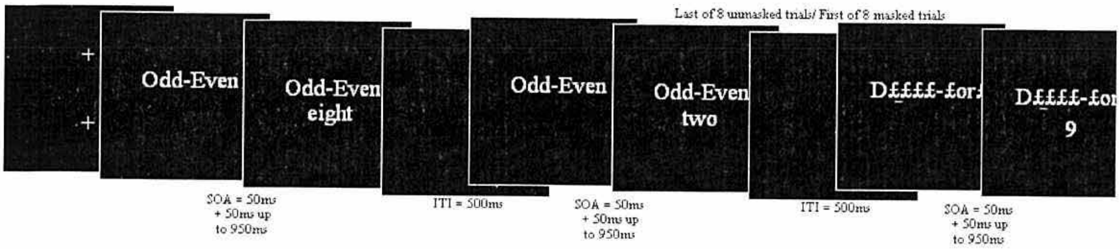


Figure 39: A pictorial representation of Logan and Bundesen's (2003) Experiment 1.

The three tasks were magnitude, parity, and form. Subjects had to differentiate: in the magnitude task whether the number was greater or lesser than 5; in the parity task whether the number was odd or even, and in the form task whether the number was a number or word. After a practice block where they carried out masked and unmasked trials, with differing CTI, subjects moved onto the experimental block. Here they did eight unmasked trials, followed by 8 masked trials, which then continued to alternate every 8 trials. There were 128 repetition trials and 256 alternating trials. Accuracy and speed were improved in unmasked versus masked trials; this was similar in relation to the longer CTI times, in comparison to shorter time periods, and when comparing a repeat to a switch of task. The results showed faster response times (RTs) and greater accuracy on repetition trials than on alteration trials. Masking was similarly slowed with an increase in RTs and poorer accuracy. Short CTI seemed to increase costs and Model 2 was said to best to fit the results.

In their second experiment Logan and Bundesen (2003) were concerned because of the amount of practice and number of experimental trials that participants had, suggesting that this was causing them to treat the cues and targets as compound stimuli. So in experiment 2 there were 32 participants, who completed only one session, using similar cues and targets to those in experiment 1. Half these trials were masked and the other half were not. The CTI went from 100ms to 900ms in increments of 100ms.

Logan and Bundesen's (2003) results for experiment 2 showed that the RT decreased as the CTI increased; RT was faster for cue repetitions than it was for cue alterations, and this difference decreased as the CTI increased. Overall RT was slower when cues were masked, which was particularly obvious at short CTI. There was also an underadditive effect noticed between masking and repetition. This experiment was said to be best fit by model 2 and it was suggested that no switch of set was occurring in this type of explicitly cued experiment. Masking a cue may allow the cue and target to share a similar language label.

In the third experiment Logan and Bundesen (2003) stated that their model 1 proposed that the benefits associated with a cue repetition originate from a saving in set-switch time, whereas model 2 states that these benefits are a consequence of savings made in the cue-encoding time. Model 3 combines the two previous models and predicts that benefits in cue repetitions are a consequence of benefits from both set-switching times, and cue-encoding times.

In this experiment Logan and Bundesen (2003) had two different cues for each task: a "name cue", and a "mapping cue". Therefore, the parity task had the cues Parity or Odd-Even, and the magnitude task had the cues Magnitude or High-Low; there was no form task in this experiment, as only numbers rather than words were used as targets. Responses were different in this experiment as they used the same keys for the two tasks. Numbers 1,2,3,4,6,7,8, and 9, were the target stimuli, and they responded by identifying if the target number was odd or even or higher or lower than 5. Cue words were presented either as pairs that mirrored the position of the correct response keys, i.e. Odd-Even, and High-Low, or as single language labels, Parity or Magnitude. The CTI was varied from 0 to 800ms, in increments of 100ms, refer to figure 40. Their 3 different models predicted three different results. Model 1 was said to assume that the benefits associated with a cue repetition were linked to a repetition in the task set, so a cue alteration when the task repeats, and a cue repetition, should have similar RTs. Model 2 on the other hand would suggest that task repetition benefit was a consequence of faster cue-encoding times, so when there is a change in cue and a repeat of task there should be no benefit in comparison to when there is a cue repeat and task repeat. Model 3 assumes that benefits will occur due to the combination of cue encoding times and task repetition times. Therefore, task repeats where the cue repeats should be the most efficient, unlike task repeats where the cue switches, which should be more costly, but more efficient than when there is a switch in task.

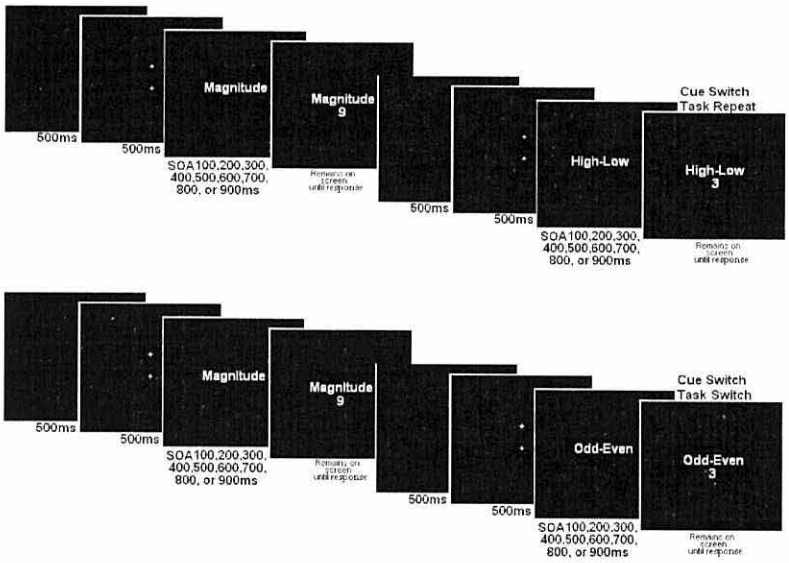


Figure 40: A pictorial representation of Logan and Bundesen's (2003) experiment 3.

The results of Logan and Bundesen's (2003) experiment 3 showed that the difference between cue repetitions and task alterations decreased as the CTI increased. What was important was that model 1 predicted that cue repetitions and task repetitions where the cue repeated should resemble each other, whereas model 2 suggested that task repetitions where the cue changes should be similar to task changes. Model 3 on the other hand predicted that the task repetitions should be the most efficient, and task repetitions where the cue changes should be more costly, but still more efficient when the task changed. Their results best fit model 3, but because of the CTI seeming to affect the task repeat, cue changing, sequence differently to the other two sequence types, i.e. the cost went up as the CTI increased, it was proposed that model 2 could also be mapped onto the findings. Either way their results did seem to show that there was a substantial benefit linked to cue encoding, with the cue repeats being the most efficient, and a smaller but still significant benefit when the task repeated, and the cue changed, when compared to when there was a change in task.

Logan and Bundesen's (2003) fourth experiment replicated Meiran's (1996) experiment but used two different cues. Participants saw a grid that dissected the screen into four quadrants. In one of the quadrants a smiley face would appear in each trial and the objective of the experiment was to either identify if the target was above or below the central horizontal line, or to state if it was to the left or right of the central vertical line. The cues could either be the words Above-Below or Horizontal, or Left-Right or Vertical. The CTIs were the same as in their experiment 3 and the RCI was 1,500ms. Responses were made on one of four keys that mirrored the position of the target, refer to figure 41.

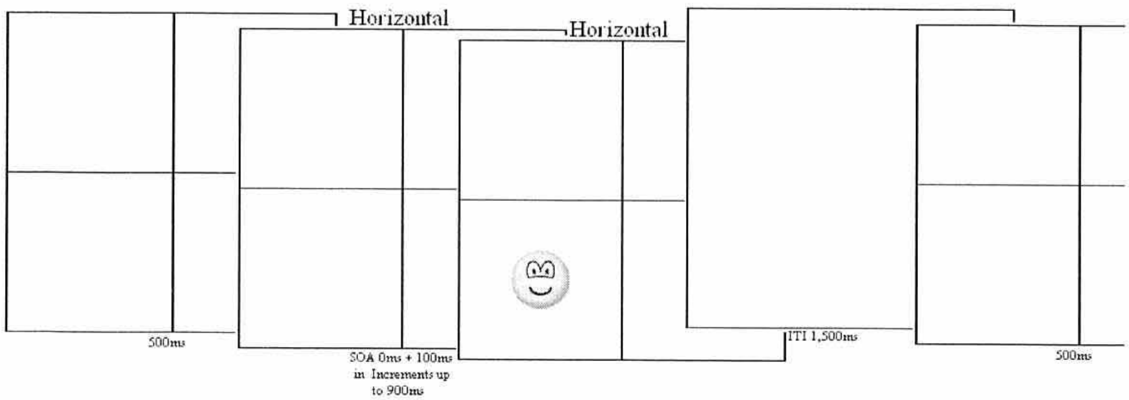


Figure 41: A pictorial representation of Logan and Bundesen's (2003) experiment 4.

The results showed that the RT decreased as the CTI increased; there was also a decrease in the difference between the repetition conditions as the CTI decreased. In this experiment, there was only 14ms difference between a task repeat where the cue changed and a task switch, whereas both of these sequences were substantially slower than a cue repeat sequence, fitting model 2 predictions almost exactly.

In their fifth experiment, Logan and Bundesen (2003) were concerned that the regularity of the same RCI, in the previous experiments, may be having an effect as it created a correlation between the RCI interval time and the appearance of a new target. This could have meant that the costs they were attributing to the CTI were not linked to that, but to the interval before seeing the next target. To address this issue they used a CTI similar to experiment 3, but also varied the RCIs to 250, 500, or 100ms, independently from each other. They again only used two cues, High-Low, or Odd-Even, and used the same number of targets that they had previously used. Responses were mapped onto two keys, which either reflected a high/odd, or low/even decision. The RCI seemed to have little effect, specifically when looking at the two types of task repeating conditions, where there was only a small effect noticed that was linked to task switches.

After these experiments, Logan and Bundesen (2003) concluded that explicitly cued tasks do not necessarily involve an endogenous act of control and suggested that cost is associated with a priming effect linked to the action of a compound cue stimulus. This is said to occur because of the actions of two mechanisms: the residual activation of cues in short term memory and the retrieval of responses from long term memory through the actions of a compound cue-target. Logan and Schneider (2006) also proposed that a mediator can be attached to the cue, and this acts to identify the goal of the task and is similar to an explicit or implicit cue. They suggested two ways in which an abstract cue may operate, presenting an associated strength or mediator retrieval model. The associated strength model assumes that transparent and non transparent cues are directly associated with the task set or task goal. The difference identified in the slower response times when using a non transparent cue is linked to the associated strength between that and the task set, which is less than the transparent cue. This retrieval of task sets is required when tasks switch. The mediator retrieval hypothesis assumes that a non transparent cue is not directly associated with the task set or goal of the task but that a transparent cue is. The transparent cue mediates the way for a non transparent cue, so the mediator has a direct link to the task-set or goal of a task. They tested this by using two different cues in three different experiments. In the first experiment they used transparent language cues, i.e. Odd, Even, High, or Low, in the second they used implicit letter cues, i.e. O, E, H, or L, and in the third experiment there were non transparent letter cues that did not have an immediate association with the language cues, i.e. D, V, G, and W. They proposed that the language cues would show the congruency effects first identified by Schneider and Logan (2005), where the cue could be congruent with the response, Odd-3, or incongruent, Odd-4, and found that incongruent responses were more costly than congruent. Logan and Schneider's (2006) experiment showed similar congruency effects with the transparent, and implicit language cues, but not initially with the non transparent letter cues, although this congruency effect did reappear when half way through the non-transparently cued session they explained the relationship between the letter and the language label to the participants.

They also found that the congruency effect seemed to dissipate with practice in the non transparent cued condition, which may be linked to the association between the letter, and goal of the task becoming more concrete, so the use of the mediator became less important. These results suggested to them that the mediator retrieval model was the most accurate account of how extra cost can be added to overall response times. It also accounted for how Mayr and Kliegl's (2003) results contradicted the above, where repeat of task with a change of cue was less costly than a switch in task but was still more costly than a repeat of cue and task.

Schneider and Logan's (2005) model works through the use of two different mechanisms: firstly, the priming of the cue from cues that are in short term memory, and secondly the compound cue retrieval of the appropriate response category from long term memory, refer to figure 42.

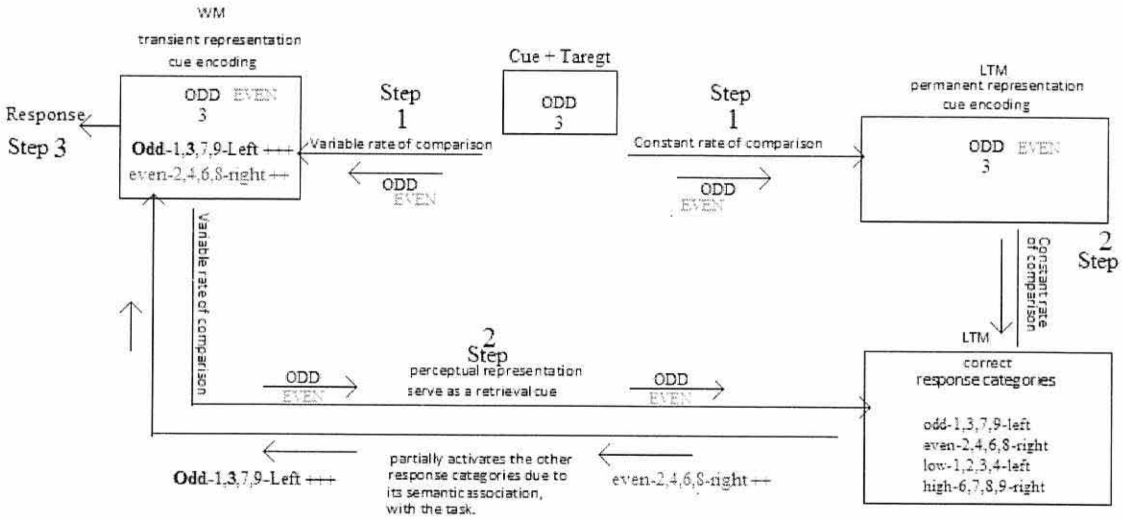


Figure 42: Graphical representation of Schneider and Logan's (2005) model.

Schneider and Logan (2005) suggest that a cue needs to be encoded with a top down language label in WM prior to it being able to retrieve responses from LTM. This encoding begins as a race between its transient representation in WM and its permanent representation in LTM; cue encoding time is linked to which process completes this first. The speed of encoding in working memory is based on how long ago that cue was last seen, whereas the encoding in LTM is fairly constant. Once the encoding of the cue is complete, its perceptual representation is said to serve as a retrieval cue for the correct response in LTM. The cue is said to be able to be associated with a variety of correct responses; for example if the cue was the word “Odd-Even” then it would highly be associated with odd numbers and the appropriate response. It would also have a lesser but still more active association with the word ‘even’ and the numbers associated with its correct response, but little-to-no responses linked to the words high or low. It also assumes that the cue that is presented becomes the most active cue in working memory, and also as a consequence of the retrieval of the correct responses from LTM, partially activates the other response categories associated with it, due to its top down language association with the task. It is also assumed that the activation of a cue’s representation dissipates between trials; when the presented cue is the same as the previous trial’s cue, this increases the speed of retrieval of correct response from LTM. It is the residual activation of a previous trial’s cue that determines the speed of the retrieval of the correct response categories associated with the cue. This priming effect, linked to the speeded retrieval by the working memory of the response categories from LTM when there is a repeat of cue, is made even more effective if the target is directly linked to the cue’s response category, making retrieval of the specific response even more efficient.

Mayr and Kliegl (2003) disagree with this and suggest that cost is linked to the simple retrieval of an appropriate response from LTM, which is linked to a compound cue-target. They suggest that cost is a consequence of firstly a cue driven retrieval of a previously inhibited task set from long term memory, that is then placed into working memory, combined with a secondary stage of an automatic application of rules to a specific stimulus. Mayr and Kliegl (2003) believed this because they had found that a large proportion of costs were linked to a switch in cue, which was sensitive to practice and preparation effects. Unlike Logan and Bundesen (2003), there was an extra cost linked to a switch in task, which was not affected by practice or preparation time. Task switch costs, unlike cue switch costs, were also found to be sensitive to response-priming and task-set inhibition.

Mayr and Kliegl's (2003) findings caused them to hypothesise a different model based on the following experiments. Their first experiment used two different tasks: identify the colour or shape of a target object. The targets were either a triangle, square, or circle, which could be green, red, or blue. The letters G and S signified colour, with B and W identifying the shape task. Responses were recorded on three separate keys which had both a shape and colour mapped onto them. Participants could not move onto another trial until a correct response was made. A letter cue was presented above the target frame prior to the target's arrival and remained on the screen until the correct response was made, refer to figure 43.

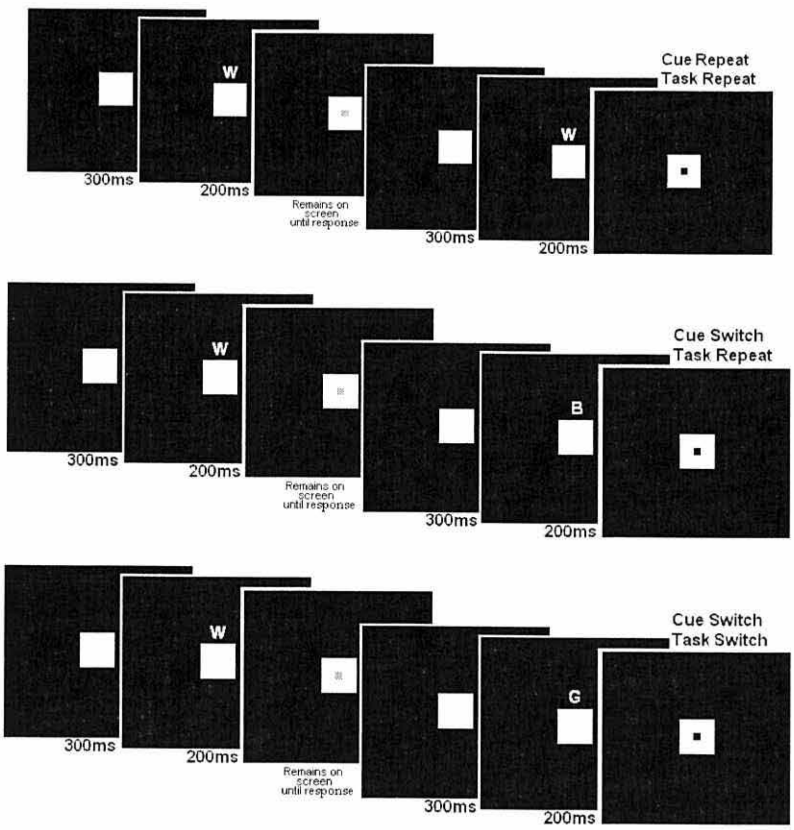


Figure 43: Graphical representation of Mayr and Kliegl's (2003) first experiment.

In their first experiment, Mayr and Kliegl (2003) found considerable costs when the task repeated but the cue changed. This they believed was linked to the cost of retrieving the new task-set from LTM and placing it in WM. The extra cost between a cue switch cost and the larger task switch cost was attributed to the application response stage. Response repetition benefits were also apparent in the cue change sequence but were reversed in the task switch sequences. This suggested to them that there was an independent representation of a task-set that was separate from the recovery stage, which is supposed to reflect how task rules are applied to a specific stimulus. Therefore, they propose that the response costs are linked to a secondary process to that of task-set retrieval. The cue switch cost was also affected by practice, but not the task switch cost. This they proposed backed up their two stage model, as the cues and responses would become more associated with each other with practice and make recovery from LTM more efficient.

In their second experiment Mayr and Kliegl (2003) hypothesised that the cue stimulus interval (CSI) should affect cue switching costs, if it is linked to the recovery of the task set from LTM, whereas the task switch cost (TSC) should not be affected. To test this they altered the CSI and response cue interval (RCI), into three separate conditions that could have the following CSI and RCI, 200ms and 1300ms, 200ms and 200ms, or 1300ms and 200ms. These conditions ran consecutively after each other in blocks and were counterbalanced for the order in which they were presented across participants. Their results were as predicted in the cue switching sequences: when there was a large CSI, cost was removed completely when the response changed, and substantially reduced when there was a repeat of response, although the task switching cost was not reduced. The RCI had little effect on either of the cue switching sequence types. They again showed that response priming was noticed in the task switching sequences when the response position was repeated, whereas the reversed occurred in the cue switching sequence. This again suggested to them that the stimulus response stage was separate from the first stage where the task set is retrieved. They also hypothesised that the priming effects noticed in the cue repeating sequences may be linked to some sort of integration between the cue-related and stimulus response representation.

Mayr and Kliegl's (2003) third experiment specifically looked at costs associated with an ABA sequence. This was because there were two accounts of inhibition, which linked it either to the cue encoding and task retrieval stage, or to the stimulus response application stage. My results so far would suggest that some of this cost may very well be linked to cue encoding stage.

The third experiment carried out by Mayr and Kliegl (2003) therefore had three different tasks, each of which were cued by two different letters. The tasks were judgements about colour (red or blue), shape (circle or square) or size (large or small). The cues were D and R for colour, M and V for shape, and T and K for size, refer to figure 44.

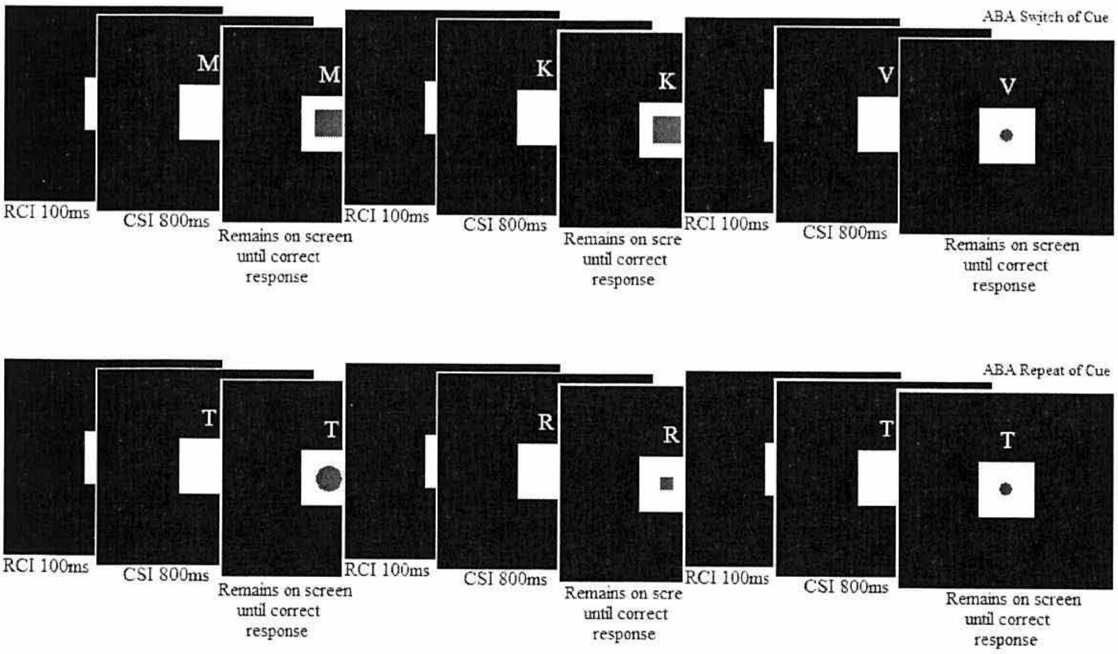


Figure 44: Graphical representation of Mayr and Kliegl's (2003) third experiment.

Mayr and Kliegl's (2003) results suggested that the inhibition was linked to the task-set application stage, due to there being an absence of cost when there was an ABA sequence when the cue repeated itself. They suggested that an ABA cost was actually present when the cue repeated itself but was absent because of the priming effect of the cue. Further statistical analyses did seem to confirm that an ABA cost was occurring in the ABA sequence where the cue repeated itself, but was not noticeable in the overall response times. They suggested that backward inhibition is not tied to the retrieval of the task set but is more likely to be linked to representation associated with the task set application.

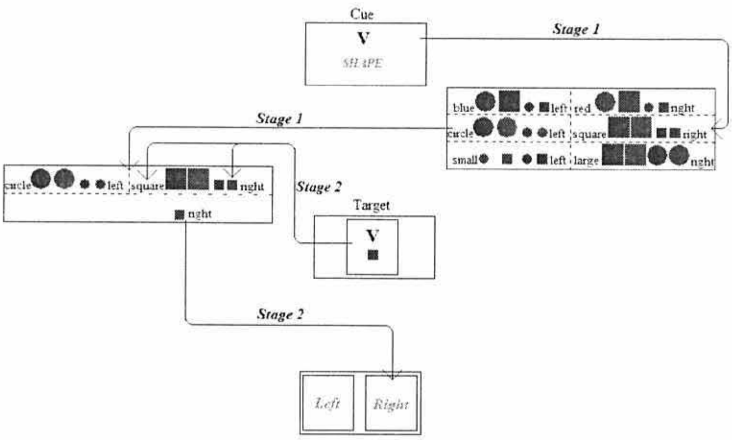


Figure 45: Graphical representation of Mayr and Kliegl's (2003) model.

The stages of the model were explained as follows. Firstly, on the presentation of the cue the relevant task set rules are retrieved from LTM. Costs which were linked to a repeat of cue, when compared to a change in cue and repeat of task, were said to be linked to this process. In the second stage, the retrieved task rules that are in WM are applied to the target stimulus when it appears. Cost differences linked to comparing sequences where the cues and task switched in comparison to where the cues switched and the task remained constant, refer to figure 45. Because much of the cost that was seen in their first two experiments was linked to a change in cue rather than a change in task, it was suggested that much of the cost seen in explicitly cued task switching experiments, where they compare AABBAABB sequences, is not linked to the time taken to reconfigure the cognitive system. Rather it is the time required to remove the appropriate task set from LTM and for it then to be placed into WM. They also identified a 100ms cost linked to repeating the same response when the cue changes. This they hypothesised may be linked to the cue, target, and response in the previous trial, having a comparatively rigid relationship with each other. They believed that this required additional time to that which was required for retrieving the correct stimulus-response map from the task category that was in working memory. Mayr and Kliegl (2003) conclude that inhibition originates in the configuration stage and not the retrieval stage. If this is the case, then surely the process of configuration that occurs in working memory operates on the level of amalgamating the cue, target, and appropriate response into an understandable representation that can be acted upon. The results in the experiments in my study so far would seem to suggest that they are correct, but unlike them I believe it is the top down language label that is being retrieved from working memory. We see that response times can improve in the second condition completed, suggesting that the retrieval of the top down language label from working memory from LTM is more efficient. But this improvement in overall response times seems to have little effect on the lag-2 costs that we see, where I believe this label is applied to the bottom up visual representation of the target in working memory. My study suggests that we are first seeing a retrieval stage where the top down language label is retrieved from LTM memory. This label is then taken to working memory (where the previous bottom up images are gradually dissipating, as they are not inhibited), and applied to the appropriate target. In a lag-2 repeat trial (ABA), this top down language label is still more inhibited than it would be in a lag-2 non repeat sequence (CBA), so takes longer to be applied to the target.

The question of the cue

Monsell and Mizon (2006) completed a set of interesting experiments that looked specifically at the effect of the cue on costs associated with a task switch. In their first experiment they used a "Stroop-like" pairing of tasks, with an arrow that could face right or left, which contained a the word, "Right" or "Left". The word and the arrow could be congruent or incongruent with each other. The cues were four different sounds; two sounds required participants to respond to the arrow's direction and the other two sounds required a response in the direction that the word stated. Reponses were made either to a right or left positioned key, refer to figures 46, 47, and 48. This experiment found very similar results to those of Logan and Bundesen (2003) where there seemed to be an advantage gained by a repeat of cue, as the cost in a switch in task and a switch in cue were comparatively similar.

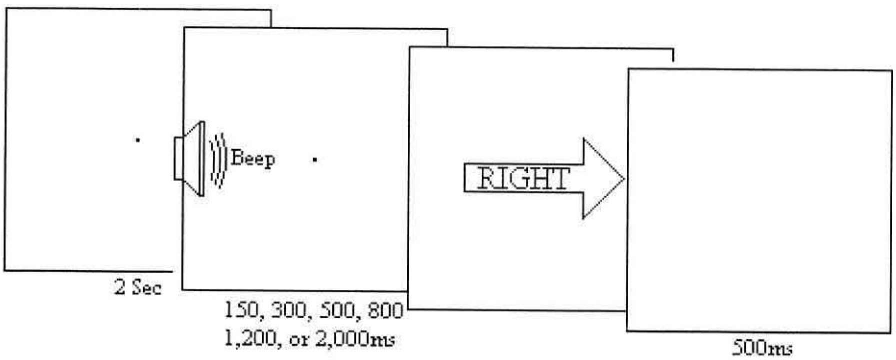


Figure 46: Experiment 1 of Monsell and Mizon (2006), sequence of switch

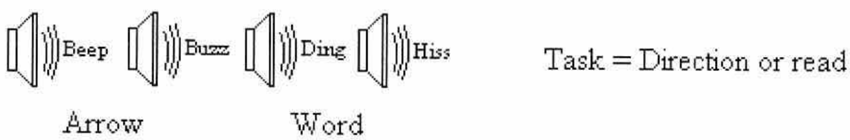


Figure 47: Experiment 1 of Monsell and Mizon (2006), cues for task.

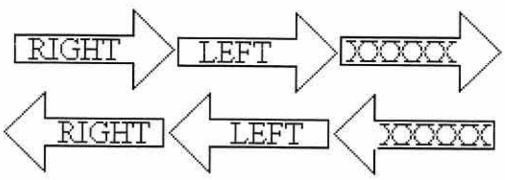


Figure 48: Experiment 1 of Monsell and Mizon (2006), targets for task.

In Monsell and Mizon's (2006) second experiment, participants were asked to either report the number of syllables (one or two) of a word, or state whether the word represented an object which was larger or smaller than a football. The position of the cue, which was in one of four locations on the screen, determined what task participants were required to carry out. The results of experiment 2, unlike those of experiment 1, replicated Mayr and Kliegl's (2003) results, with a cue switch and the task repeat having a similar response time and a task switch being equally as costly when compared to these two types of sequences, refer to figures 49 and 50.

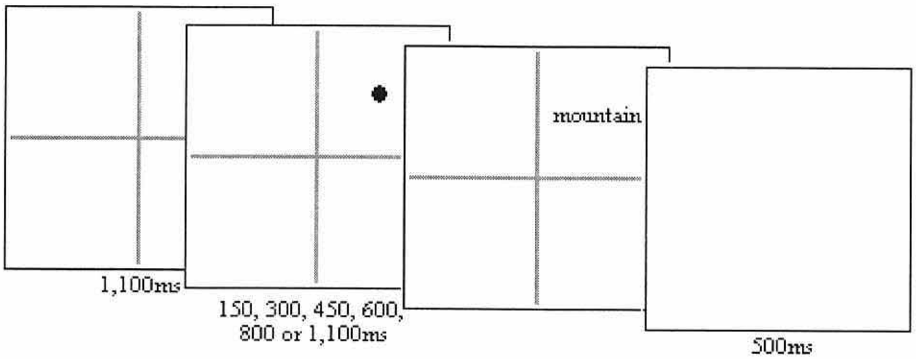


Figure 49: Experiment 2 of Monsell and Mizon (2006), sequence of switch

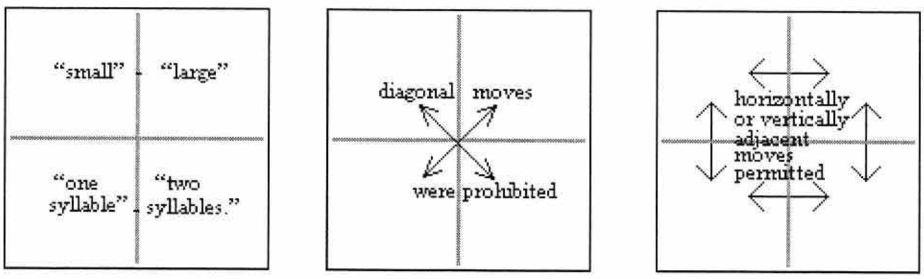


Figure 50: Experiment 2 of Monsell and Mizon (2006), example of meanings that location cues had, showing disallowed and permitted directional moves cues from trial to trial.

Monsell and Mizon's (2006) third experiment tackled a concern they had about their second experiment. This was that critics may state that participants were not using all four quadrants of the screen as separate cues, and were simply dividing the screen into two, so that a cue change did not truly represent a change in cue but a repeat of cue. To do this they used four visual icon cues; refer to figures 51 and 52. The objective of the experiment remained the same as in experiment 2. The results of this experiment mirrored those of Mayr and Kliegl's (2003) initial experiment even more closely, with the most costly sequence being a switch in task, then a repeat in task but a switch in cue, and the least costly was a repeat in task and cue.

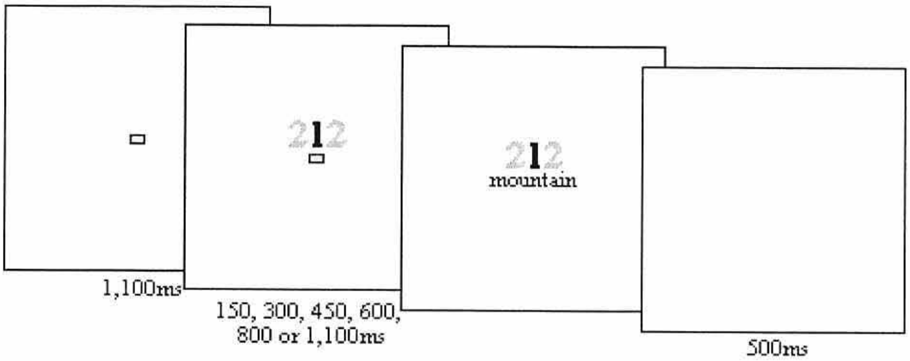


Figure 51: Experiment 3 of Monsell and Mizon (2006), sequence of switch

Figure 52: Experiment 3 of Monsell and Mizon (2006), visual icon cues.

In the last experiment Monsell and Mizon (2006) highlighted their concerns about the probability of a task switch in a sequence of switches and repeats of task, as they believed this may influence cost. They highlighted that in the Logan and Bundesen (2003) experiments, the overall probability of a task switch was 0.5, whereas the probability of a cue plus task change was 0.67. This was different to the Mayr and Kliegl (2003) experiment; here probability for all types of sequence was 0.33. It was suggested that participants may begin to prepare for a switch in task prior to the arrival or after a cue has been presented. This would mean they would be fully prepared for a switch in task on the arrival of a new cue, so hiding any effect linked to the cue specifically and making a cue switch look very much like a task switch. To tackle this issue, they designed an experiment that used two language cues and two visual icon cues. The tasks were either to identify the colour of a target or to classify its shape, refer figures 53 and 54.

Figure 53: Monsell and Mizon's (2006) experiments, language and shape cues

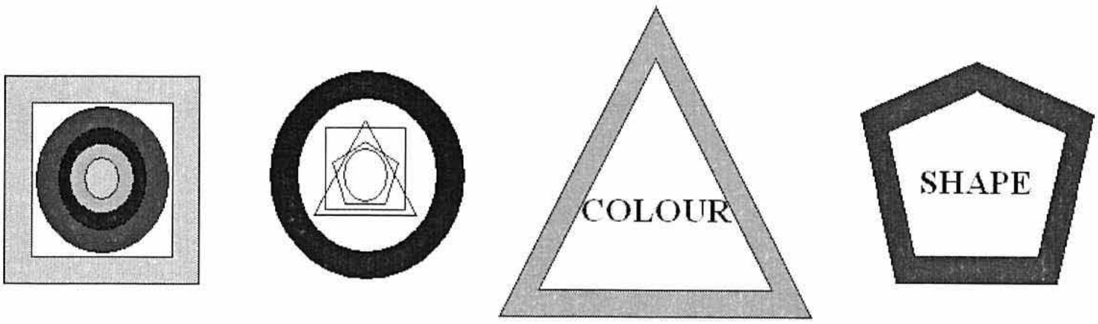


Figure 54: Monsell and Mizon's (2006) experiments, examples of how cues and targets may look together

In experiment 4 (Monsell & Mizon, 2006), the cue changed each trial from an icon to a language cue; there was a CSI of 140ms and 790ms. There was also a 25%, 59%, or 75% chance of a task change which was manipulated between participants. The two primary purposes of this experiment were to look at how the probability of a switch cost affected the cost of a switch in task. Secondly, the CSI was used as a measure of endogenous preparation, which should reduce the cost of a switch in task at longer intervals (RISC).

In the 25% group, there was a substantial switch cost; the RISC was also affected, with a longer CSI dramatically reducing cost in comparison to the shorter CSI. In the 50% probability group, there was a similar effect linked to CSI but the difference between the small and long intervals was reduced. The 75% probability group had little to no difference between the CSI times; if anything the longer time increased overall response time. Therefore, the greater the probability of a task switch, the more attenuated the costs associated with a switch in task became, similarly decreasing the RISC effect to nothing in the 75% probability group. These results did suggest that when participants are unprepared for a switch in task, they are less likely to pre-prepare for that switch prior to the arrival of the cue. This is reflected in the evidence of an endogenous preparation for an up and coming task, as a longer CSI seems to reduce the cost associated with a task switch. This effect is not apparent in the 75% probability group, as they are believed to have prepared for the switch in task prior to the arrival of the cue, so the CSI has little effect on the costs associated with the switch in task.

Monsell and Mizon's (2006) final experiment almost replicated Logan and Bundesen's (2003) experiment, with one subtle difference. When the probability of a switch in task was reduced, this seemed to alter the results so that they now mirrored Mayr and Kliegl's (2003) results. The repeat in task remained the most efficient, with the switch in cue and repeat in task being significantly more costly, but still significantly less costly than the switch in task. A high probability of a switch in task, as found in the Logan and Bundesen (2003) experiments, seemed to have caused participants to prepare for a switch in task prior to the arrival of the cue. This meant that when a cue changed and the task repeated, the participant who was already prepared for a switch in task would have to reverse gear, which added to the smaller cost associated with a switch in cue and repeat of task. This added cost in the cue switch task repeat sequences, causing them to have similar costs that we see in a task switch. When this reconfiguration cost, linked to reversing the preparation for a change in task back to a repeat of task, was removed, cost associated with a switch in cue but repeat of task was reduced from that associated with a switch in task. The cost that was now apparent, when compared with the repeat of cue and task, was said to similarly reflect costs linked to the reconfiguration of the new cue with the appropriate stimulus response map in working memory.

As previously mentioned, Gade and Koch (in press) also carried out a similar experiment to Mayr and Kliegl (2003) but specifically looked at the ABA sequential costs. They again had three different tasks linked to identifying the size (large or small), colour (blue or red), or form (letter or number) of a target letter "A" or number "4". Cues for colour could either be a green or yellow square, arrows or arrow heads pointing up or down, which signified the size task, and a dollar or percentage sign that identified the form task , refer to figure 55. They completed two experiments one of which altered the CTI while the other did not.

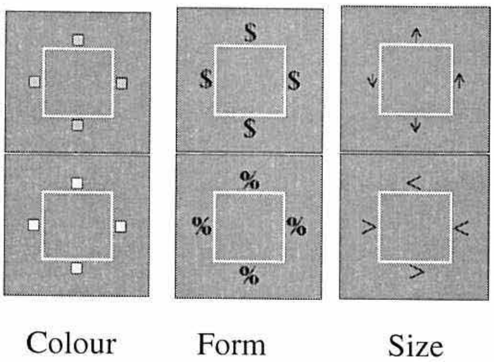
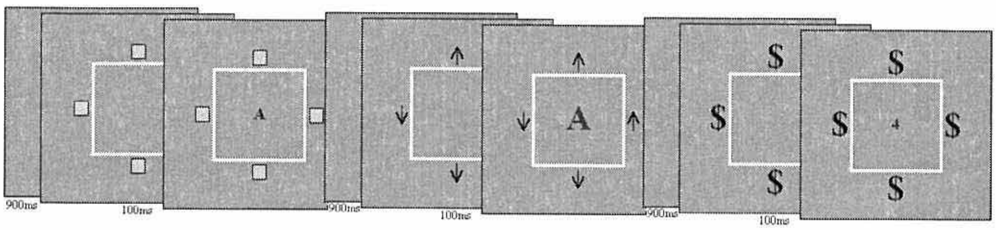
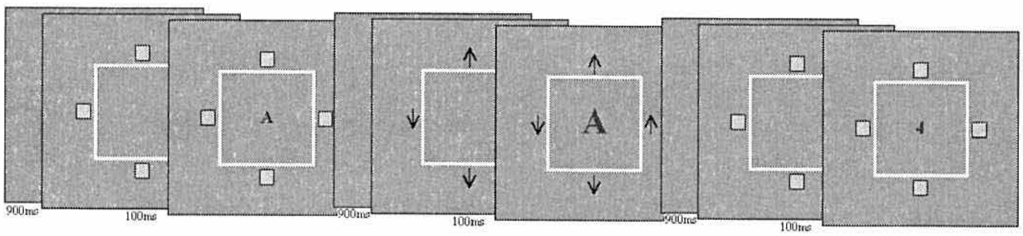


Figure 55: Cues used to identify task in Gade and Koch (in press).

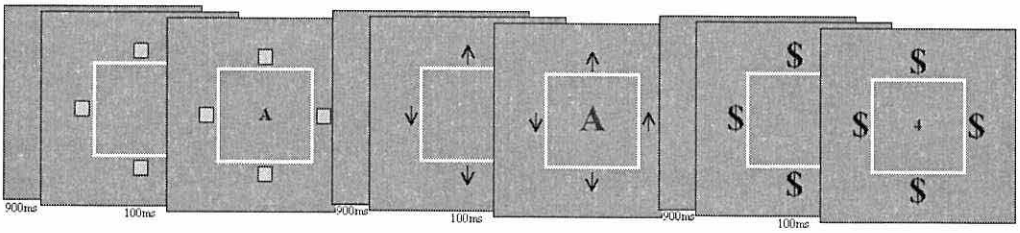
Responses were registered on keys that signified left or right. This gave three different types of sequences: a CBA, an ABA repeat of cue, and an ABA non repeat of cue sequence, refer to figure 56.



CBA sequence



ABA repeat of cue sequence



ABA non-repeat of sequence

Figure 56: Task switching sequences in Gade and Koch (in press).

Gade and Koch's (in press) results, like Mayr and Kliegl's (2003) results, showed an ABA cost in the cue switching sequence, but unlike Mayr and Kliegl (2003), they also saw it in the ABA repeat of cue sequence in the RTs. They did not find that CTI had any effect on the ABA cost, and there was little difference between the cue repeat, and cue non repeat sequences. They also identified a higher level of errors being made in the cue repeat sequence in their second experiment where CTIs were altered, which counteracted the cue priming hypothesis. These results suggested to Gade and Koch (in press) that the cue target relationship has little to do with the costs associated with an ABA sequence. They hypothesised that cost may be originating as a consequence of task processing and not cue processing. Inhibition, they believe, acts on the task set. They now seem to believe that inhibition of a task's target response processes are linked to backward inhibition costs, not the cue target relationships.

I believe that these differing results leave the question about where costs originate still open to enquiry. I would suggest that the whereabouts of the origins of the backward inhibition costs are dependant on where a top down language label is required to be applied to a bottom up image or response. My findings seem to suggest that there is interplay between the target and the cue's previous visual and top down language labels, and that inhibition acts to suppress a previous top down language label in the cue which is different to the top down language label representing the target. This effect noticed between the cue and target may however similarly affect the response if its top down language or visual label is different to the target. Cost may be linked to where research is targeted, as methodological influences may highlight certain parts of the sequence more specifically, i.e. cue-target relationships, or target response relationships. I hope in the next and final experimental chapter to explore this question in more depth, as some of the post hoc tests I completed on repeat and non-repeat of response position appear to shed more light into this area.

Altmann (2007) proposed that the above compound cue model explains switch costs in terms of cue switches and not task switches and investigated whether this model can also be superimposed onto the ABA methodology. To test this, Altman used a run based design which meant that the cue would appear prior to a run of trials which required the same choice to be made about the target's features. It was said to separate costs linked to the switch in cue and task from those related to the target and response to that target. The tasks were to identify the colour, parity, or magnitude of the target, and the language cues to these tasks were Colour or Red Blue, Parity or Odd Even, and Magnitude or High Low, respectively. Targets were the numbers 1,2,3,4,6,7,8, and 9, which were coloured red or blue. Participants responded by pressing one of two keys. Run lengths were from 2 to 19 trials and averaged at 4 trials, refer to figure 57.

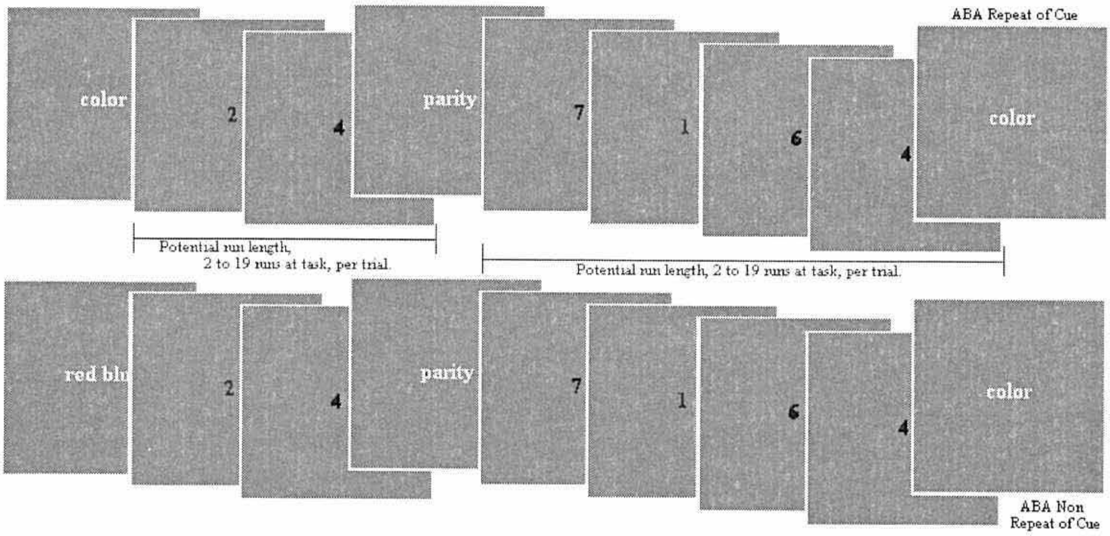


Figure 57: Graphical representation of Altmann's (2007) experiment.

Altmann's (2007) findings showed that costs were similar for the AB'A' and ABA sequence in comparison to the CBA sequence. What was also important to him was that the use of a mediator, in his opinion, could have explained the costs found in Mayr and Kliegl's (2003) experiments. This he believed could not occur in his experiments as the cues were said to have a transparency that did not require the use of a mediator. He suggested that lag-2 costs are linked to a multitude of processes. What was interesting in the results was that lag-2 costs only affected the first stimulus response mapping in the run. This suggested that the cost was linked to the involvement of the cue with the target and response. The costs only seemed to occur on the first trial of a run and suggested to Altman that costs are linked to a top down language process related to the cue, but independent from the bottom up effects of the cue, target and response. As discussed later in this present study, my results seem to agree with this. With the bottom up image and response not being inhibited and its associated language label being inhibited. Altmann also proposed that this may be linked to processes that are concerned with encoding of the relevant dimensions linked to the target and appropriate response. They like Gade and Koch (2005) found that costs depreciated as the distance lengthened between the initial response to the target and the reappearance of the next task cue. But unlike Gade and Koch (2005), it was suggested by Altman (2007) that inhibition immediately dissipated after the first response.

Rationale behind the following experiments

The experiments described above suggest that we are seeing costs that originate from two different systems using two different types of mechanism. Logan and Bundesen (2003) suggested they were seeing costs linked to the priming effect of a compound cue-target that was accessing long term memory, via working memory, more efficiently. Mayr and Kliegl (2003), like Logan and Bundesen (2003), also suggested that LTM needed to be accessed to retrieve a new task set, which was then placed into working memory. But unlike Logan and Bundesen (2003), they suggested this accessing of LTM was always completed first on the arrival of the cue. They agreed that a substantial proportion of the cost was linked to a change in cue, in explicitly cued experiments, but Mayr and Kliegl (2003) proposed that there were different costs which were linked to a switch of cue when the task repeated. Mayr and Kliegl (2003) suggested that there was a separate lesser cost that was specifically linked to a change in cue, and this was as a consequence of a mechanism in working memory that was reconfiguring the relationship between the new cue and target in relation to the repeated task category.

Monsell and Mizon's (2006) experiment seemed to suggest that Mayr and Kliegl's (2003) two stage mechanism was correct, with the largest cost originating as a consequence of retrieving a new task set from long term memory when a task changed. There was, however, a smaller cost linked to the reconfiguration of a new cue, with a similar response category that had just been repeated in the sequence, which occurred in working memory. Monsell and Mizon (2006) concluded that the reason why Logan and Bundesen (2003) had not seen this was linked to the high probability they had of a task switch, in comparison to Mayr and Kliegl's (2003) experiment. It seemed as if when there was high probability, participants would prepare in advance of the cue for a switch in task. This meant when a cue changed but there was a repeat of task, the participant was actually ready for a switch, so had to spend time reconfiguring the system to repeat the task. This added extra time onto the process of switching cue and repeating task so that this cost looked similar to the cost associated with a switch in task.

Altmann's (2007) experiment seems to suggest that Logan and Bundesen's (2003) compound cue-target model is not easily transferable into understanding the cost found in an ABA sequence. If it were, they proposed that an ABA sequence would be equally costly when compared to both an AB'A' and CBA sequence. This they did not find, as the AB'A' and ABA sequences were equally as costly when compared to a CBA sequence. This suggested that costs in an ABA sequence are linked to a mechanism in working memory that reconfigures the relationship between the elements that make up the task set category and the appropriate stimulus response map.

How this reconfiguration is occurring is open to debate. Mayr and Kliegl (2003) propose it is concerned with the new cue and stimulus reconfiguring, so that the correct stimulus response map can be extracted from the task set category. Gade and Koch (in press) disagree with this, and believe that the cue has little to do with the reconfiguration cost, and that cost is associated with the application stage, but is specifically linked to the relationship between the target and response. Altmann (2007) concludes that the top down language label for the bottom up visual image held in the cue may be linked to where the cost may originate.

The mechanisms that have appeared to be present in the previous experiments of the present study do seem to suggest that all of the above researchers could be correct. Both the top down language and visual representations of the cue and target seem to come into play. The response element associated with this will be discussed in the next chapter, along with consideration of post hoc tests that were linked to the target repeating and not repeating its position in the ABA sequence.

This chapter aims to shed more light into this area when using two cues to one target. I continue to use the same methodology as I have used previously, in order to maintain continuity between the experimental results.

Experiment 5 – Two language cues to one icon target

Considering all the issues raised above, and that in each trial of my own experiments the cue, target, and any associated top down label are all repeated in a lag-2 sequence, I cannot be sure that only the top down label is being inhibited in an ABA sequence. By using two cues to one target, some of these anomalies can be overcome as there would be a repeat of the target at lag-2 but a change in the bottom up language cue and the top down language label. Experiment 5 was designed to see if we could replicate the costs found in the above experiments that had used two cues to one target when comparing ABA, AB'A', and CBA sequences. It involved one condition that used two verbally implicit language cues; they were lexically different but shared a similar meaning. This created a change in both the bottom up characteristics and top down label associated with the cue in an AB'A' sequence; in the ABA sequence all three potential components repeated themselves.

Taking this into consideration and based on the episodic priming argument where the cue, target, and any language label become amalgamated into one set snap shot, the AB'A' sequence should take longer than the ABA sequence. This is because there will be fewer elements of the previous snapshot available to prime the repeat of what was at lag-2. If the elements of the cue are inhibited, the ABA sequence should take longer than the AB'A' sequence as the cue at lag-2 in an AB'A' sequence will have been inhibited prior to lag-2, so will have had more time to reactivate. I also decided to double the number of trials to see if any practice effect would be apparent, as these findings were not conclusive in experiment 2.

Experiment 5 Method

Participants

Twenty five participants were gathered from the same experimental pool as for the previous experiments, and were similarly rewarded.

Apparatus & Stimuli

The design of the following experiment and procedure was the same as the language condition in experiment 1, expect that there was also a second language cue given to each target. These were, Border or Outline, Shaded or Filled, and Angled or Slanted. There was also a second block of 126 trials that was completed after the first block.

Experiment 5 Results

Trimming of the data was carried out using the same criteria as previous experiments; this meant that only one participant was removed for making more than 10% of errors.

Error analysis

Error trimming was completed as in the previous experiments. One participant out of an original 25 was removed due to making more than 10% of errors.

Error Analyses

A mixed ANOVA comparing lag type x3 (ABA, AB'A', or CBA sequence) by block type (first or second block of 126 trials) was completed. Error analysis showed no lag affect, or interactions, but did show a main effect of practice, $F(1,24)=8.39$, $p=.008$. A paired t test comparing the first or second block with the ABA and CBA sequences collapsed into each other, showed a significant 2.03(SD = 3.51, SEM = 0.70) increase in the number of errors in the first block, $t(24)=2.9$, $p=.009$.

Response Time Analyses

In experiment 5 I initially completed a 2x2 ANOVA, which had both types of ABA sequences collapsed into each other, comparing Lag Type (ABA or CBA sequence), by Block Type (first or second block of trials). There was no main effect of block type, $F(1, 23) = 1.72$, $p = .202$, although there was a suggestion of an underlying trend in the lag type that was not significant, $F(1, 23) = 3.00$, $p = .097$, there was also no interaction identified. A post hoc pair wise t test comparing the ABA and CBA sequences in both blocks showed no significant effects, there was however an underlying trend that suggested that a backward inhibition cost was developing in the second block of the experiment. This was because there was only a 6ms (SD = 45.46, SEM = 9.28) cost in the ABA sequence in the first block, t(23) = .633, p = .533, and a 15ms (SD = 53.14, p = 10.85) cost in the second block, t(23) = 1.35, p = .190, although this was not significant, refer to table 13 and figure 58.

Table.13: A comparison of the mean Response Times (ms) for lag type and order, in the Two Language Cues condition in Experiment 5.

Experiment 5, Pair wise t test comparing ABA and CBA sequences.

Two Language Cues Experiment		Mean Response Time		Difference between ABA and CBA sequences					
Exp No	Condition First block and second blocks	ABA	CBA	Mean Time difference	Std. Deviation	Std. Error Mean	t value	df	Sig. (2-tailed)
5	First Block ABA-CBA	685.49ms	679.62ms	5.87ms	45.46	9.28	.633	23	.533
	Second Block ABA-CBA	676.08ms	661.42ms	14.66ms	53.14	10.85	1.351	23	.190

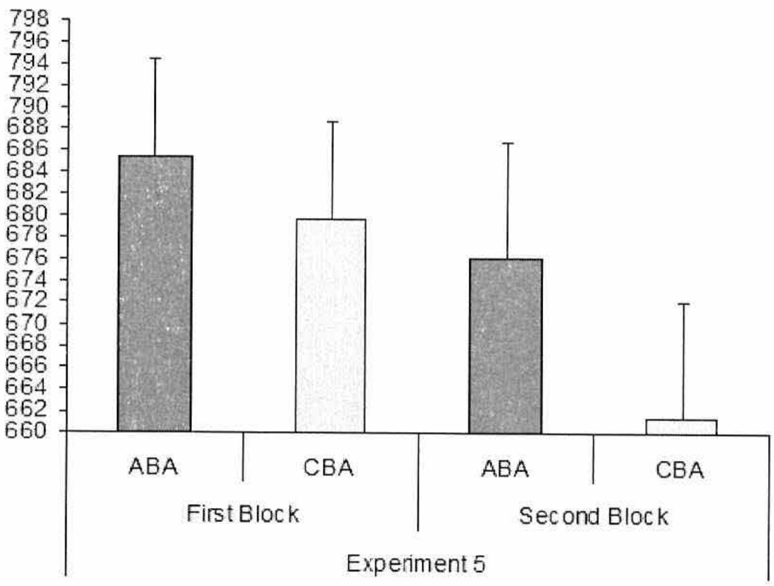


Figure 58: Mean Response Times (ms) for lag type and order in Experiment 5. Error bars show the standard error of the mean.

I then completed a 3x2 ANOVA, that split the ABA sequences into two sequences, one that repeated the cue type (ABA) and another that changed the cue to the one that was used at lag -2 (AB'A'), comparing Lag type (ABA, AB'A', or CBA) by Block Type (First or second block completed). There were again no significant effects or interactions identified. Because of this I separated the two blocks and ran post hoc t tests on them individually to see if there were any underlying trends that were being missed. These results did seem to show some underlying trends that were not picked up by the initial analysis. In the first block there were no significant effects identified with the ABA sequence only being 0.83ms (SD = 60.56, SEM = 12.36) faster than the AB'A' sequence, t(23) = -.067, p = .947, and 5ms (SD = 60.81, SEM = 12.41) slower than the CBA sequence, t(23) = .440, p = .664. Evidently this similarly only made the AB'A' sequence 6ms (SD = 47.63, SEM = 9.72) slower than the CBA sequence, t(23) = .647, p = .534. This did not occur in the second block, where the ABA sequence was now significantly 24ms (SD = 55.63, SEM = 11.36) slower than the CBA sequence, t(23) = 2.15, p = .042, and approaching significantly 20ms (SD = 51.17, SEM = 10.44) slower than the AB'A' sequence, t(23) = 1.87, p = .074. This in turn meant there was less than 5ms (SD = 62.14, SEM = 12.69) difference between the AB 'A and CBA sequences, t(23) = .385, p = .703, refer to tables 14 and 15 and figure 59.

Table 14: Mean Response Times (ms) for lag for the first block first in Experiment 5.

Experiment 5, Pair wise t test comparing ABA and CBA sequences.

		Mean Response Time		Difference between ABA and CBA sequences					
Exp No	Two Language Cues Experiment, First block	ABA	CBA	Mean Time difference	Std. Deviation	Std. Error Mean	t value	df	Sig. (2-tailed)
5	First Block ABA-CBA	685.08ms	679.62ms	5.46	60.81	12.41	.440	23	.664
	First Block ABA-AB'A'	ABA	AB'A'						
		685.08ms	685.91ms	0.83	60.56	12.36	.067	23	.947
	First Block AB'A'-CBA	AB'A'	CBA						
		685.91ms	679.62ms	6.29	47.64	9.72	.647	23	.524

Table 15: Mean Response Times (ms) for lag for the second block first in Experiment 5.

Experiment 5, Pair wise t test comparing ABA and CBA sequences.

Exp No	Two Language Cues Experiment, Second block	Mean Response Time		Difference between ABA and CBA sequences: Mean Time difference	Std. Deviation	Std. Error Mean	t value	df	Sig. (2-tailed)
		ABA	CBA						
5	Second Block ABA-CBA	685.84	661.42	24.43	55.63	11.36	2.151	23	.042
		ABA	AB'A'						
	Second Block ABA-AB'A'	685.84	666.31	19.54	51.17	10.44	1.871	23	.074
		AB'A'	CBA						
	Second Block AB'A'-CBA	666.31	661.42	4.89	62.14	12.68	.385	23	.703

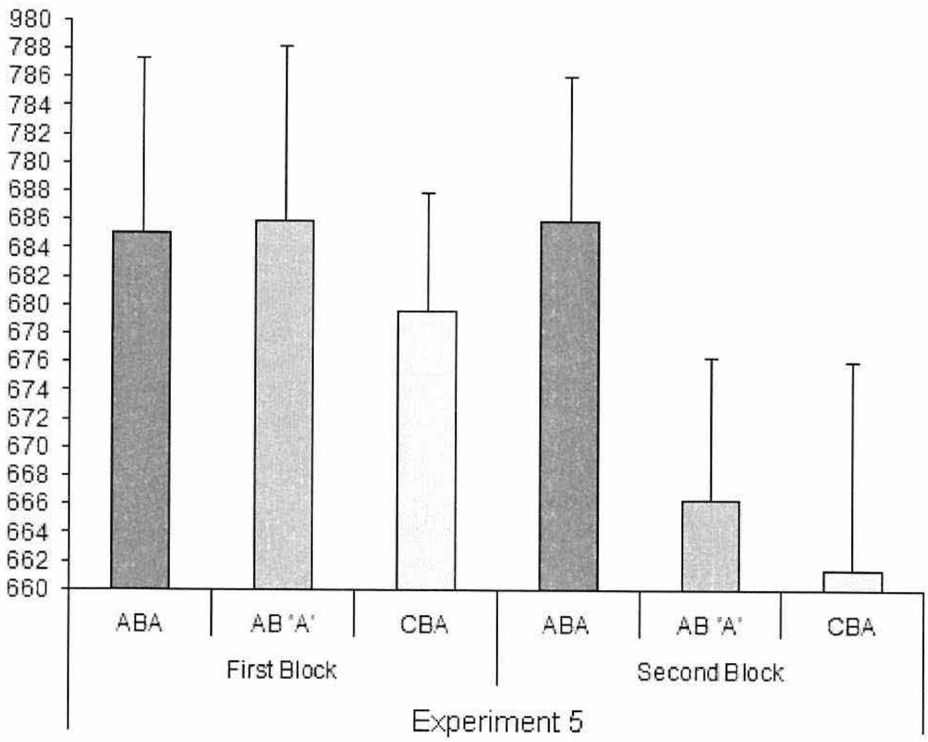


Figure 59: Mean Response Times for each block by lag type in Experiment 5. Error bars show the standard error of the mean.

Summary of results

Initially the first analysis of these results showed very little, but post hoc analysis did seem to highlight the following. There was little to now difference in response times between the AB'A' and CBA sequences. This was similar to that of the ABA sequence except for what occurred in the second block of the experiment. Here the ABA sequences become slower than the AB'A' sequence and significantly slower than the CBA sequences. It suggests that the repeat of the cue that was present at lag-2 was essential for the appearance of backward inhibition. It implies that something that is linked either to the cue's unique bottom up representation or its associated top down language label is being inhibited. It also highlighted that the backward inhibition cost is not linked specifically to the repeat of the target, which was at lag-2, or both the ABA and AB'A' sequences would have been equally costly as they shared this common component of their trials.

Experiment 5 Discussion

These results were somewhat inconclusive due to there being a lack of significance found, but certain trends seemed to be apparent. Practice did seem to increase backward inhibition costs but reduce overall response times. There was also a reduction in the amount of errors made. What did seem to become apparent was that the AB'A' and CBA sequence were equally efficient when compared to the ABA sequence. It suggested that either the unique bottom up representation of the cue or its associated language label was being inhibited. It also highlighted that it was unlikely that any component of the targets bottom up representation was being inhibited. This was because in both the AB'A' and ABA sequences it was present at lag-2 and if it were being inhibited would have caused similar costs in both types of sequences. Experiment 6 tries to address the issue of whether it was the unique characteristics of the bottom up representation of the cue, or its associated top down language label being inhibited, or if it was an amalgamation of these two components being inhibited as a common code.

Experiment 6 – Two implicit icon cues to one target

Experiment 6 used two icon cues that were different visually on a bottom up level but could share a common top down language label. This meant that in the AB'A' sequence, the top down label would be the same at lag-2, but the bottom up image would change. This should mean that if it were the unique bottom up characteristics of the cue, that were being inhibited, then the AB'A' sequence should be as efficient as the CBA sequence. Where as if it were the language label being inhibited then the AB'A' and ABA sequences should be equally as inefficient and have a similar backward inhibition cost.

Experiment 6 also introduced the language condition from experiment 1 and 3 to see if this would influence cost as there was a suggestion in experiment 4 that there may have been some influence of a second condition on the overall costs.

Experiment 6 Method

Participants

Twenty nine students were recruited from the same research pool as in the previous experiments, and were rewarded similarly.

Design

There were two different conditions, a language and an icon condition. The language condition had 3 cues that had a one-to-one relationship to the target, whereas the icon condition had 6 cues which had a two-to-one relationship to one target.

Apparatus & Stimuli

The apparatus was the same as used by all of the experiments in this study. There were two separate conditions, one using icon cues and the other using language cues. In the icon condition there were two types of cue to each of the three potential target stimuli, which were same in both conditions. Each cue was comprised of two triangles, one of which shared a common feature with the target and was blue, while the other was drawn in black and was neutral and common to all of the icon cues. The icon cue was 5cm in width and 2cm in height. The two icon cues that were associated with the specific target stimuli were differentiated from each other by the position of the neutral and non-neutral triangles, with the two types of cue being mirror images of each other, refer to figure 60. The language condition was a repeat of that found in experiment 1.

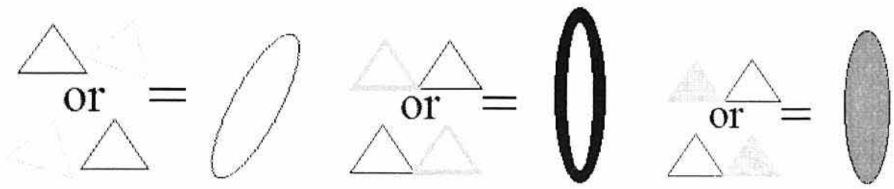


Figure 60: Implicit icon cues and relevant targets.

Procedure

As in all of the experiments the participants were first taught about the relationship between the cue and the target in each condition separately; they then completed a practice block of trials prior to completing the experimental condition.

Experiment 6 Results

Trimming of the data was the same as in previous experiments and 4 participants were removed because they made more than 10% errors.

Error Analysis

A mixed ANOVA comparing lag type x2 (ABA or CBA) by cue type x2 (Icon or Language) between order of conditions x2 (Language or Icon cues First or Second) was completed and no error significances were identified.

Response time analysis

There were originally 29 participants, four were removed because of making more than 10% of errors, and one participant was also removed, being an outlier.

Error analysis was completed and no significant main effects or interactions were found so I have only reported the results linked to response times.

In experiment 6 I initially completed a 2x2 within by 2 between Mixed ANOVA comparing Cue Type (Triangle Icon cue or language cued condition) by Lag Type (ABA (ABA and AB'A' sequence collapsed into each other)or CBA sequence) within, between the order of conditions (whether the triangle or language cued condition was completed first).

There was no main effect of cue type, $F(1, 22) = .304$, $p = .587$, which interacted with the order in which the conditions were completed, $F(1, 22) = 19.42$, $p < .001$. There was a main effect of lag type, $F(1, 22) = 10.73$, $p = .003$, and no other interactions, refer to table 16.

Table 16: Mean Response Times (ms) for order by condition and lag type in Experiment 6.

Experiment 6, Independent Samples t test of order of conditions.

Exp No	Condition and Lag Type	Difference between Language and Icon conditions: Mean difference	Difference between Language and Icon conditions: Std. Error difference	Difference between conditions: Triangle cue first	Difference between conditions: Language Cue First	t	df	Sig. (2-tailed)
6	Triangle repeat & change ABA	7.26 ms	68.50	664.52ms	657.26 ms	.106	22	.917
	Triangle Cue CBA	9.26 ms	67.41	644.26 ms	635.00 ms	.137	22	.892
	Language Cue ABA	119.95 ms	64.68	594.27 ms	714.22 ms	-1.854	22	.077
	Language Cue CBA	137.33 ms	69.26	560.48 ms	697.82 ms	-1.983	22	.060
			Backward Inhibition:- Cost	Triangle cue first	Language Cue First			
			Triangle Condition	20.26 ms	22.26 ms			
			Language Condition	33.79 ms	16.4 ms			

Planned comparison and Post hoc analysis was completed that compared the order effect found on the cue type which was done with an independent samples t test. There was less than 10ms difference between the triangle icon cued sequences, when the order of conditions was taken into consideration, with the ABA sequence being 7ms (SEM = 68.50ms) slower, t(22) = .106, p = .917, and the CBA sequence being similarly 9ms (SEM = 67.41) slower when the triangle cued condition was completed first, t(22) = .137 , p = .892. Unlike the triangle cued condition, the language cued condition response times dramatically decreased when the triangle cued condition was completed first. In the language cued condition, the ABA sequence was reduced by 120ms (SEM = 64.68), (22) = -1.85, p =.077, and the CBA sequences response times were similarly improved by 137ms (SEM = 69.26), when the triangle cued condition was completed first, t(22) = -1.98, p = .060.

I then completed a pair wise t test comparing the ABA and CBA sequences in the language condition. This showed a 27ms (SD = 55.46, SEM = 11.32) cost when doing a trial in the ABA sequence in comparison to when doing the CBA sequence, t(23) = 2.34, p = .028, refer to table.

After this I completed another 3 within by 2 between Mixed ANOVA that compared lag type (ABA, AB'A', or CBA) within, between order of conditions (Triangle or language cued condition first). A main effect of Lag Type was identified, F(2, 44) = 4.28, p = .020, that did not interact with the order of conditions, F(2, 44) = .870, p = .426.

Planned comparisons were then completed, comparing the lag type sequences, with a pair wise t test. The ABA sequence was found to be 17ms (SD = 43.77, SEM = 8.93) slower than the CBA sequence, t(23) = 1.92, p = .067, and only 8ms (SD = 49.00 SEM = 10.00) faster than the AB'A' sequence, t(23) = -.785, p = .441, which meant that the AB'A' sequence was 25ms (SD = 36.92, SEM = 7.54) more costly than the CBA sequence, t(23) = 3.32, p = .003, refer to table 17 and figure 61.

Table 17: Mean Response Times (ms) for lag type by condition in Experiment 6.

Experiment 6, Pair wise t test comparing ABA and CBA sequences.

		Difference between ABA and CBA sequences			Mean Response Time				
Exp No	Condition	Mean Time difference	Std. Deviation	Std. Error Mean	ABA	CBA	t	df	Sig. (2-tailed)
4	Language Cue	26.54ms	55.46	11.32	644.24ms	617.71ms	2.344	23	.028
	Triangle Cue	17.17ms	43.77	8.93	657.57ms	640.40ms	1.921	23	.067
					AB'A'	ABA			
	Triangle Cue	7.85ms	49.00	10.00	665.42ms	657.57ms	.785	23	.441
					AB'A'	CBA			
	Triangle Cue	25.013ms	36.920	7.53	665.42ms	640.40ms	3.319	23	.003

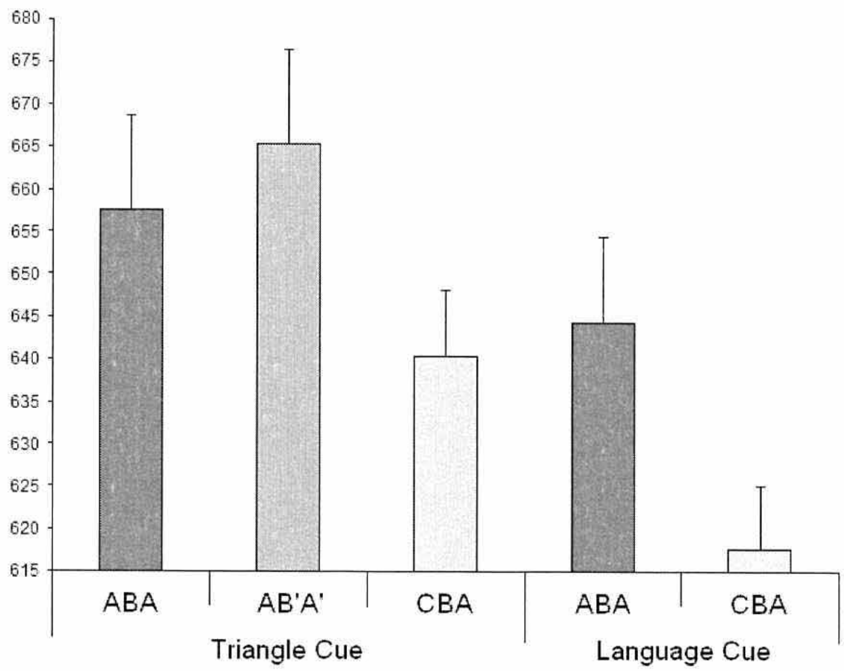


Figure 61: Mean Response Times for lag type in each condition in Experiment 6. Error bars show the standard error of the mean.

Summary of results

The above showed that on average trials in the ABA sequences took longer to complete than did trials in the CBA sequences. This was true for both the language and triangle cued experiments. What was also identified was that there was a decrease in overall response times when completing the language cued experiment after the triangle cued experiment. This effect was not noticed in the triangle cued experiment. This reduction in overall response times seemed to reduce the backward inhibition cost by half but this was not picked up in the statistical analysis.

When the triangle cued experiment was independently analysed the results were very different to those found in experiment 5. This was because the AB'A' sequence was now significantly slower than the CBA sequence; in fact it was even slower than the ABA sequence. It suggested that the ABA and AB'A' sequences were sharing a similar component which was being inhibited. This seems to be the shared common language label that the two different icon cues had. One criticism of this is that the similarity between these two icon cues could have caused them to be collapsed into a common cognitive representation which would have caused similar results.

Experiment 6 Discussion

The results from experiment 6 were more conclusive in relation to the AB'A sequence. If anything, the differences between the ABA and AB'A' sequences were lessened. Its results suggested we were seeing inhibition of the top down language label associated with the cue and not that of the bottom up visual representation of the cue. This was because there seemed to be a reduction in the difference in the response times between the AB'A' and ABA sequences in experiment 6 when compared to experiment 5. There was however an underlying problem linked to the characteristics of the icon cues used, as they may have been able to be collapsed into one by the participant. They may have ignored the triangle that did not hold any information about the up and coming target and see the two cues as one. This would have given similar results, to what we see in experiment 6, but would not have been caused by inhibition of a common language label but that of a common bottom up representation of the cue. The shared nature of the bottom up characteristics of the cue and target may also have reduced any inhibition that may have been occurring, or even caused a priming effect.

Experiment 7 was designed to see if it was possible to clarify exactly what was happening with any potential top down language label associated with the cue. It also tried to remove any of the concerns noted above regarding the visual representations of the cues that I had used in experiment 6. This was done by using cues that had an abstract relationship to the target, but also had no obvious bottom up characteristics that would attract an automatic top down label similar to those used in experiment 3. This meant that I was able to provide a label for them that could be used to identify the target. It also meant that we could either give the two cues associated with a target their own unique language label, or give them separate labels.

Thus, I could have two types of AB'A' sequences, one where the bottom up representation of the cue and its associated label were different at lag-2, as in experiment 5, and one where only the bottom up representation of the cue changed but the language label associated with it repeated, as in experiment 6. Experiment 7 set out to explore this potential relationship between an AB'A' and ABA sequence and the uniqueness of the visual bottom up image and top down language labels associated with the cue, and whether we could influence the above cost. Mayr and Bryck (2005) manipulated the relationship between the abstract response rules and their associated stimulus-responses which operate under these rules, finding that the top down rule, as represented by the language cue, becomes directly associated with the bottom up stimulus-response top down language label. If this were to occur, in this experiment, it then may be difficult to differentiate between the above scenarios, as even if it were the top down language label being inhibited it would have a unique quality to it based on it having shared common code with the unique bottom up representation of the cue. A critic could then say that we are only seeing the inhibition of the bottom up visual image of the cue. Either way the following experiment set out to see if we could differentiate between whether we were seeing inhibition of the bottom up representation of the cue or inhibition of the top down language label associated with the cue. While taking into consideration that we may actually be seeing inhibition of a top down language label that is unequally linked to the bottom up representation of the cue as they share a common code.

Experiment 7 – Two abstract icon cues to one icon target

Experiment 7 Method

Participants

There were 45 students who were drawn from the same student pool as in previous experiments, and similarly rewarded.

Design

There were two separate conditions, which were individually completed by one of two groups; neither group did the other condition. In both conditions, there were two cues associated with one of three targets as with all of the previous experiments in this chapter.

The only difference between the conditions was that, in one condition, the two cues shared a common top down language label to the target, but in the other condition each cue was given its own top down language label. Therefore the design was a 3 (Lag type, AB'A', ABA, CBA sequences) within by 2 (top down language labels; one label to two cues or two labels to two cues) between.

Apparatus and Stimuli

Experiment 7 was similar to experiment 5, except for the change of cue and target type. As there was a likelihood of more errors being made and the effect this would have on trimming, there was an increase in trials to 200 trials in each block and 50 trials in the practice block.

Cues, Stimuli, and Response

In experiment 7, there were two separate conditions: each condition had two iconic cues associated with one target stimulus. One of these conditions had one verbal label given to two iconic cues associated with the target stimulus, refer to figure 62.

Square=海 Or 路 Circle=無 Or 雲 Triangle=徑 Or 邊

Figure 62: Experiment 7, one semantic label to two cues.

In the other condition, each of the six iconic cues were given their own verbal label; three of the labels were associated with the internal features of the target stimuli, and the other three labels were associated with the general shape of the target stimuli. This meant that each target stimuli had two cues connected with it, one that identified its general shape and another which related its internal characteristics, refer to figure 63.

Circle=無　Dotted=雲　Square=海

Border=路　Triangle=徑　Filled=邊

Figure 63: Experiment 7, one top down language label to each taregt.

The target stimuli were a circle with dots, a triangle with a filled centre, and a square with a thick border. Each participant only carried out one condition, refer to figure 64.

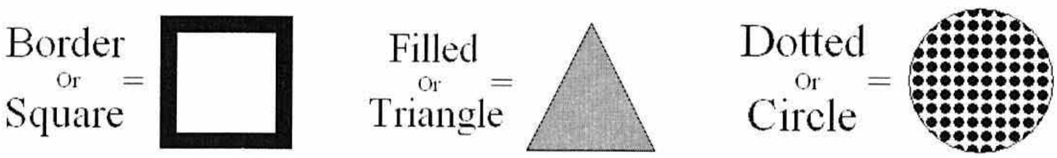


Figure 64: Experiment 7, language labels associated with targets.

In both of the conditions above we were concerned that cost differences may be linked to the type of language label we used. So both groups were also split into two smaller groups, one using the language labels shown above, or the language labels shown below to the cues.

All of the cue's language labels were balanced so there were two groups, one that used the above language labels and the other group used the below language labels, refer to figure 65.

Border=海 Or 路　Dotted=無 Or 雲　Filled=徑 Or 邊

One language label to two cues or each cue has its own language label.

Circle=雲　Dotted=無　Square=路

Border=海 Triangle=邊 Filled=徑

Figure 65: Experiment 7, other group's language labels.

Procedure

The participants first learned and rehearsed the language label for the appropriate cue; they did this by being shown the language label and iconic cue that they were to associate with each other. They were then given a piece of paper with the six icon cues repeated randomly eighty times in columns, and they were asked to label them from memory. This process of learning the top down language label for the cue was on average completed successfully within 10 minutes. Once they were able to associate the correct label with the specified iconic cue, they were shown the target stimuli that were associated with the cue and their appropriate label. It was then explained to them, as in experiments 5 and 6, what the objective of the experiment was and how they were to register their response on the keyboard. They were not told that the internal feature of the target stimulus would remain the same throughout the block of trials. Participants completed the practice block with the experimenter present, prior to completing the experiment on own. Please refer to appendixes 2 and 3.

Experiment 7 Results

Trimming of data was less conservative than in Experiments 6 and 7 due to the difficulty of the task. Participants now included in the data up to making more than 13% of errors which resulted in five participants being removed. One participant was also removed because of being an outlier, having an overall response time over 2 seconds slower than that of the other participants, and being faster than others in the CBA sequence. Trials were also included in the data with response times between 300ms and 3000ms unlike in the previous experiments that limited to trials between 200ms and 2000ms.

Error analysis showed no significant effects, so the focus is on RTs.

Response time analysis

In experiment 7, I first carried out a 2 within by 2 between Mixed ANOVA, comparing Lag Type (ABA (collapsed ABA and AB 'A sequences) or CBA) within, dependent on whether the two abstract icon cues associated with the one target had one or two language labels. This identified an approaching significant main effect of lag type, $F(1, 38) = 3.32$, $p = .076$, that did not interact with the number of language labels used, $F(1, 38) = .237$, $p =.629$. I then completed a 2 within by 4 between Mixed ANOVA, comparing Lag Type (ABA or CBA) within between the type of language labels used (Circle, Squire, and Triangle, or Dotted, Border, and Filled, or , Circle, Square, Triangle, Dotted, Border, and Filled, or Dotted, Border, Filled, Circle, Square, and Triangle). This again identified an approaching significant effect of Lag type, $F(1, 36) = 3.18$, $p = .083$, that did not interact with the type of language label used, $F(3, 36) = .719$, $p = .547$.

After this I completed planned comparisons and used a pair wise t test to compare the ABA and CBA sequences and found that the ABA sequence on average was 19ms (SD = 64.50, SEM = 10.20) slower than the CBA sequence, $t(38) = 1.90$, $p = .065$, refer to figure 66.

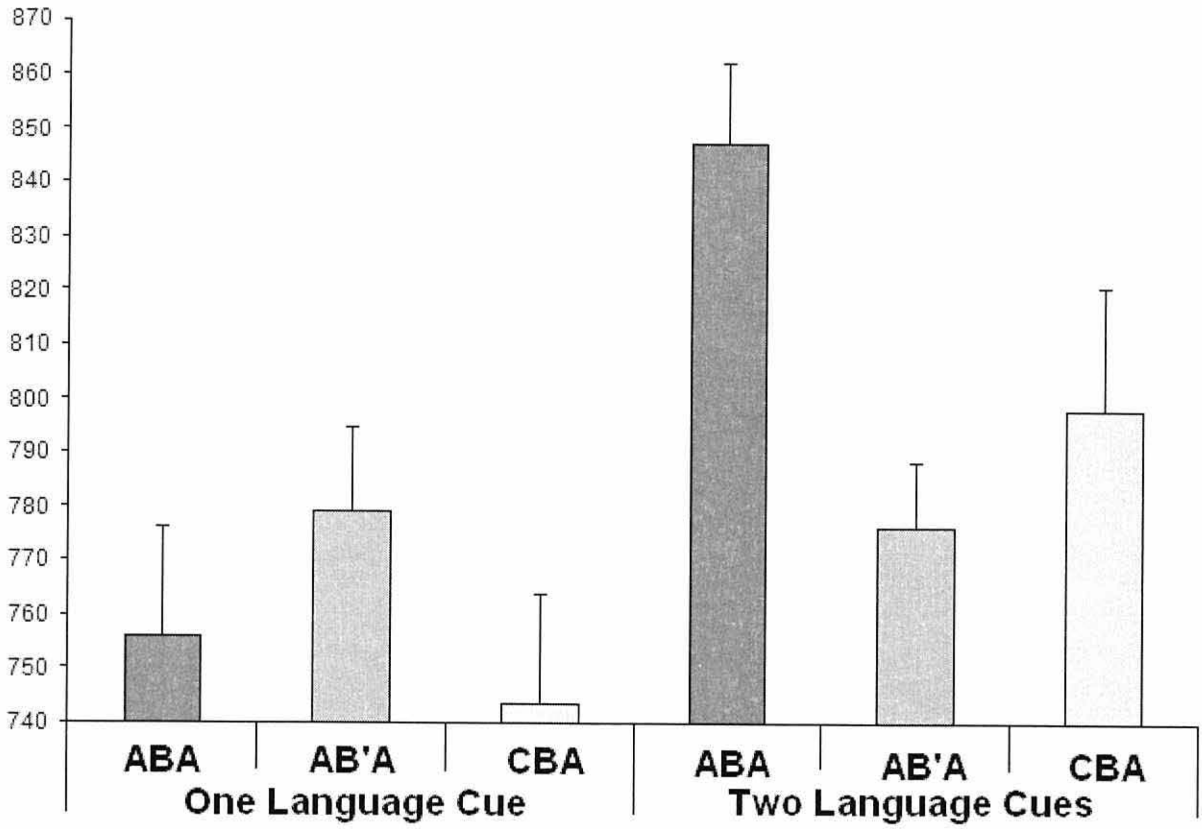


Figure 66: Mean Response Times (ms) for both conditions by lag type in Experiment 7. Error bars show the standard error of the mean.

After the above I reran the analyses and split the ABA sequences into two different sequences, one where the cue was a repeat of the cue that was at Lag-2 (ABA) and another where the cue was different to the cue that was at Lag-2 (AB'A'), and compared them to the CBA sequence. I did this by running a 3 within by 2 between Mixed ANOVA, that compared Lag Type (ABA, AB'A', and CBA) within and between the numbers of language labels used (One or Two). This identified an approaching main effect of Lag Type, $F(2, 76) = 2.69$, $p = .074$, that interacted with the number of language labels used, $F(2, 76) = 5.74$, $p = .005$. I then did another 3 within by 4 between Mixed ANOVA that compared Lag Type (ABA, AB'A', and CBA) within and between the type of language labels used (Circle, Squire, and Triangle, or Dotted, Border, and Filled, or , Circle, Square, Triangle, Dotted, Border, and Filled, or Dotted, Border, Filled, Circle, Square, and Triangle). This identified that there was no main effect of Lag Type, F(2, 72) = 2. 23, p = .115, although the Lag type did interact with the type of language label used, F(6, 72) = 2.26, p = .047, refer to table.

I then completed planned comparisons using a pair wise t test to compare the ABA, AB'A' and CBA sequences and found that the ABA sequence was 29ms (SD = 89.48, SEM = 14.15) slower than the CBA sequence, t(39) = 2.05, p = .047, and was also 19ms (SD = 108.60, SEM = 17.17) slower than the AB'A' sequence, t(39) = 1.12, p = .268. This meant that the AB'A' sequence was 9ms (SD = 78.82, SEM = 12.46) slower than the CBA sequence, t(39) = .781, p = .440, refer to table 18.

Table 18: Mean reaction time (ms) for lag type across all conditions in Experiment 7.

Experiment 7, Pair wise t test comparing ABA and CBA sequences.

		Difference between ABA and CBA sequences			Mean Response Time				
Exp No	Condition	Mean Time difference	Std. Deviation	Std. Error Mean	ABA	CBA	t	df	Sig. (2-tailed)
7	One Language Label	12.41ms	94.85	20.22	755.90ms	743.48ms	.614	21	.546
	Two Language Labels	49.33ms	80.38	18.95	847.18ms	797.85ms	2.604	17	.019
					AB'A'	CBA			
	One Language Label	35.41485	85.13651	18.15116	778.90ms	743.48ms	1.951	21	.065
	Two Language Labels	21.66ms	58.32	13.75	776.19ms	797.85ms	1.576	17	.133
					AB'A'	ABA			
	One Language Label	23.00ms	97.83	20.86	778.90ms	755.90ms	1.103	21	.283
	Two Language Labels	70.99ms	100.45	23.68	776.19ms	847.18ms	2.998	17	.008

This initial result suggested that the AB'A' and CBA sequences were very similar and the ABA sequence has a unique quality. It would, on first readings, suggest that I was seeing inhibition of the bottom up visual representation of the cue, or of an amalgamated code comprising of the bottom up representation and top down language label associated with the cue. Not just the inhibition of the top down language label associated with the cue. Although the above interaction identified between the number of language labels used and the type of cue used, with the lag type, would suggest that this interpretation may not be correct.

Because of these interactions identified in the initial Mixed ANOVAs, where the number of language labels, and separately the type of language label used, both seemed to be affecting the cost associated with the Lag Type, I completed separate pair wise t tests on the lag type taking these factors into consideration.

I first completed a pair wise t test, on the group that used one language label, comparing the ABA, AB'A', and CBA sequences. I found that the ABA sequence was only 12ms (SD = 94.85, SEM = 20.22) slower than the CBA sequence, t(21) = .614, p = .546, but was 23ms (SD = 97.83, SEM = 20.86) faster than the AB'A' sequence, t(21) = .-1.10, p = .283. This meant that the AB'A' sequence was 35ms (SD = 85.14 , SEM = 18.15) slower than the CBA sequence, t(21) = 1.95, p = .065.

I then completed a pair wise t test on the ABA, AB'A', and CBA sequence on the group that used two language labels. This unlike the group that had used one language label had an ABA sequence that took 49ms (SD = 80.38, SEM = 18.95) longer than the CBA sequence, t(21) = 2.60, p = .019, and was 70ms (SD = 100.45, SEM = 23.68) slower than the AB'A' sequence t(21) = 3.00, p = .008. This also meant that unlike the group that used one language label the AB'A' sequence was now 22ms (SD = 58.66, SEM = 13.75) faster than the CBA sequence, t(21) = -1.58, p = .133, refer to figure 67.

I finally carried out post hoc analysis, using pair wise t tests, on all of the four groups that used different types of cues and found the results mirrored the above results that were linked to the number of language labels associated with them, refer to figure 67. The two groups that that had cue types that had only had one language label (Dotted, Border, and Filled, group or Circle, Square, and Triangle group) had an AB'A' sequence more costly than both the ABA and CBA sequences. Where as the groups that had a cue types that had a unique language label for each cue (Circle, Square, Triangle, Dotted, Border, Filled group and Dotted, Border, Filled, Circle, Square, and Triangle group) had an ABA sequence that was more costly than both the AB'A and CBA sequences, refer to figure 67. What also became apparent was that the groups that had a unique language label, for each cues, had on average had longer response times than did the group which had one language label for the two cues, refer to figure 67.

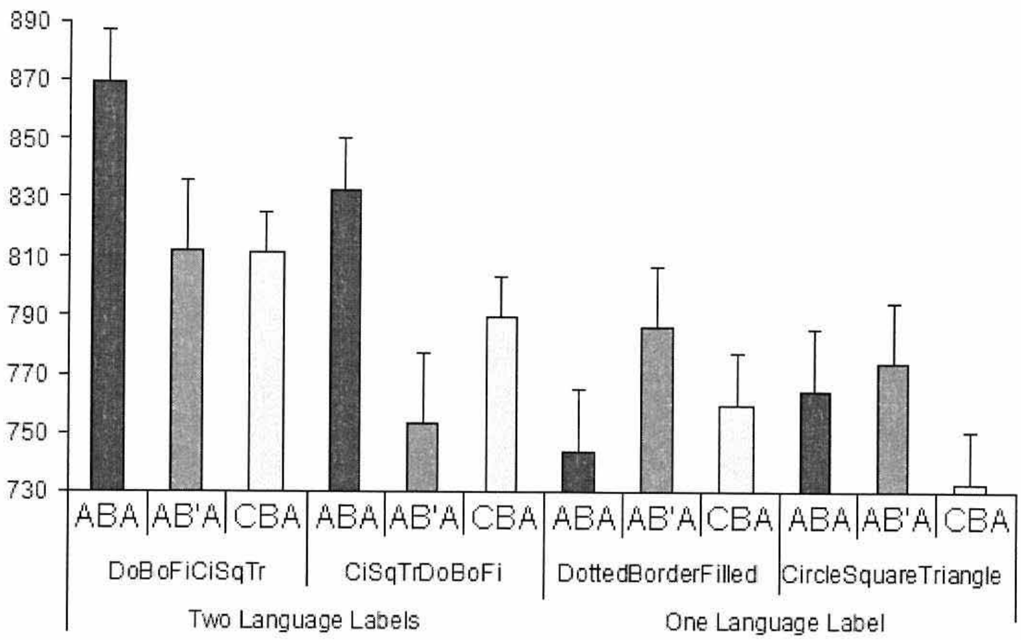


Figure 67: Mean Response Times (ms) for all conditions across cue type and lag type in Experiment 7. Error bars show the standard error of the mean.

Summary of results

First and foremost the above results identified three effects that seemed to be directly linked to the number of language labels used. Firstly, when there was only one language label used, the AB'A' sequences were more costly than both the ABA and CBA sequences. Secondly, when there were two language labels used, the ABA sequences were now more costly than both the AB'A' and CBA sequences. Thirdly when there were two language labels used this seemed to increase the overall response times. These results seem to mirror the results of experiment 5 and 6. As in experiment 5, where there was a different language label for each of the two cues that were linked to one target, the ABA sequence was more costly than both the AB'A' and CBA sequences. The opposite seemed to occur in experiment 6, when the two cues that shared a common language label, as in this experiment the AB'A' sequence was more costly than both the ABA and CBA sequences. Finally, when there were two language labels the overall response times were slower than when there was only one language label used. The results do seem to suggest that it is not the unique quality of the bottom up image of the cue that is being inhibited but the top down language label associated with it.

Experiment 7 Discussion

The results of experiment 7 seemed to be conclusive: as they showed very similar results to experiment 5 and 6. Even so there was one anomaly that was difficult to explain and that was why the ABA sequence seems to have a reduction in the amount of backward inhibition when there was only one language label used for the two cues.

What was interesting was that the AB'A' sequence only exhibited a backward inhibition cost when there was only one language label for the two different cues. The results suggested that when the two different bottom up representations of the cue shared a common language label backward inhibition was present in the AB'A' sequence. This was not the case when there was a unique language label for the cue. It suggested that it was the language label being inhibited and not the bottom up representation of the cue or target. If it had been the bottom up representation of the cue then the AB'A' sequences should have shown no backward inhibition cost in both of the language label groups. This was because there would have been more time for the cues bottom up visual representation to recover in an AB'A' sequence, as it would have previously been inhibited at earliest at lag-4 or before. If on the other hand there had been an equal amount of backward inhibition seen in both the AB'A' and ABA sequences, in both of the language label groups, it could have suggested that we were seeing inhibition of the bottom up representation of the target. This would have been linked to the fact that the only component of the trial that was repeated from the trial at lag-2 was the bottom up representation of the target. The above experiments results seem to suggest that backward inhibition, when using this methodology is not linked to the bottom up inhibition of the visual representation of the cue or the target. Cost seems to be linked to the reapplication of a previously inhibited top down language label that is used to identify the bottom visual representation the cue and subsequent target.

Chapter 4 Discussion

The results in chapter 4, combined with those of chapter 3, may go someway to explain the difference between Logan and Bundesen's (2003) and Mayr and Kliegl's (2003) experimental results. Chapter three seemed to suggest that two different language labels, one for the cue and one for the target, can be used in a trial. Both of which can also be inhibited if the next language label used is different to the previous language label. Chapter 4s experiments results imply that it is the language label, and not the bottom up image of the cue or target, that is inhibited. If this is the case it may be possible to explain why there were the differences in Logan and Bundesen's (2003) and Mayr and Kliegl's (2003) experiments even though they were not looking at ABA sequences. Logan and Bundesen's (2003) and Mayr and Kliegl's (2003) used a methodology where there was a switch of task every two trials with the next trial after a switch being a repeat of task. This repeat of task could either involve a repeat of cue or a switch of cue. They also always looked at what was occurring at lag-1 to explain where this cost may be originating from. My results would suggest that cost is as consequence of how quickly one returns to a previously inhibited top down language label. If this were so then the cost they were seeing may also be linked to how quick one is returning to a previously inhibited top down language label and how many conflicting language labels there are in their trials. Logan and Bundesen's (2003) methodology suggested that the two cues they used did not have conflicting top down language labels where as Mayr and Kliegl's (2003) did. If this is the case by factoring in what was occurring at lag-4 lag-5, lag-8, and lag-9, to determine when the present cue was last switched away from, while also factoring in if the cue and targets top down language labels conflict with each other or not, may identify if their cost differences are linked to the factors I seem to have identified, or are directly linked to their conclusions.

Chapter 5

Between or within trial influences on ABA costs

Chapter 5 Abstract

The previous experiments both replicated and removed backward inhibition costs associated with ABA sequences, suggesting the top down language label associated with a bottom up visual image is inhibited. What remains unclear is how much the bottom up image of the cue influences backward inhibition. Chapter 5 aims to answer this question. Experiment 8 had a language and icon cued condition, both having two different cue-target relationships within them, one where the cue and target relationship explicitly matched each other, the other where there was an abstract relationship between them. Experiment 9 altered the cue-target interval (CTI) and target response interval (RTI) to see if within or between trial conflicts were linked to the amount of backward inhibition. Results of experiment 8 suggested that when there is no necessity to use a top down or bottom up language label, both the language labelling system and the previous language label are inhibited. For experiment 9, results suggested that the language and icon cued conditions were operating differently, with the language label being applied when the cue appears, in the icon cued condition, and when the target appears, in the language cued condition.

Chapter Summary

This chapter looks more closely at further methodological factors that influence backward inhibition costs. It has been shown that both the transparency and characteristics of the trial at lag-1 can affect these costs, as well as the response-cue interval (RCI) between trials and the cue target interval within trials (CTI).

Experiment 8 set out to look at the effects that cue-target relationship at lag-1 may have on backward inhibition. Gade and Koch (2007) showed that unless there were overlapping response sets between the trials at lag-1 and lag-2 no backward inhibition would be seen. Experiment 8 used similar methodology to explore how the transparency of the cue-target relationship at lag-1 and lag-2 may influence these costs. Experiment 9 looked at the RCI and CTI. The RCI has been linked to the amount of inhibition required to remove previous conflicting features from the previous trial (Gade & Koch, 2005), whereas the CTI has been linked to the time required for reconfiguring previously inhibited features.

Experiment 8 had unforeseen results, as the transparency of the relationship between the cue and target at lag-1 and lag-2 was found to have significant effects on backward inhibition costs that were linked to the type of target used. This suggested that we were seeing both inhibition of a language label and inhibition of the system that applies the language label in the icon condition. Experiment 9 showed that by altering the RCI and CTI, backward inhibition could be seen in a matching icon condition, although it was not possible to determine whether it was the RCI or CTI that was causing this effect. Further, planned comparisons on the position of the response (described in chapter 6) suggests that a language label is attached to the icon cue when there is a long CTI.

The experiments described in chapter 2 set out to see if it was possible to replicate the costs seen by Mayr and Keele (2000) when participants were switching between tasks that consisted only of switching between three one to one cue target relationships. I also wanted to see how much the role of language played in these costs. Experiment 1 set out to do this by having two conditions, one that had implicit language cues and another which had transparent matching icon cues, both of which used the same icon stimuli. The results suggested that we were seeing inhibition of the language label associated with the target. This was because there was no backward inhibition identified in the icon condition, although there was in the language cued condition. This suggested that either the bottom up component of the cue was being inhibited by the bottom up component of the target, within trial, or that the top down language label was being inhibited by the next trial's top down language label between trials. Experiment 2 looked specifically at the overall response speed because there was a concern that there may be a floor effect in operation in the icon condition that was hiding any backward inhibition. More trials were also introduced to see if practice would also affect cost. Experiment 2 therefore simplified the relationship between the cue and the target by using colour. There was again an implicit language condition and a matching explicit icon cued condition that used the same coloured icon stimuli. The experiment managed to speed up overall response times and to show backward inhibition in both conditions, showing that it was unlikely to be any floor effect that was stopping us seeing backward inhibition in the icon cued condition in Experiment 1. It also showed a practice effect, but it was unclear exactly how this was operating. Most importantly, backward inhibition was seen in the icon condition in experiment 2 suggesting that we were seeing between trials inhibition of a potential top down language label associated with the target. This was because there was no bottom up conflict between the cue and target within trial in the icon condition in experiment 2. The only conflict that was likely was between the trials' language labels. Conflict between the trials' bottom up visual images was also highly unlikely because there was the same level of potential conflict in all of the previous experiments and no backward inhibition was found in the icon condition in Experiment 1.

The experiments described in Chapter 3 sought to see if we were seeing inhibition of a top down language label, by potentially increasing the number of potential top down language labels in a trial and whether the switch in modalities within a trial or between conditions was having any effect on these costs. I attempted to increase the number of language labels within a trial by having an abstract relationship between the cue and target, in two of the conditions (experiment 3 and experiment 4). The icon cues were designed in the abstract condition so that they were shapes that were given an automatic top down language label that was different to that of the target. This should mean that both the cue and the target had their own top down language labels. These experiments also had one other condition; in experiment 3 this was an implicitly language cued condition and in experiment 4 it was a matching explicit language cue target relationship. The hypothesis was that two top down language labels would be used in the abstract condition, one for the cue and one for the target. One would be used in the implicit language cued experiment and none would be used in the matching cued condition. I hypothesised that there would be a systematic increase in backward inhibition linked to the number of potential language labels used in a trial and this is what was found. The abstract relationship had the greatest backward inhibition cost, then the implicit language cued condition, with no cost in the matching condition. One major concern was that the increase in backward inhibition cost was incrementally linked to the increase in overall response times that became greater as the relationship between the cue and target became less transparent. This concern was countered when I looked at the order of conditions effect. As in experiment 1, in experiments 3 and 4, abstract conditions were affected by the order of conditions, with a more than 100ms improvement in overall response times if the more transparent cued condition was first. This increase in overall response times had no effect on the backward inhibition costs in experiments 1 and 3, but may have had some effects in experiment 4. Although this increase in backward inhibition and overall response times, in experiment 4, may have been linked an anomaly in this experiment where there was a repeat in cue and change in target type between conditions. It also highlighted the likelihood that we were seeing a two stage model in operation which first recovered the top down language label from LTM then secondly applied it to the bottom up visual image in working memory. Practice when doing the less transparent condition first led to better recovery but did not assist in the process of reapplication of this label to the bottom up visual image. This order effect was not apparent in the less transparent condition. With the completion of the experiments described in chapter 3, it did seem to be that we were seeing inhibition of a top down language label and cost was associated with it being reconfigured with a bottom up visual representation. It also seemed to suggest that this inhibition could occur within and between trials dependant on where the conflict occurred between top down language labels.

What was not clear was if any of the bottom up characteristics of the cue were being inhibited, although the results of the icon condition in experiment 2 did seem to suggest that this was not occurring. Chapter 4 set out to see what would occur if two cues to one target were used, as this, it was believed, may clarify this relationship. The results did seem to suggest that we were seeing inhibition of the top down language label, but could not be totally conclusive, as it may also be part of an amalgamated code that involved the bottom up visual representation of the cue. If this were so, our results would suggest that its recovery was helped by practice. This practice did not benefit backward inhibition costs and this suggested that if it were an amalgamated code that was being inhibited, then there may be more difficulty when one wishes to extract its top down language label in the second stage when applying it to the target.

Chapter 5 sets out to see if more clarity can found relating to these factors by modifying two experiments that were designed by Gade and Koch (2005; 2007). They were able to identify factors that were linked to switches in task set by using these methodologies and I hoped that they too would assist me in understanding what may be going on in my own experiments. Gade and Koch's (2005; 2007) experiments investigated how the time between trials (Gade & Koch, 2005), and how we represent the cue, target, and response, influences the cost we see in an ABA sequence (Gade & Koch, 2007). Gade and Koch (2007) hypothesised that cost in an ABA sequence was linked to the extent that response and task sets overlapped; they completed three experiments which seemed to confirm their hypotheses, which were discussed in the introduction to this thesis.

As previously mentioned the *task-set* represents a cognitive representation of a specified task, which is ether activated or inhibited on the basis of whether it is linked to an upcoming task (Rogers & Monsell, 1995). Control process are said to monitor the success we have in achieving specified goals by monitoring the sequence involved in attaining a specific objective (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Gade and Koch (2007) highlight how the task-set is represented, suggesting that there is both a stimulus related process, that highlights a top down language label which identifies the specific stimulus, and a stimulus-response process that determines the correct relationship between the identification of a specific feature in a stimulus being looked for and how one should correctly respond to it (Meiran, 2000; Philipp & Koch, 2005; Rogers & Monsell, 1995; Schuch & Koch, 2004). Gade and Koch (2007) highlight how Meiran divides the task set into two specific components: one linked to the stimulus's representation and the other to a response set. This is interesting as Gade and Koch also seem to be talking about a two stage process that firstly labels and identifies the stimulus, then secondly a process that identifies the feature in the stimulus one being looked for, and the correct response to it.

Meiran's (2000) model suggests that the stimulus set is susceptible to intentional alterations in activation. The response set is said to represent the specific tasks stimulus response mappings. A stimulus response mapping holds the meaning of how a correct response is made: when a colour judgment is made for example, the relevant key which is to be pressed for a specific colour has the associated colour word cognitively superimposed upon it. Meiran's model also suggests that the stimulus set can be influenced by intentional changes that alter the activation of the stimuli associated with a specified task, but the response set is influenced by the previous response, which cannot be prepared for.

Because of Schuch and Koch's (2003) experiment, which used go/no-go, they have suggested that inhibition occurs as a consequence of competition at the response selection stage at trial n-1. This they believed occurred because of the persisting activation of the previous category response rule from the trial at n-2. Because of this, Gade and Koch (2007) sought to provide more evidence that costs are linked to between task competition, task inhibition and the overlapping of response sets. They did this by designing an experiment that used four different tasks, three of which used multivalent stimuli; this meant that there were three different features within the target stimuli that could be identified, but they needed a preceding cue to classify which feature was relevant on any particular trial. Gade and Koch (2007) suggested that this was an overlap which was similar to a response set that also overlapped, in that the words Left and Right each corresponded to one of the three identifiable features that could be looked for in any of the trivalent target stimuli (i.e. they had a stimulus that could either be structurally small or large, red or blue, or a letter or number). The target stimuli were a letter A, or number 4. These tasks were known as trivalent (T). They also had neutral stimuli which had no relationship to the trivalent stimuli, and a response that could or did not overlap with the previous types of responses. This univalent (U) task involved deciding on whether a rectangle was filled or empty. All of the trials were cued by the use of four symbols that were placed at the corners of a white rectangle that eventually contained the target stimuli. The cues were four pound signs (Filled or Empty), dollar signs (Form), arrows pointing up or down (Size), or four yellow squares (Colour). Responses were made verbally in both U and T trials, and participants mapped the words left or right onto the appropriate choice to be made to the T trials. The response to U trials altered between experiments.

In Gade and Koch's (2007) experiment 1, the response of Filled or Empty was made about the U target, that related to whether the target rectangle was shaded in or not. Their results showed that a TUT trial was overall more costly than a TTT trial. There was no ABA cost in the TUT trial but there was in the TTT trial; even so, the TUT ABA was 20ms slower than the equivalent TTT trial. In the second experiment they were concerned that this lack of cost in the ABA sequence in the TUT trial may be linked to the U trial, unlike the T trial, not having an arbitrary response. In the next experiment, the U trial was given an arbitrary response which was to say Up or Down. They found similar results to those from experiment 1, but the small cost that was in the ABA sequence in the TUT trial was removed, and now showed a 20ms benefit. The third experiment was designed to see if the cost was linked to an overlap of the stimulus set, or if it was specifically linked to the overlap of response sets. To test this they changed the response to the U trial to the same as the T trials, i.e. to say Left or Right. They found that the ABA cost then appeared in the TUT sequences, which suggested that it was not the lack of overlapping stimulus sets that was causing the cost, as the U and T trials still did not have overlapping stimulus sets, but must be linked to the response set. This is interesting as cost does seem to be linked to the conflict that is occurring between top down labels associated with the correct response. Could they not have become amalgamated with the bottom up components of the task? It also raises the issue of episodic negative priming linked to the change in a recent snapshot of amalgamated components of the task. What is important is that it is the shared language label that seems to be at the root of the cost occurring.

Gade and Kochs (2007) experiment looked specifically at the response component of a task set, and how the overlapping effect of the language label associated with the response, affected costs between trials. Gade and Koch (2007) were specifically looking at overlapping language labels associated with the response. My research suggests that conflicting language labels seem to be linked to the cost. Gade and Koch's (2007) experiment suggests that the response label on the task may become amalgamated into a common set; my work suggests that a top down language label is being inhibited and the bottom up image associated with it may be inhibited too, but not as part of an amalgamated top down and bottom up representation. An adaptation of this experiment I believed may help me to understand this relationship between the bottom up image and top down label more accurately.

To do this I decided to have four different cue-target relationships. There were two abstract relationships, which I called translating relationships (T trials), one matching cue and target relationship (M trial). This gave us three different types of CBA and ABA relationships that we could analyse. In trials ending with a 'T' trial we were able to look at an ABA, TTT and TMT sequence, and a CBA, TTT and MTT sequence. Because it was presumed that an 'M' trial would be quicker than a 'T' trial, we could not compare sequences that ended with either type of trial independently, although we were able to compare a MTM (ABA sequence) with a TTM (CBA sequence).

My previous experiments suggested that cost was originating as a combination of inhibition of the top down language label associated with the target and may also involve the bottom up inhibition of the cue by the target. If cost was only related to between trial inhibition of the top down conflicting language labels, there should be no backward inhibition in the TMT (ABA) sequence as there would be no conflict between the two trials as no top down label would be used in the M trial. Therefore the TMT (ABA) and TMT (CBA) and MTT (CBA) sequences should be similar. This would mean that the TTT (ABA) trial would take the longest. If the cue was inhibited within trial, there would be a backward inhibition cost in the TMT (ABA) trial but this still should be less than the TTT trial, as in the T trials both within trial inhibition and between trial inhibition of the competing language labels would occur. In the trials finishing with an M trial, there should be no difference in any of the sequences' response times as there should be no conflict within trial between the cue and target and as no language label is used, it cannot conflict with an up an coming trial.

Experiment 8 – Abstract and matching cue relationships within an ABA and CBA sequence

Experiment 8 Method

Participants

There were 26 students drawn from the same student pool as in previous experiments, who were similarly rewarded.

Design

There were two conditions (icon or word) that could be in an ABA or CBA sequence. These could also be subdivided into 2 ABA sequences and 2 CBA sequences that could end with a T trial, into 1 ABA sequence and 1 CBA sequence that could end in an S trial.

There were 250 trials. There was on average 50 trials of each type of sequence, TTT/ABA, TMT/ABA, TMT/CBA/, MTT/CBA, and MTM/ABA, and TTM/CBA. This meant that 50% of trials were ABA sequences, and 50% were CBA sequences.

Apparatus and Stimuli

Other than the alterations described above and below, all other factors remained the same in this experiment as those in Experiment 1.

Cues, Stimuli, and Response

Other than the design changes described above, all other factors remained constant in this experiment. There were two different conditions that all of the participants completed: a language and icon cued condition. In each condition there were two cues that had an abstract relationship to the target (T trials) and one simple matching cue target relationship (M trials). The language cued T trials had the cue to target relationship of Lake-Plug, Coal-Seat, and the M trials were Milk-Milk. The icon condition is as set out below, refer to figure 68.

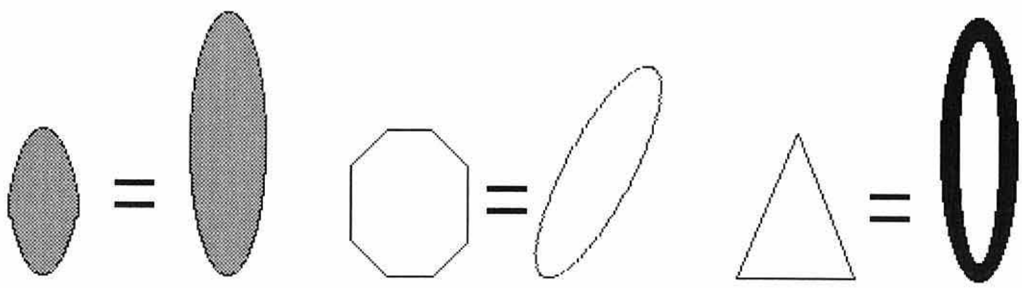


Figure 68: Icon cues and targets, one Simple (M), two Translatable (T).

Procedure

Participants were introduced to the experiment and completed it, as in experiment 1.

Experiment 8 Results

I completed the error analysis and trimming of the data as in all of the previous experiments prior to experiment 7. No participants were removed because of error. Error analysis was completed and no significant results were identified so the results concentrate on the response time analysis.

Response time analysis was carried out separately on the sequences that ended with a T trial (TMTaba, TTTaba, TMTcba, MTT) from trails that ended with an M trial (MTMaba or TTMcba). This was because the M trials were substantially quicker than the T trials and therefore made it difficult for any valid comparative analysis to be made between them.

Analysis of sequences ending with a T trial

I initially completed a 2x2x2 within by 2 between Mixed ANOVA, which compared Cue Type (Icon or Language) by Lag Type (ABA or CBA) by transparency of the relationship between the cues and targets at Lag–1 and Lag–2 (TMT and TTT or TMT and MTT) within and between the order of conditions (Icon or Language cue first). The analysis identified a main effect of Cue Type, $F(1, 24) = 16.50$, $p < .001$, that interacted with the order of the conditions, $F(1, 24) = 11.79$, $p = .002$. There was also a main effect of Lag Type, $F(1, 24) = 16.59$, $p = .001$, although there was no main effect linked to the transparency of the cue target relationship at lag-1 and lag-2, $F(1, 24) = .521$, $p = .468$. There was an approaching significant interaction between the Cue Type and Transparency linked to Lag Type, $F(1, 24) = 3.11$, $p = .091$; there was also a significant interaction between Lag Type and the

Transparency linked to Lag Type, F(1, 24) = 21,73, p < .001. There was also an approaching significant three way interaction between the Lag Type, the Transparency of the Lag Type, and the order in which the conditions were done, F(1, 24) = 3.67, p = .067, and a significant three way interaction between the Cue Type, Lag Type, and Transparency of the lag Type, F(1, 24) = 5.43, p = .029. Finally there was an approaching significant four way interaction between the Cue Type, lag type, Transparency of the lag Type, and the order in which the conditions were completed in, F(1, 24) = 2.99, p = .096.

After I completed the above analysis I carried out an independent samples t test looking at the effects linked to the order of the conditions. This identified no significant effects linked to the order of conditions in the language condition but did find effects on overall response times in the icon conditions. This was reflected in the icon condition being carried out far more slowly when completed after the language condition. In the icon TMTaba sequence there was a 171ms (SEM = 66.84) benefit, t(24) = 2.56, = .017, in the TTTaba sequence there was a 130ms (SEM = 58.82) benefit, t(24) = 2.21, = .037, there was also a 181ms (SEM = 69.51) benefit in the TMTcba sequence, t(24) = 2.60, p = .016, and finally there was an approaching significant 100ms (SEM = 58.24) benefit in the MTT sequence, t(24) = 1.72, p = .098, refer to table 19.

Table 19: Mean Reaction Time (ms) for order of conditions, by lag, across both conditions, in Experiment 8.

Experiment 8, Independent Samples t test of order of conditions.

Exp No	Condition	Lag Type	Difference between Language and Icon conditions: Mean difference	Std. Error difference	Mean response times: Language Cue	Icon Cue	t	df	Sig. (2-tailed)
4	Language Cue	ABA (TMT)	9.06	72.34	832.88	823.82	.125	24	.901
		ABA (TTT)	4.11	61.65	790.74	786.63	.067	24	.947
		CBA (TMT)	32.05	79.00	796.51	764.47	.406	24	.689
		CBA (MTT)	45.05	69.48	802.10	757.05	.648	24	.523
	Icon Cue	ABA (TMT)	171.24	66.84	650.72	821.95	2.562	24	.017
		ABA (TTT)	130.00	58.82	621.10	751.09	2.210	24	.037
		CBA (TMT)	180.57	69.51	621.51	802.08	2.598	24	.016
		CBA (MTT)	100.37	58.25	594.89	695.25	1.723	24	.098

I then completed pair wise t tests on all of the sequences ending with a T trial, separately comparing the icon and language conditions, TMTaba, TTTaba, MTTcba, and TMTaba sequences. I first analysed the language cued condition and found that the TMTaba sequences, unlike the other sequences, were on average 40 ms (SD = 88.40, SEM = 17.34) slower than the TTTaba sequences, t(25) = 2.30, p = .030, 47ms (SD = 84.34, SEM = 16.54) slower than the MTT sequences, t(25) = 2.87, p = .008, and 47 ms (SD = 93.91, SEM = 18.42) slower than the TMTcba sequences, t(25) = 2.55, p = .017. The other sequences were hardly different from each other, with the TTTaba sequences being only 8 ms (SD = 72.11, SEM = 14.14) slower than the MTTaba sequences, t(25) = .533, p = .599, and 7 ms (SD = 83.68, SEM = 16.41) slower than the TMTcba sequences, t(25) = .434, p = .668. Finally the

MTTcba sequences were 0.42 ms (SD = 81.50, SEM = 15.98) faster than a TMTcba sequences, t(25) = -.026, p = .979, refer to table 20 and figure 69.

Table 20: Mean Reaction Time (ms) for lag type across the Language Cue condition in Experiment 8.

Experiment 8, Pair wise t test comparing ABA and CBA sequences.

		Difference between ABA and CBA sequences			Mean Response Time				
Exp No	Condition	Mean Time difference	Std. Deviation	Std. Error Mean	ABA(TMT)	ABA(TTT)	t	df	Sig. (2-tailed)
8	Language Cues	39.86	88.40	17.34	828.70	788.84	2.299	25	.030
					ABA(TMT)	CBA(MTT)			
		47.40	84.34	16.54	828.70	781.30	2.866	25	.008
					ABA(TMT)	CBA(TMT)			
		46.98	93.91	18.41	828.70	781.72	2.551	25	.017
					ABA(TTT)	CBA(MTT)			
		7.54	72.11	14.14	788.84	781.30	.533	25	.599
					ABA(TTT)	CBA(TMT)			
		7.12	83.68	16.41	788.84	781.72	.434	25	.668
					CBA(MTT)	CBA(TMT)			
		0.41	81.50	15.98	781.30	781.72	.026	25	.979

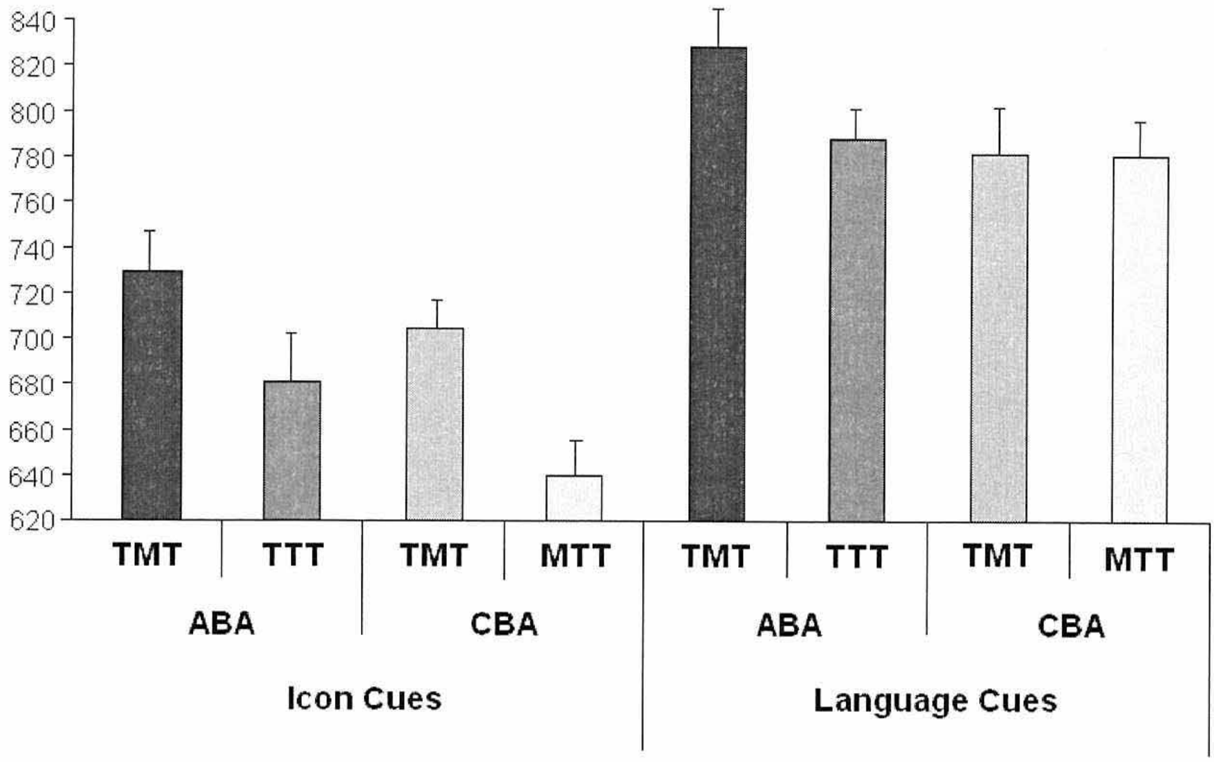


Figure 69: Mean Response Times (ms) across both conditions, cue type, and lag type in Experiment 8. Error bars show the standard error of the mean.

I then looked at the icon condition and found that nearly all of the sequences had approaching or significantly different response times. The pair wise t test showed that the TMTaba sequences were 49 ms (SD = 81.44, SEM = 15.97) slower than the TTTaba sequences, t(25) = 3.05, p = .005; they were also 89 ms (SD = 94.07, SEM = 18.45) slower than the MTTcba sequences, t(25) = 4.80, p < .001, and 25 ms (SD = 79.62, SEM = 15.61) slower than the TMTcba sequences, t(25) = 1.60, p = .123, although this was not significant unlike the other two previous sequences. Again, different to the language cues, the TTTaba sequences were 40 ms (SD = 61.56, SEM = 12.07) slower than the MTTcba sequences, t(25) = 3.30, p = .003, and 24 ms (SD = 67.92, SEM = 13.32) faster than the TMTcba sequences, t(25) = -1.78, p = 087. Finally the MTTcba sequences were also 64 ms (SD = 82.48, SEM = 16.17) faster than the TMTcba sequences, t(25) = 82.48, p = .001, refer to table 21.

Table 21: Mean Reaction Time (ms) comparing lag type for the icon cue condition in Experiment 8.

Experiment 8, Pair wise t test comparing ABA and CBA sequences.

		Difference between ABA and CBA sequences			Mean Response Time				
Exp No	Condition	Mean Time difference	Std. Deviation	Std. Error Mean	ABA(TMT)	ABA(TTT)	t	df	Sig. (2-tailed)
8	Icon Cues	48.65	81.44	15.97	729.75	681.10	3.046	25	.005
					ABA(TMT)	CBA(MTT)			
		88.54	94.07	18.45	729.75	641.21	4.799	25	.000
					ABA(TMT)	CBA(TMT)			
		24.90	79.62	15.61	729.75	704.85	1.595	25	.123
					ABA(TTT)	CBA(MTT)			
		39.89	61.56	12.07	681.10	641.21	3.304	25	.003
					ABA(TTT)	CBA(TMT)			
		23.75	67.92	13.32	681.10	704.85	1.783	25	.087
					CBA(MTT)	CBA(TMT)			
		63.64	82.48	16.17	641.21	704.85	3.934	25	.001

Because of the order effect, that had an approaching interaction with the Lag Type and the Transparency of the Lag type, I decided to repeat the above analysis on the two separate groups individually. I first looked at the group that did the language condition first and completed a 2x2x2 ANOVA, which compared Cue Type (Icon or Language) by Lag Type (ABA or CBA) by Transparency of the relationship between the cues and targets at Lag–1 and Lag–2 (TMT and TTT or TMT and MTT). I found that there was still a main effect of Cue Type, $F(1, 13) = 30.85$, $p < .001$, and Lag Type, $F(1, 13) = 7.40$, $p = .017$, and no main effect linked to the transparency of the cue type, $F(1, 13) = 2.40$, $p = .146$, but there was an approaching significant interaction between the Lag Type and the transparency of the lag type, F(1, 13) = 3.63,p = .079.

After this I completed separate planned comparisons of the language and icon cued conditions comparing the lag transparency sequence types using pair wise t tests.

In the language condition there seemed to be a very similar process occurring to those that were identified in the original analysis. This was because the TMTaba sequence was far more costly than all of the other sequence types and all of the other types of sequences had very similar response times. In this case none of these differences were significant but they were still going in the same direction as the initial analysis. This was reflected in the TMTaba sequence being 42ms (SD = 105.02, SEM = 28.07) more costly than the TTTaba sequence, t(13) = 1.50, p =.157, 31ms (SD = 79.04, SEM = 21.12) more costly than the MTTcba sequence, t(13) = 1.46, p = .169, and 36ms (SD =97.94 , SEM = 26.17) more costly than the TMTcba sequence, t(13) = 1.39, p =.188. Whereas the TTTaba sequence was only 11ms (SD = 65.80, SEM = 17.59) faster than the MTTcba sequence, t(13) = .646, p =.530 , and 6ms (SD = 91.38, SEM = 24.42) faster than the TMTaba sequence, t(13) = .236, p =.817. Finally the MTTcba sequence was only 6ms (SD = 71.52, SEM = 19.12) slower than the TMTcba sequence, t(13) = .292, p = .775, refer to figure 70.

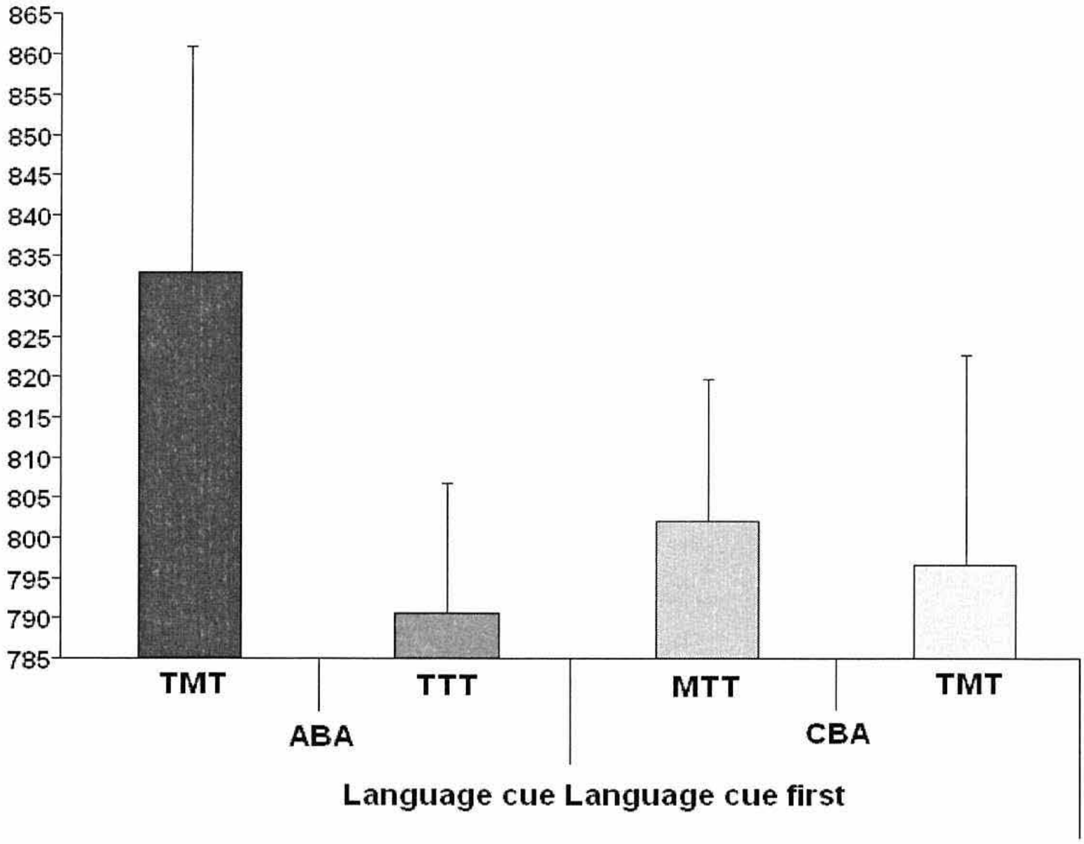


Figure 70: Illustrates the mean response times (ms) for lag type and trial sequence type of subject who carried out the Language cue condition first. Error bars show the standard error of the mean.

The icon conditions results again seemed very similar to those in the initial analysis as the transparency of the lag sequence in this case seemed to be having a major effect on their associated response times. The exception to this was in the TTTaba and TMTcba sequences response times as they were almost exactly the same. This was reflected in the TMTaba sequence being 30ms (SD = 53.75, SEM = 14.36) slower than the TTTaba sequence, $t(13) = 2.06$, $p = .060$, 56ms (SD = 43.57, SEM = 11.65) slower than the MTTcba sequence, $t(13) = 4.79$, $p < .001$, and 30ms (SD = 39.39, SEM = 10.53) slower than the TMTcba sequence, $t(13) = 2.78$, $p = .016$. The TTTaba sequence was also 26ms (SD = 60.93, SEM = 16.28) slower than the MTTcba sequence, $t(13) = 1.61$, $p = .131$, and the MTTcba sequence was 27ms (SD = 54.35, SEM = 14.52) faster than the TMTcba sequence, $t(13) = 1.83$, $p = .090$.

Finally as I previously mentioned there was only 0.41ms (SD = 70.26, SEM = 18.78) between the TTTcba and TMTcba sequences, t(13) = .022, p =.983, refer to figure 71.

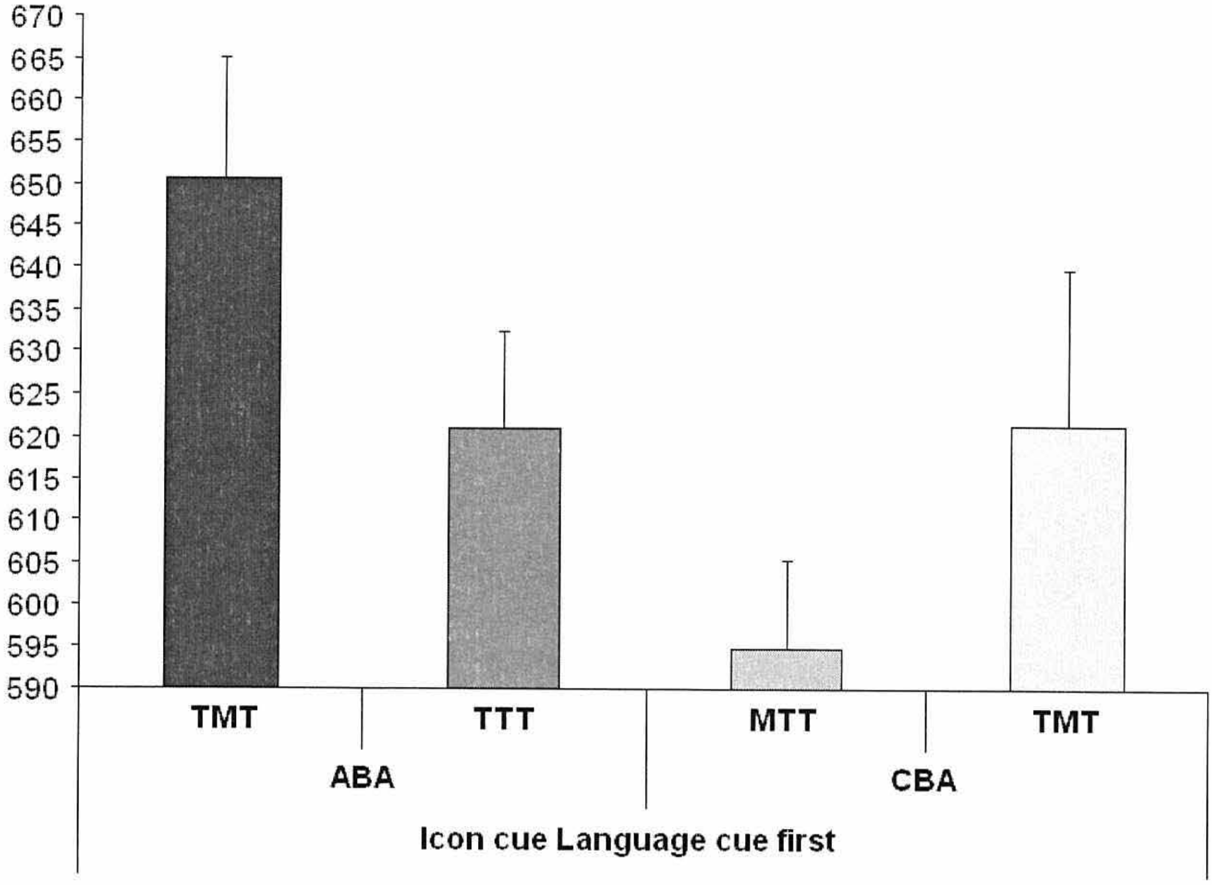


Figure 71: Illustrates the mean response times (ms) for lag type and trial sequence type of subject who carried out the Icon cue, Language cue condition first. Error bars show the standard error of the mean.

I then repeated the above analysis on the group that had carried out the icon cued condition first and found the following, again completing a 2x2x2 ANOVA comparing Cue Type (Language or icon), by Lag Type (ABA or CBA), by Transparency of Lag Type (TMTaba and TTTaba or MTTcba and TMTcba). Unlike the group that did the language cued condition first, there was no main effect of Cue type, $F(1, 11) = .181$, $p = .679$, although there was a main effect of Lag Type, $F(1, 11) = 8.90$, $p = .012$, but no effect linked to transparency, $F(1, 11) = .013$, $p = .912$. There was also a two way interaction between Lag

Type and the transparency type, F(1, 11) = 23.54, p = .001, and a three way interaction between Cue type, Lag Type, and the transparency type, F(1, 11) = 5.00, p = .047.

I then used pair wise t tests to compare the sequences and found the following. The language cued conditions TMTaba sequence were again more costly than all of the other sequence types, being 37ms (SD = 68.66, SEM = 19.82) more costly than the TTTaba sequence, t(11) = 1.88, p = .087, 67ms (SD = 89.57, SEM = 25.86) more costly than the MTTcba sequence, and 59ms (SD = 91.63, SEM = 26.45) more costly than the TMTcba sequence, t(11) = 2.24, p =.046. The TTTaba sequence was 30ms (SD = 75.62, SEM = 21.83) more costly than the MTTcba sequence, t(11) = 1.36, p = .203, and 22ms (SD = 74.75, SEM = 21.58) more costly than the TMTcba sequence, t(11) = 1.03, p = .326, neither of which were significant. Finally the MTTcba sequence was only 7ms (SD = 94.62, SEM = 27.31) faster than the TMTcba sequence which was again not significant, t(11) = .272, p = .791, refer to figure 72.

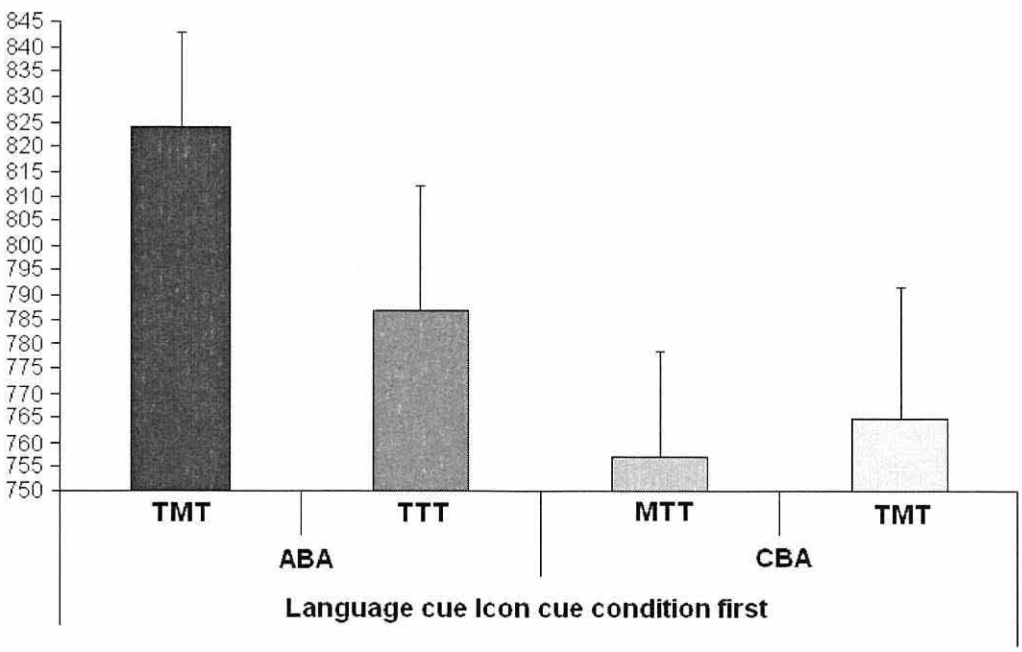


Figure 72: Illustrates the mean response times (ms) for lag type and trial sequence type of subject who carried out the Language cue condition first. Error bars show the standard error of the mean.

Planned comparisons, using pair wise tests, were then used on the icon condition. They found that all of the other sequences were substantially quicker than the TMTaba and TMTcba sequences, which were not significantly different. This was reflected in the TMTaba sequence being 70ms (SD = 103.25, SEM =29.81) slower than the TTTaba sequence, t(11) = 2.38, p =.037, 127ms (SD = 122.13579, SEM =35.25756) slower than the MTTcba sequence, t(11) = 3.593, p =.004, but only 20ms (SD = 111.90, SEM =32.30) slower than the TMTcba sequence, t(11) = .615, p =.551. The TTTaba sequence was also 56ms (SD = 60.91, SEM =17.58) slower than the MTT sequence, t(11) = 3.18, p =.009, whereas the TMTcba sequence was 51ms (SD = 56.10, SEM =16.19) slower than the TTTaba sequence, t(11) = 3.15, p =.009, and 107ms (SD = 90.50, SEM =26.13) slower than the MTT sequence, t(11) = 4.09, p =.002, refer to figures 73, 74, 75.

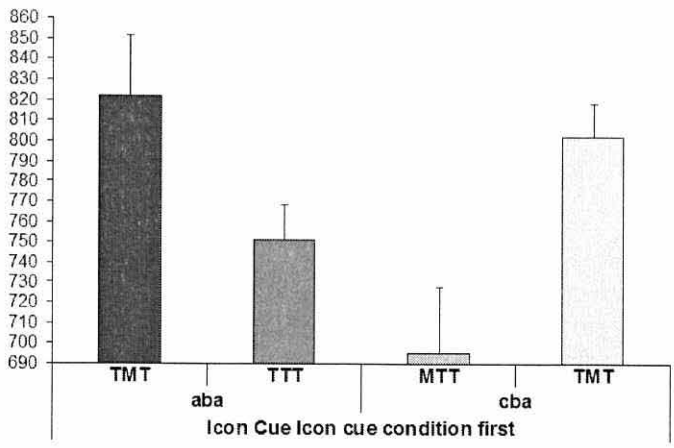


Figure 73: Illustrates the mean response times (ms) for lag type and trial sequence type of subject who carried out the Icon cue condition first. Error bars show the standard error of the mean.

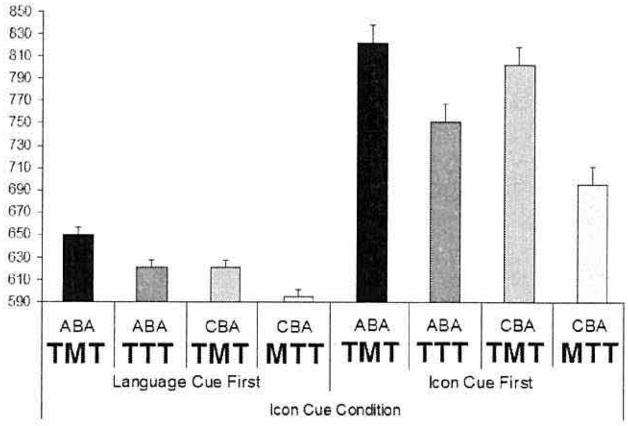


Figure 74: Mean response times (ms) for the icon cue condition, across both order, lag type and cue type. Error bars show the standard error of the mean.

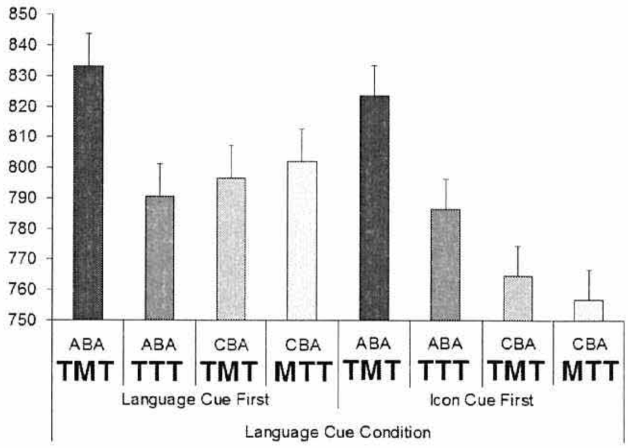


Figure 75: Mean response times (ms) for the language cue condition, across both order, lag type and cue type. Error bars show the standard error of the mean.

Analysis of sequences ending with an M trial

After this I looked at the two sequences that finished with an M trial, the MTMaba and TTMcba sequences, comparing them in the language and icon conditions, while taking into consideration the order in which the experiments were carried out. This I did by using a 2x2 within by 2 between Mixed ANOVA that compared Cue Type (Language or Icon condition) by Lag Type (MTMaba or TTMcba sequences) within and between the order of conditions (Language or icon cued condition first).

This analysis identified a main effect of Cue Type, $F(1, 24) = 46.43$, $p < .001$, which interacted with the order in which the conditions were completed in, $F(1, 24) = 9.83$, $p = .004$. There was no main effect of Lag Type transparency, $F(1, 24) = .845$, $p = .367$, although there was an approaching significant interaction between Lag Type transparency, and the order in which the conditions were completed in, $F(1, 24) = 3.17$, $p = .088$. I then completed planned comparisons, linked to the above order effect identified, using an independent samples t test. This identified an order effect very similar to the one previously seen in the sequences ending with a T trial. In the sequences ending with an M trial there seemed to be a general benefit in overall response times in the second condition completed, although this was only significant in the icon cued condition. This seemed to have little effect on the backward inhibition costs in the language condition but did seem to increase this cost in the icon condition when the language condition was completed first.

The independent t test showed that the language conditions MTMaba sequence was 57ms (SED = 48.34) faster, $t(24) = 1.18$, $p = .249$, and the TTMcba sequence was 21ms (SED =43.39) faster, , $t(24) =.479$, $p = .636$, when icon condition was completed prior to the language condition, refer to figure 76 and table 22.

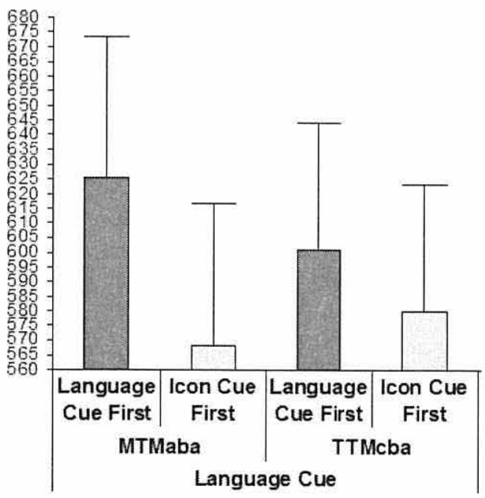


Figure 76: Illustrates the mean response times (ms) for the Language cue condition, across both order, trial sequence type and lag type. Error bars show the standard error of the mean.

The icon conditions MTMaba sequence were similarly 62ms (SED =31.04) faster, t(24) = 2.00, p = .058, and the TTMcba sequence was -65.52 ms (SED = 32.34) faster, , t(24) = -2.03 , p = .054, when the language cued condition was completed prior to the icon condition, refer to figure 77 and table 22.

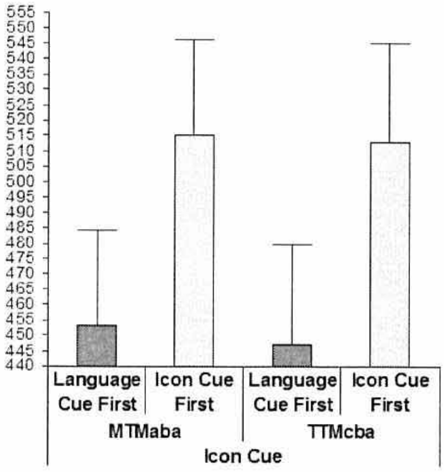


Figure 77: Illustrates the mean response times (ms) for the icon cue condition, across both order, trial sequence type and lag type. Error bars show the standard error of the mean.

Table 22: A comparison of the order of conditions mean response times (ms), across condition, lag type and trial sequence type.

Experiment 8, Independent Samples t test of order of conditions.

			Difference between Language and Icon conditions		Mean response times				
Exp No	Condition	Lag Type	Mean difference	Std. Error difference	Language Cue	Icon Cue	t	df	Sig. (2-tailed)
4	Language Cue	ABA (MTM)	57.15	48.34	625.25	568.10	1.182	24	.249
		CBA (TTM)	20.80	43.39	600.89	580.09	.479	24	.636
	Icon Cue	ABA (MTM)	61.79	31.04	453.26	515.05	1.991	24	.058
		CBA (TTM)	65.52	32.34	447.24	512.76	2.026	24	.054

Because of previously identified approaching significant interaction between the lag type and the order in which the conditions were completed, I separated the participants into two separate groups. This was dependent on whether they had completed the icon or language condition first. I then used pair wise t tests to compare the Lag Type transparency sequences in the two groups.

In the both of the groups, I first competed two 2x2 ANOVAs on each group, comparing Cue Type (language or Icon Cue) by Lag Type transparency (MTMaba or TTMcba). In the group that completed the Icon Cued condition first there was still a main effect of Cue type, $F(1, 13) = 43.12$, $p < .001$, there was also a main effect of Lag Type transparency, $F(1, 13) = 6.17$, $p =.028$, which did not interact, $F(1, 13) = 2.10$, $p = .171$. In the group that did the icon condition first there was again a main effect of Cue type, $F(1, 11) = 8.70$, $p = .013$, although there was no main effect of Lag Type, $F(1, 11) = .242$, $p = .633$, or interaction, $F(1, 11) = .681$, $p = .427$.

I then completed pair wise t tests, on the two different groups separately, comparing the Lag type transparencies. In the group that did the language cued condition first there was 24ms (SD = 39.38, SEM = 10.52) cost when doing the MTMaba sequence, $t(13) = 2.32$, $p = .038$, in the language cued condition, when compared to the TTMcba sequence. There was no significant difference between the MTMaba and TTMcba sequences in the icon condition (MRT = 6.02ms, SD = 24.93, SEM = 6.66), $t(13) = .903$, $p = .383$, refer to table.

In the group that completed the icon condition first, pair wise t tests showed there was no backward inhibition cost in either of the cued conditions. In fact in the language cued condition there was a 12ms (SD = 33.22, SEM = 9.59) benefit when doing the MTMaba sequence when compared to the TTMcba sequence, $t(11) = 1.25$, $p = .237$. There was also only 3ms (SD = 55.00, SEM = 15.88) separating the MTMaba and TTMcba sequences in the icon cued condition, t(11) = .145, p = .888.

Summary of results

The initial results showed that different transparencies of the cue-target relationships at lag-1 and lag-2 had a direct effect upon the response times of a trial at lag-0.

This effect influenced the previously seen classic backward inhibition costs associated with an ABA sequence. This was best reflected in the icon conditions TMT sequences which were the most costly whether or not they were an ABA or CBA sequence. It suggested that when a language label was not required in an M trial, at lag-1, in a TMT sequence, both the previous top down language label and the cognitive system that generated it at lag-2 were equally inhibited.

What also became apparent was an order affect that speeded up the overall response times in the second condition completed. This effect was only significant in the icon condition although there also seemed to be an underlying trend in this direction in the language condition too.

An order effect was also identified linked to an approaching significant interaction that occurred between it and all of the other variables. Because of this I also split the participants into two groups linked to which condition they completed first. The results seemed to confirm the above hypothesis that explained why the TMTaba and TMTcba trials were the most costly in the icon condition. This was reflected in the results, in the icon condition, showing that the TMTcba sequences were significantly faster than the TMTaba sequence when the language cued condition was completed first, but not when the icon condition was completed second. It suggested that when the language condition is completed first a top down label is used for the M trials but not when the icon condition is completed first. Because of this when the language cued condition is completed first the system used to generate the language label cannot be inhibited.

I also looked at the sequences that finished with an M trial expecting there to be no cost differences between sequences due to the M trials not necessarily needing a top down language label. This seemed initially to be correct as there was no main effect of lag type identified. But there was an approaching significant interaction between lag type and the order of conditions so I again looked at the two groups that did different conditions first. I found that there was only backward inhibition in the language condition, when it was completed first, and not when completed second. It again suggested that a language label was being used, in the language cued condition, when an M trial was completed, but only when the language cued condition was completed first.

The same order effect, as seen previously in the sequences ending with a T trial, linked to an improvement in overall response time in the second condition completed, was also noted.

Experiment 8 Discussion

The results of the sequences that ended with a T trial were not as predicted and needed to be considered carefully. Firstly, both the ABA and CBA the TMT sequences, in the icon condition, were significantly slower than both the TTT (ABA) and MTT (CBA) sequences. This was very much like the Gade and Koch (2007) results as their TUT sequences also took more time than their TTT sequences. It suggested that an extra process was in operation when switching from a trial that required a language label to one that does not. It implies that there may be a process that inhibits the system that applies the language label in the icon cued condition. The language cued experiment seems to be doing something different to the icon cued condition. In this condition both the TMT and TTT (ABA) sequences were more costly than the TMT and MTT (CBA) sequences. This suggests that the M trials are being treated differently. The only obvious difference between them is that the M trial, in the icon condition, would have no need to automatically access the language system unlike the M trial in the language cued condition.

However what is not occurring in the icon and language cued conditions is what I originally proposed as the TTT (ABA) sequence is not the most costly. It is unclear whether within trial conflict is causing the cost, or between trial conflict of the language labels. What is apparent however is that the icon cued condition's M trial seems to be interacting differently with the T trials when compared with the language conditions. This suggests that the M trial in the icon cued condition, which is likely not to be using a language label, may be generally inhibiting the language system. What I can take from this experiment is that the language system associated with labelling the bottom up visual image seems to be integral in explaining some of the costs associated with backward inhibition.

One other final result that is apparent but not significant is a trend that shows a reversal in the amount of backward inhibition costs when the TMT (ABA) and TMT (CBA) difference is compared with that of the TTT (ABA) and MTT (sequences) in the icon and language conditions. In the icon condition the backward inhibition cost in the TMT sequences is smaller than that of the cost difference between the TTT and MTT sequences. This backward inhibition cost is reversed in the language cued condition.

In conclusion, the top down language element of the trial does seem to be playing some part in the backward inhibition costs. What is not clear is how much of a part in backward inhibition any of the bottom up components in the cue are playing.

Experiment 9 - alterations in CTI and RCI within and between conditions.

Experiment 9 tried again to see how much of the backward inhibition cost was linked to between trial inhibition of conflicting top down language labels and how much may be linked to within trial conflict between the bottom up visual image of the cue and target. This I proposed to do through altering the CTI and RCI. As I have previously mentioned, Gade and Koch (2005) had shown how the activation of a previously conflicting trial was directly linked to the amount of backward inhibition cost observed. Activation was directly linked to the proximity in time between the previous response and the up and coming cue, the response cue interval (RCI). The closer in time between them, the higher the level of activation in the response, which needed greater inhibition on the arrival of the new cue, that led subsequently to more cost in a trial in an ABA sequence. I proposed therefore to have two conditions: one with a long cue target interval (CTI) and short RCI, and another with a short CTI and a long RCI. My previous experiments had suggested that much of the backward inhibition cost is linked to between trial conflict unless the cue is abstract, where within trial conflict can also occur between conflicting top down language labels. There has however been a suggestion that there may also be a bottom up cost linked to conflict within trial between the bottom up visual representations of the cue and target. If this was correct, then I believed that by altering the CTI and RCI, it would be possible to determine where that conflict was. In the short CTI, long RCI condition, conflict will predominantly occur within trial whereas in the long CTI short RCI condition it will occur principally between conditions. If cost is greater in the condition where conflict occurred within trial, it is likely that most of the cost is linked to conflict between the cue and target. Conversely, if backward inhibition cost is greater in the condition where there is more conflict between trials, it is the top down label that is causing the greatest cost.

The CSI has been linked to a means of measuring the endogenous preparation time for a change in task, which Logan and Bundesen (2003) have previously challenged (Monsell & Mizon, 2006). Monsell and Mizon (2006) note how this component of the methodology has tended to be ignored in the past as it has only been seen as a precursor to endogenous processing of the up and coming task. The CTI has been shown to reduce the time cost associated with a switch in task as it increases in time, and has been reduced to 0ms (Logan & Bundesen, 2003). Logan and Bundesen (2003) used several different CTIs and found they had a dramatic effect in comparison to altering the RCI. Although they accounted for costs in task switching experiments as not originating from endogenous processes, but as a consequence of compound cue-target priming in the repeat of cues, they nevertheless stated that the CTI differences had highlighted processes that were occurring between the cue and targets presentation. Mayr and Kliegl (2003) found that the CTI interacted with a change in cue and practice, although they did not find a reduction in switch costs that was linked to changing the CTI. Monsell and Mizon (2006) highlighted how this dichotomy between Logan and Bundesen's (2003) and Mayr and Kliegl's(2003) results relating to CTI , where Mayr and Kliegl did not find a reduction in switch cost times related to increasing CTI, did make it problematic to suggest that CTI was linked to endogenous process related to the reconfiguration of the task set.

Monsell and Mizon's (2006) first experiment used sound cues, and directional language targets that were embedded into a directional arrow, and responses were left or right placed keys (please refer to chapter 4); they found little to no effect linked to the CTI. In their second experiment where they used a location cue, and language targets, that either had to be responded to as bigger or smaller than a football, or contained one or two syllables, they found that the longer CTI caused a reduction in task switching costs. They concluded in this experiment that the CTI was an index of endogenous reconfiguration of task set. Experiment 3 was the same design as experiment 2 except the location cue was replaced by iconic cue. This CTI effect was noted again but reduced from a 110 ms benefit to a 60ms benefit in a task switch, when comparing a long to short CTI in the third experiment. In their fourth experiment, the effect that the longer CTI had on the reduction in task switching costs was noted to be directly affected by the probability of a switch in task in comparison to a repeat of task. The higher the probability of a switch in task, the more likely the participant would prepare for the change in task prior to the arrival of the cue, so any CTI effects were lost. This probability effect should in turn not affect our results as participants cannot simply prepare in advance for a switch in task, as they do when only two tasks are involved, as they would be unaware of what cue is about to occur. In Monsell and Mizons (2006) experiment 4 they used iconic and language cues, which were linked to identifying the colour or shape of that target, which was communicated by making a response onto one of four keys that represent one colour and one shape on one key. Monsell and Mizon (2006) were also concerned that the CTI was constant in the Mayr and Kliegl (2003) experiment and fluctuated in the Logan and Bundesen (2003) experiment and this constancy of CTI may be a hidden confounding variable. Their concerns were linked to the Rogers and Monsell's (1995) finding that in predictable switches in an AABBAABB sequence of tasks, an increase in the time between a responses and the appearance of a stimuli (RS) reduced switch costs when the RS was constant within block, but was removed when it fluctuated within block. Rogers and Monsell (1995) accounted for this as the participant actively endogenously preparing for a task when the RS was constant but not when it fluctuated. If this were the case then in the

Logan and Bundesen's (2003) experiment participants may have not been actively preparing for the task that would be counter to Monsell and Mizon's (2006) conclusions. Monsell and Mizon's (2006) fifth experiment therefore fluctuated the CTI to see if it would discourage active preparation for the task. Their result showed that it had little effect but slightly reduced the benefits of longer preparation times. They concluded that, as the RCI remains constant, this encourages preparation and although the CTI alters, the participants still use the cue to prepare for a task switch, when the probability of that switch remains low. Monsell and Mizon (2006) also conclude that when the transparency between the cue and target is very low, this becomes a task in itself.

Gade and Koch (in press) wished to show, in their experiment using two cues to one stimuli, that it was task processes that were being inhibited and reactivated, and not cue process that was linked to priming (Schneider & Logan, 2005), that were the basis of costs that we are seeing in ABA sequences. Gade and Koch (in press) found ABA costs when using both short and long CTIs and concluded that it is task processing and not cue processing that is the target for inhibition. My experimental results would suggest that they may to a degree be almost completely correct, but that the cue-target relationship is still important part of task processing. My results would suggest that if this interplay between the top down language labels that represent the cue and target occurs, then it is likely to continue down the line with the target and response having the same conflict, which finally occurs between the response in that trial and the next cue in the upcoming trial. If this is the case then it is the processing of the task that is the target of inhibition, but in a graduated way based on the conflict between each component of the task-set and finally with the up and coming task set. An aggregate of these inhibited top down language and visual top down language labels that represent each step of moving through the trial would then need to be reactivated.

Mayr and Keele (2000) altered the CTI to check that sequential expectancy theory was contributing to the ABA cost (i.e. when the participant is believed to expect a CBA sequence and when this does not occur a cost is incurred). There was no CTI effect found that interacted with the ABA cost. This allowed Mayr and Keele (2000) to reject the expectancy violation as an answer to why they were seeing costs, and to link ABA costs to the inhibition of the task set. They did find that the longer CTI improved overall response times but this was not linked to the inhibition they were seeing, but was seen as a part of the process of preparation. Mayr and Keele (2000) found that smaller RCI did heighten the ABA costs but there was some inconsistency in this result compared with other experiments they completed. It was proposed that this cost was linked to the conflict between the two trials, and that a larger amount of inhibition may be required when they were in close proximity to each other.

This insight was later tested and confirmed by Gade and Koch (2005). They altered the RCI in two experiments comparing its effects on ABA and CBA sequences. They looked at the relationship between task activation and task inhibition, specifically testing two theoretical explanations for how inhibition and activation may interact. One of these theories suggested that inhibition was linked to a gradual decrease in the level of inhibition. The alternative sees inhibition being directly linked to activation, as activation of new task set causes confusion in the cognitive system, and inhibition resolves this conflict. Gade and Koch analysed this by comparing ABA and CBA switches, but also took into consideration the n-2 RCI (RCI in trial n-2), and the n-1 RCI (RCI in trial n-1) in the sequence. If inhibition was directly linked to activation, then the n-2 RCI should affect cost in an ABA sequence and the n-1 RCI should have little to no effect on the ABA cost. This is what they found and therefore they linked inhibition directly to the activation of the previous task set at lag-2.

Taking all of the findings described above into consideration, I decided to repeat experiment 1, but altered the CTI and RCI in the conditions and split the participants into two separate groups. One group's conditions had a short CTI and long RCI, whereas the other group had a long CTI and short RCI. Each group, as in experiment 1, had an implicitly cued language condition and an explicit matching icon target condition. I proposed, as there was likely to be no conflict within trial between the bottom up representation of the cue and target, as well as no use of a top down language label, there would be no backward inhibition cost in the icon condition in either group. In the language condition, I predicted that if there was a greater backward inhibition cost in the short CTI long RCI group, most of the backward inhibition cost was linked to bottom up conflict within trial. On the other hand, if the greatest backward inhibition cost was greatest in the long CTI and short RCI group, cost was linked to between trial conflicts of the top down language labels.

Experiment 9 Method

Participants

There were 30 students drawn from the same student pool as in previous experiments, who were similarly rewarded.

Design

Experiment 9 was the same as Experiment 1, except for the following factor. There were two separate groups, one of which had a CTI of 50ms and a RCI of 500ms, whereas the other group had a 500ms CSI and a 50ms RCI. In no other way did this experiment differ from experiment 1.

Experiment 9 Results

No participants needed to removed because of error and significant effects or interaction were identified that were linked to error.

I initially completed 2x2 within by 2 between Mixed ANOVA, comparing Cue Type (Language or icon cue), by lag Type (ABA or CBA), within, between the type of CTI and RCI (CTI 500ms – RCI 50ms or CTI 50ms – RCI 500ms) carried out.

This analysis showed a main effect of Cue Type, $F(1, 28) = 31.70$, $p < .001$, and Lag Type, $F(1, 28) = 7.57$, $p < .010$, that did not interact with the type of CTI and RCI. Post hoc analysis using pair wise t tests identified an approaching significant 9ms (SD = 27.07, SEM = 4.94) cost when doing the ABA sequence in comparison to the CBA sequence, $t(29) = 1.89$, $p = .069$. There was also a significant 18ms (SD = 43.87, SEM = 8.01) cost when doing the ABA sequence in comparison to the CBA sequence when using the language cue, $t(29) = 2.31$, $p = .028$, refer to figure 78 and table 23.

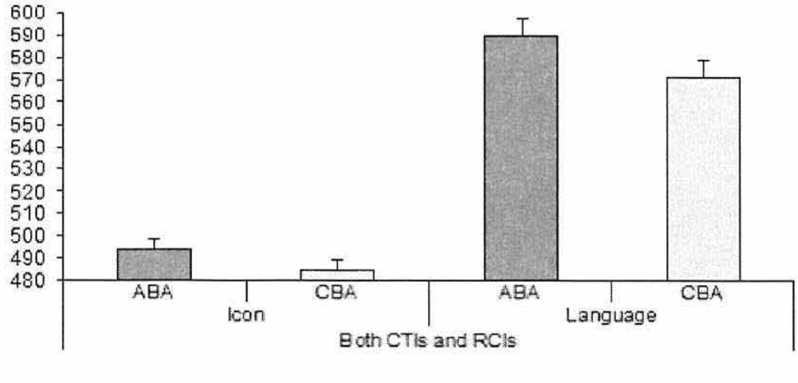


Figure 78: Illustrates the mean response times (ms) for lag type and cue type for both response cue interval (RCI) and long cue target interval (CTI) conditions. Error bars show the standard error of the mean.

Table 23: A comparison of mean response times (ms) across lag type, cue type and both response cue interval (RCI) and long cue target interval (CTI) conditions.

Experiment 9, Pair wise t test comparing ABA and CBA sequences.

		Mean Response Time		Difference between ABA and CBA sequences					
Exp No	Condition	ABA	CBA	Mean Time difference	Std. Deviation	Std. Error Mean	t Value	df	Sig. (2-tailed)
9	Icon Cue Both CTI & RCI	494.15ms	484.82ms	9.33ms	27.07	4.94	1.888	29	.069
	Language Cue Both CTI & RCI	589.88ms	571.40ms	18.48ms	43.87	8.01	2.307	29	.028

Summary of results

The above results identified that when participants were doing a trial using an icon cue they were far faster than when they did a trial using a language cue. What also became apparent was that in both the icon and language cued conditions; they were, on average, faster when doing a trial in an ABA sequence in comparison to a CBA sequence. The CTI and RCI did not seem to differentiate between these results in either of the conditions. What did occur, which was not evident in the icon condition in experiment 1, was that there now did seem to be a backward inhibition cost. It did seem to suggest that the difference in the CTI and RCI to that of experiment 1 was influencing the appearance of this cost.

Experiment 9 Discussion

These results were very interesting, even though initially there was no significant difference found between the two groups, when compared together. When the groups were looked at separately, there was a suggestion that there was an underlying effect. In the 50ms CTI – 500ms RCI group, there was no backward inhibition cost. This suggested that bottom up conflict between the visual image of the cue and target had little to nothing to do with the previous backward inhibition costs found. In the 500ms CTI – 50ms RCI group there was a backward inhibition cost in both groups which suggested that the previous backward inhibition cost was linked to conflict between the trial's top down language labels. The backward inhibition cost in the icon condition may have been linked to the necessity to recruit a language label to remember the target over the 500ms between the cue and target's appearance. What seems to be clear from this experiment is that it is more likely that it is between trial conflict that is causing the inhibition that leads to backward inhibition, and not within trial conflict. It also seems to be linked to the inhibitor of conflicting top down language labels and not bottom up factors within trial.

Chapter 5 Discussion

Although both of the above experiments results were inconclusive, their findings continued to highlight the importance of the role that a top down language label may be playing in backward inhibition costs. It seemed in the icon condition in experiment 8 that the mechanism that assists in the application of a language label to a target was being inhibited as much as the previous top down language label itself. There are some previous experiments on the Stroop effect that I have already mentioned that may give some weight to this idea. Allport and Wylie (2000) showed how it was more costly to return to a well practised task than to a less practised task when switching between colour identification (less practised task) and reading the word (well practised task). This effect, the reverse Stroop effect, was believed to occur because of the larger amount of inhibition required inhibiting the mechanism linked to reading in comparison to identifying the colour. A similar process could have been going on here when switching to a cue-target relationship that did not need a top down language label. Experiment 9's results did seem to suggest that it was conflict between trials' top down language labels that was causing the cost. This was inconclusive statistically but a significant backward inhibition cost was only found in the short RCI condition. Any bottom up conflict between the previous trial's target and the up and coming new trial's cue was also highly unlikely, as this conflict was exactly the same in all of the previous experiments, whether there was a backward inhibition cost or not. It is highly likely that these results suggest that the backward inhibition cost, which we are seeing in all of the previous experiments, is linked to the inhibition of an amalgamated bottom up and top down language label code when it comes into conflict with a different top down language label. Cost is highly likely to result from the reapplication of a previously inhibited top down language label, or its amalgamated code, to a new bottom up visual image in working memory.

Chapter 6

Response selection

Chapter 6 Abstract

In the previous experiments, one factor was overlooked, as it was believed to be playing little to no part in affecting backward inhibition costs; this was the position of the target. Chapter 6 looks specifically at this question. Experiment 9 is revisited and the position of the target in both an ABA and CBA sequence is factored in. Because of methodological concerns that made any statistical analysis questionable, the analysis was carried out cautiously to look for any potential trends that may influence future experiments. It was hypothesised that if there was only backward inhibition, in an ABA sequence, when the target position changed, there was a high likelihood that episodic priming rather than inhibition had been seen in the previous experiments. However, if backward inhibition was present in both circumstances where the target's position repeated or changed, in an ABA sequence, we were seeing inhibition and not episodic priming. The results suggested that both inhibition and episodic priming were occurring, it being dependant on the cue type and the CTI and RCI which of the two cognitive processes were in operation.

Chapter Summary

Chapter 6 takes into consideration the possibility that we may have been seeing episodic priming of the target, based on the position of the response, in all of the previous experiments. All of the previous experiments have seemed to be suggesting that we are seeing inhibition of the top down language label, with cost being linked to the reapplication to a new bottom up image. The experiments described in Chapter 4 could only partially prove this, as the results were inconclusive. There was a suggestion that when there is only one language label for two cues the AB'A' sequence is the most costly and when there is a unique language label for each of the two cues the ABA sequence was more costly. Taking into account that position had not been factored into the methodology, because Mayr and Keele (2000) had found this not to be a problem, I proceeded to do some planned comparisons on response position in Experiment 9. Realising that any significant differences could also be linked to a practice effect, due to 0.75% of trials being a change in position and only 0.25% were repeats, any interpretation of the results needed to be taken very guardedly. If episodic priming was a factor in these costs then there should only be a cost in the ABA sequence where the position of the response, at lag-2, had changed, and priming where it repeats. The results were very interesting as episodic priming and backward inhibition both seemed to be in operation. Episodic priming was apparent in the language condition in the 500ms CTI – 50ms RCI group whereas backward inhibition was seen in the 50ms CTI – 500ms RCI group. This was completely different in the icon condition, as episodic priming was occurring in the 50ms CTI – 500ms RCI group and backward inhibition was seen in the 500ms CTI – 50ms RCI.

These final results seem to suggest that the cost associated with an ABA sequence may be linked to a combination of episodic priming and backward inhibition. It may also explain why previous researchers are reaching such different interpretations of their results. Simple methodological changes in the transparency of the cue-target relationship, and maybe response transparency, combined with changes in CTI and RTI, may subtly alter the results so that the episodic priming becomes more evident in some experiments and backward inhibition in others.

Throughout this study, I have tried to use similar methodology, only changing the cue-target relationships, so that I could specifically look at how the cue-target relationship may be influencing cost. What has been forgotten up until this point is that of response position of the target at lag-2 and does it repeat itself at lag-0. Because of the methodology used throughout the experiments, 75% of response positions were different to the response at lag-2 and 25% of the responses were the same as the response position at lag-2. This methodological anomaly was the same in Mayr and Keele (2000) experiment and noted by them in their initial paper. Mayr and Keele (2000) decided that this aspect of the methodology was little understood in the context of task switching experiments (Rogers & Monsell, 1995), so decided to remove response repetitions at lag-2 and lag-1 from their research data, as they had found that their inclusion had little effect on the overall findings. Because of the previous results and the debate I have been having about whether inhibition is focussed on within trial components or between trials, I thought it was important to look at this aspect in more detail. More importantly Gade and Koch (2005, 2007) have recently highlighted how cost may be linked to inhibition of overlapping response top down language labels, rather than overlapping stimulus top down language labels. Because of this, I decided to look again at the results from experiment 9, and now to also factor in the response position. This was because the results of Experiment 8 seemed to suggest that the icon and language cued conditions were doing something different in relation to backward inhibition. The results from experiment 9 had further suggested that the CTI and RCI may be able to highlight what was happening. When looking at the following results I took into consideration that statistically their findings may be flawed, as this factor was not taken into consideration previously. I was also aware that the frequency of the repeat and non repeat of position trials was also not equally balanced so any effect could be as much be linked to frequency as to the position of response.

This planned comparisons was completed with the foreknowledge that statistically it had little to no power, as only 25% of trials repeated the position of the target at lag-2; therefore any cost difference we found may be linked to the frequency difference between repeats and non repeats of position as much as to the topographical position of the target in relation to the other stimuli.

Further Analysis of Experiment 9

After I had carried out the analysis for experiment 9, I then completed 2x2x2 within by 2 between Mixed ANOVA, comparing Cue Type (Language or icon cue), by lag Type (ABA or CBA), by Position of target (Repeat or non repeat of the position at lag-2), within, between the type of CTI and RCI (CTI 500ms – RCI 50ms or CTI 50ms – RCI 500ms). While taking into consideration the statistical anomalies that may undermine these findings, I looked for any trends that may influence further research into this area.

The above statistical analysis identified a main effect of Cue Type, $F(1,28) = 29.92$, $p < .001$, an approaching significant main effect of Lag Type, $F(1,28) = 3.65$, $p = .066$, and a main effect of the Position Type, $F(1,28) = 4.14$, $p = .051$. Position type also interacted with the type of CTI and RCI that a group of participants had carried out, $F(1,28) = 4.68$, $p = .039$; there was also an approaching significant interaction between Lag Type and Position Type, F(1,28) = 3.53, p = .070, finally there was a four way interaction between the Cue Type, Lag Type, Position Type, and the type of CTI and RCI used, F(1,28) = 18.95, p < .001.

Because of all of the main effects identified, interacting with the type of CTI and RCI carried out by participants, I repeated the above analysis again on the two different groups that had differing CTI and RCI.

I first looked at the group that had a 50ms CTI and 500ms RCI and carried out a 2x2x2 ANOVA, comparing Cue Type (Language or Icon Cue), by Lag Type (ABA or CBA), by Position of target (Repeat or non repeat of targets position at lag-2), and found the following. There was a main effect of Cue Type, F(1,28) = 16.95, p = .001, no main effect of Lag Type, F(1,28) = 1.71, p = .212, and a main effect of Position Type, F(1,28) = 7.81, p = .014. There was also a three way interaction between Cue Type, Lag Type, and Position Type, F(1,28) = 10.98, p = .005.

I then completed pair wise t tests that compared the ABA and CBA sequences, that was dependent upon whether the position of the target at Lag-0 was a repeat or non repeat of the position of the target at Lag-2. This identified that, in the icon condition, the ABA sequence was 21ms (SD = 67.24, SEM = 17.36) faster than the CBA sequence, where there was a repeat of position, t(14) = 1.23, p = .240. This effect was reversed when there was change of position of the target when there was now a 18ms (SD = 30.52, SEM = 7.88) cost when doing the ABA sequence in comparison of the CBA sequence t(14) = 2.28, p = .038. The language cued conditions ABA sequence, unlike the icon condition, had a 34ms (SD = 61.88, SEM = 15.98) cost in comparison to the CBA sequence, when the position of the target was repeated t(14) = 2.16, p = .049. There was a reduced level of cost, when there was a non repeat of position, with only a 12ms (SD = 51.65, SEM = 13.34) non significant cost when doing the ABA sequence in comparison to the CBA sequence, t(14) = .943, p = .362, refer to table.

After the above I then looked at the group that had a CTI of 500ms and RCI of 50ms and again completed a 2x2x2 ANOVA, comparing Cue Type (Language or Icon Cue), by Lag Type (ABA or CBA), by Position of target (Repeat or non repeat of targets position at lag-2) and found the following.

These results, like the above group, identified a main effect of Cue Type, F(1, 14) = 12.99, p = .003, no main effect of Lag Type, F(1, 14) = 2.15, p = .165, but unlike the above group there was now a main effect of position, F(1, 14) = .009, p = .924. There was also a significant interaction between the Lag Type and the position of the target, F(1, 14) = 6.99, p = .019, and a three way interaction between the Cue Type, Lag Type, and Position Type, F(1, 14) = 8.08, p = .013.

Post hoc t tests comparing the ABA and CBA sequences, that take into consideration whether the position of the target is repeated again or not, identified the following.

The ABA sequence was 13ms (SD = 41.69, SEM = 10.76) slower than the CBA when the position was repeated, t(14) = 1.21 , p = .246; there was also a 11ms (SD = 25.77, SEM = 6.65) cost when doing the ABA sequence in comparison of the CBA sequence when the target position was not repeated, t(14) = 1.69, p = .113, both of which were not significant. In the language condition, unlike in the icon condition, the ABA sequence was 21ms (SD = 59.19, SEM = 15.28) slower than the CBA sequence when the position was repeated, t(14) = 1.35, p = .199. This effect was reversed when the position of the target was not repeated as the ABA sequence was now 30ms, (SD = 43.30, SEM = 11.18), slower than the CBA sequence, t(14) = 2.72, p = .017, refer to table 24 and figure 79.

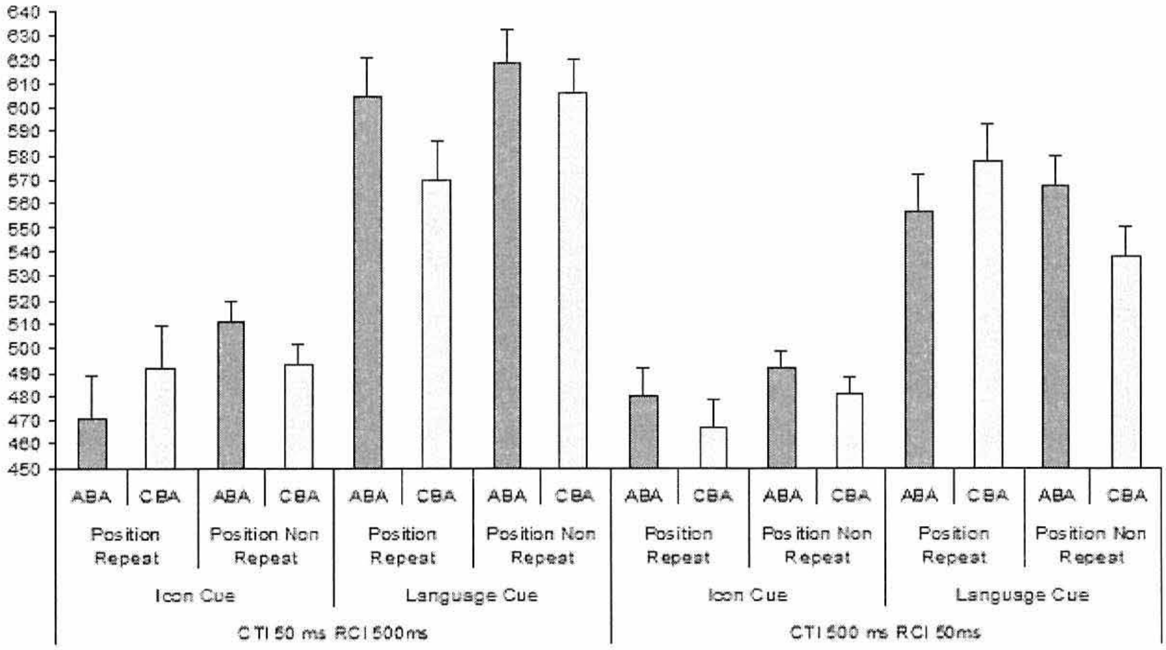


Figure 79: Illustrates the mean response times (ms) for lag type, cue type, response cue interval (RCI) and long cue target interval (CTI) conditions. Error bars show the standard error of the mean.

Table 24: A comparison of mean response times (ms) across lag type, cue type, both response cue interval (RCI) and long cue target interval (CTI) conditions and position repetition.

Experiment 9, Pair wise t test comparing ABA and CBA sequences.

		Mean Response Time		Difference between ABA and CBA sequences					
Exp No	Condition	ABA	CBA	Mean Time difference	Std. Deviation	Std. Error Mean	t Value	df	Sig. (2-tailed)
9	Icon Cue CTI 50ms RCI 500ms Lag-2 Position Repeat	470.73ms	492.03ms	21.30ms	67.24	17.36	1.227	14	.240
	Icon Cue CTI 50ms RCI 500ms Lag-2 Position Non Repeat	511.34ms	493.35ms	17.99ms	30.52	7.88	2.283	14	.039
	Language Cue CTI 50ms RCI 500ms Lag-2 Position Repeat	604.63ms	570.19ms	34.44ms	61.88	15.98	2.155	14	.049
	Language Cue CTI 50ms RCI 500ms Lag-2PositionNonRepeat	619.03ms	606.46ms	12.58ms	51.65	13.34	.943	14	.362
	Icon Cue CTI 500ms RCI 50ms Lag-2 Position Repeat	479.66ms	466.62ms	13.04ms	41.69	10.76	1.211	14	.246
	Icon Cue CTI 500ms RCI 50ms Lag-2 Position Non Repeat	491.60ms	480.35ms	11.25ms	25.77	6.65	1.691	14	.113
	Language Cue CTI 500ms RCI 50ms Lag-2 Position Repeat	556.87ms	577.48ms	20.60ms	59.19	15.28	1.348	14	.199
	Language Cue CTI 500ms RCI 50ms Lag-2PositionNonRepeat	568.12ms	537.75ms	30.37ms	43.30	11.18	2.716	14	.017

Summary of results

What becomes apparent here is dependent on what the CTI and RCI are in use. It seems to determine whether we see episodic priming or a backward inhibition costs. What also is evident is that this alteration in CTI and RCI has differing effects on the two types of cue used. In the language condition there seems to be backward inhibition occurring in the CTI 50ms RCI 500ms group as there is a backward inhibition cost in both the repeat and non repeat of target position sequences, whereas episodic priming seems to be evident in the CTI 500ms RCI 50ms group as backward inhibition seems only to be apparent when there is a change of position and priming of the ABA sequence when there is a repeat of position. The reverse occurs in the icon group with backward inhibition seeming to occur in the CTI 500ms RCI 50ms group and episodic priming in the CTI 50ms RCI 500ms group. It suggests that cost is emanating from different parts of the trial's sequence dependent on the cue type used. It would seem that the top down language label is applied on the arrival of the cue in the icon condition and when the target appears in the language condition and this is why the results for the two conditions differ.

Chapter 7

General discussion

Mayr and Bryck (2005) suggest that task set codes can become amalgamated into a common code linked to the top down language label associated with the task goal. My final results seem to suggest that two amalgamated codes are in operation when using this methodology: one that is inhibited and returns to LTM, which is the code that links the top down language label to the bottom up image of the cue, and the other that links the target to its position and remains in working memory, where it slowly dissipates with time.

This fits neatly with Arbuthnott's (2005) findings which suggest that a top down language labelling system works separately from a visual spatial system linked to the target's position. In my experiments, the target's positional code can prime the ABA sequence. This priming effect is lost when the time needed to recover the inhibited amalgamated cue code is speeded up, as it makes it more difficult to reapply the language component of it to the new bottom up image of the target which is still in working memory.

Bunge (2004) shows how biologically interconnected the brain areas are when rule retrieval is in operation. This suggests that codes are more likely to be amalgamated rather than independent when operating. Could this be the reason why I seem to be seeing two amalgamated codes in action? Gruber and Goschke (2004) hypothesise that there are two systems involved in processing complex tasks: a phylogenetically younger system, linked to language, and an older system linked to bottom information processing. Could my results be mirroring these two systems in operation?

Baddeley's (2003) model talks about an episodic buffer that amalgamates visual spatial and language codes so they can be understood by the more complex codes that operate at a top down level. Could this episodic buffer be linked to the process that causes these hypothesised top down and bottom up codes which I have suggested? All of these questions cannot be answered here but further research, using similar methodology to that used in this study, may answer or shed more light into these questions.

When I began these experiments I wanted to simplify the relationship between the cue and the target to see if its transparency was linked to any of the cost associated with backward inhibition. I wanted to do this as there had been many previous experiments looking at backward inhibition which had used a variety of methodologies. It seemed to me that because of this there had been differing findings which had given differing interpretations to the results. What seemed constant in all of these experiments was influence of a top down language label that was either associated with the cue, target, or response. What was not clear was how much the transparency of the relationship between the cue and target was having an effect on overall costs. My experiments specifically set out to look at the transparency of the relationship between the cue and the target and how much this may influence backward inhibition costs. I did this by only using one task: identify the position of the target associated with the cue. I also only switched between three, one to one, cue target relationships in nearly all of the experiments. What changed between conditions was the transparency of the relationship between the cue and target.

My final findings suggest that if there is no requirement in a trial to use a top down language label because the entire bottom up information is available in the cue to identify the target, then there is no backward inhibition cost. There is an exception to this when using coloured cues, as they seem to automatically acquire a top down language label. Backward inhibition seems, in my methodology, to be linked to the inhibition of conflicting top language labels. This conflict can occur between trials when differing top down language labels are used to identify differing targets. Transparency of the relationship between the cue and the target seems also to have an additive effect when the relationship between the cue and target is not transparent. This is because it seems that the cue and target have differing top down language labels, which means that conflict can occur within and between trials.

A two stage model also seemed to be in operation similar to that identified by Mayr and Kliegl (2003). This was because of an order effect identified, which caused overall response times to be improved in less transparent conditions when a more transparent condition was completed first. This improvement in overall response times had little to no effect on backward inhibition. It seemed to suggest that a top down language label is first recovered from LTM then taken to working memory. The speed of this recovery is benefited by having a more transparent condition first. Then secondly this language label is applied to the bottom up visual representation of the target. My final results suggested that when one switches away from a cue-target relationship that is non transparent to one that is transparent, within condition, then both the previous language label and the mechanism that produces this top down language label are inhibited.

My final results suggested that the bottom up image of the target and response position are not inhibited and slowly dissipate their activation in working memory. Both the target and the response seem to become amalgamated into a common code. This is because if it were just the repeat of the position, at lag–2 that was priming the response, the CBA sequence where position repeats at lag-2 should be as quick as the ABA sequence. It should also be quicker than both the ABA and CBA sequences, where the position does not repeat its position at lag-2. This does not occur. So the position of the response and the target need to become amalgamated for just that ABA sequence to be primed in the lag-2 repeat sequence. This priming effect is hidden if the time required to attach the top down language label to the bottom up image is shortened. Then there is a backward inhibition cost in the ABA sequence whether the position is repeated or changed. What has also become apparent is that the inhibited language label is represented as part of an amalgamated code which also contains unique features linked to the bottom up representation that it is initially associated with (see figure 80).

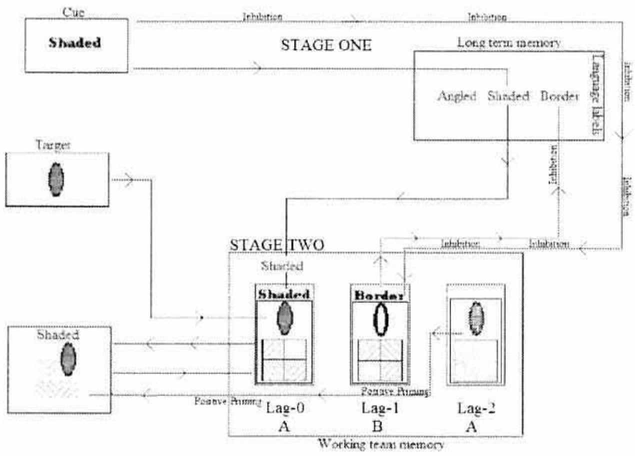


Figure 80: Proposed model of where cost may be originating

This would make logical sense and help to explain why there is a backward inhibition cost that is not affected by the order of condition. If we first see this amalgamated code being inhibited and returned to LTM, recognition of it in a new trial would first be driven by the bottom up representation of the cue, which with practice should make accessing it in LTM very efficient. If this amalgamated code is then taken to working memory it now needs to be disassembled, so the language label firstly associated with the bottom up image of the cue can be used for the new bottom up image of the target. If this code is not operating at its full activation, its disassembly may take longer to occur and this would therefore account for the backward inhibition cost.

When I look again at previous experiments it is important to recognise that they are switching between tasks and not repeating the same task and not switching through one-to-one cue target relationships. In either case, I believe that my insights may give another explanation for these earlier findings. If we return to the paper that started my enquiries, Mayr and Keele (2000), it now may be possible to assume that backward inhibition is linked to the inhibition of the language label associated with the goal and not necessarily inhibition of the task-set. If this were so, by removing the language label associated with the goal and giving all the required information to identify the target in a bottom up form, cost should subsequently be removed. This is exactly what happened in experiment 3 of Mayr and Keele's (2000) study, where they used a line of Xs as cues to an obvious response to a target and found no cost. All of the information required to identify the target in this condition was available on a bottom up level. This is exactly what happened in my experiments where the condition had matching cues and targets.

Experiments 3 and 4 (where I used abstract cues), and experiments 5, 6, and 7 (where I used two cues), when looked at together, may also explain the differing results of the two experiments carried out by Logan and Bundesen (2004) and Mayr and Kliegl (2003). They used two cues for one response-type (Task Goal) but unlike the experiments in my study, they compared task switches and task repeats and compared three different types of sequence that took into consideration what task was carried out at lag-1. This gave them three differing sequences: a cue and response-type (goal) repeat, a cue switch and response-type (goal) repeat, and a cue switch and response-type (goal) switch. What they did not take into consideration was any cost that may be linked to backward inhibition.

This is interesting as this could have easily explained Mayr and Kliegl's (2003) results in a different way, which looked very similar to my own experimental results. The reverse Stroop effect identified by Allport and Wylie (2000) has been explained by using backward inhibition terms, even though they too were looking at task repeats and switches (Mayr & Keele, 2000).

I also believe that the backward inhibition effect can also explain the Mayr and Kliegl (2003) and Logan and Bundesen (2003) results. It has been shown in experiments that compare ABA sequences, which also include a task repeat (CCAABBAA), that any backward inhibition is dissipated immediately after the switch back to the task (Altmann, 2007). If this is so, then in the sequences where the cue and task repeat, any backward inhibition associated with this will dissipate when the task is first completed at lag-1. This should mean that in a cue and task repeat sequence (AA, BB, or CC), any backward inhibition cost will be lost after the trial at lag-1. Thus, the task at lag-0 will understandably be the quickest. It also explains why in the cue switch and response-type (goal) repeat sequences, response times are slower than in the cue repeat sequences.

If my interpretation of my results is correct the new cue will have its own unique amalgamated code that contains the goal of the task, a top down language label, and its bottom up visual representation. This code will not have been reactivated at lag-1, as it was in the cue and response-type (goal) repeat sequences, so will therefore still have a level of inhibition remaining in it. This will mean that when it arrives in working memory its disassembly will be more difficult, although the repeat of response-type (goal) should be beneficial.

Finally, in sequences where the cue and task switches, neither the cue, nor target or response type will have been reactivated at lag -1, so this will mean any previous inhibition remaining when that task was last moved away from, will still be present, and cause even greater cost. Why then did Logan and Bundesen's (2003) results differ from Mayr and Kliegl's (2003) results, as Logan and Bundesen found that a switch in cue and repeat of task were equally as costly as a switch in cue and task when compared to a repeat of cue and task. I believe that Logan and Bundesen were partially correct as they hypothesised that, in the

Mayr and Kliegl experiments, a mediator was being used because the cue's meaning was not totally transparent. However, unlike them, I do not believe that cost differences were linked to a compound cue-target.

My results would suggest that this non transparent relationship between the cue and target found in the Mayr and Kliegl's (2003) experiment did require a mediator but this in itself interfered with the top down goal label associated with the task so was inhibited within trial. This within trial inhibition caused the cost difference between the previous experimenters' results. Logan and Bundesen (2004) suggest that in their experiment no mediator is used, and when by their definition they are correct. What they do not take into consideration is the number of potential conflicting top down labels needed within a trial. In the Mayr and Kliegl (2003) experiment there are three (one for the cue, one for the target and one for the response). In the Logan and Bundesen (2003) experiment there are also three but there is another level of conflict that can occur linked to how the cue is represented. The cue they use has within it a conflicting and consistent language label associated with the target; this I believe adds another level of inhibition within trials which hides any difference between the cue switch/task repeat sequences and cue switch/task switch sequences.

In experiment 6, where I used two implicit iconic cues that could share a common top down language label, there was a suggestion that they were forming two unique amalgamated codes linked to the difference in the bottom up visual representations. If this is true then this could also go some way to explaining Gade and Koch's (2007) results where they found that the attachment of a shared top down language label for the target was required in the response for there to be a backward inhibition cost. Perhaps the top down language label was being amalgamated into the bottom up visual representation, and this conflict between amalgamated codes that shared a common top down language element was the cause of the cost.

Conclusion

All of the insights I have suggested above must be treated with caution, because of the unique nature of my methodology. I looked at the switching of cue-target relationships while repeating the same task, whereas the previous research had looked at switching of task set. What is important is that I have managed to replicate backward inhibition costs when switching between three different cue-target relationships while repeating the same task. What has also become apparent is that the transparency of the relationship between the cue and target is directly linked to whether we see this cost or not.

There has also been a suggestion of a two stage model in operation linked to the recovery and then reapplication of the top down language label to the target's bottom up visual representation. Finally there may also be the coexistence of episodic priming occurring as the bottom up target and its position do not seem to be inhibited. Most previous researchers have rarely mentioned these factors linked to the transparency and coexisting episodic priming as potential influences on the backward inhibition they have seen. The re-examination of much of this previous work, while factoring in these elements, may shed more light on their results, and hopefully answer any as yet unresolved questions on the origins of backward inhibition costs, all of which I hope to explore in future research.

My final results seem to suggest that two amalgamated codes are in operation when using this methodology, one that is inhibited and returns to LTM and one that remains in working memory and gradually dissipates with time. Backward inhibition costs seem to be modulated by the interaction of these two factors, and this can determine what one sees when using explicitly cued conditions.

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Appendix 1 - Selection language cues and targets for Experiment 4

Table 25: The language cues and targets for Experiment 4 were based on the below statistics found at the MRC Psycholinguistic Database, http://www.psy.uwa.edu.au/mrcdatabase/uwa_mrc.htm.

Word	Number of letters	Number of phonemes	Number of syllables	Kucera-Francis written freq.	Kucera-Francis no. of categories	Kucera-Francis no. of samples	Thorndike-Lorge written freq.	Brown verbal frequency	Familiarity rating	Concreteness rating	Imagability rating	Meaningfulness: Colorado Norms
MILK	4	4	1	49	8	26	663	12	588	670	638	515
COAL	4	3	1	32	8	10	291	3	513	584	581	377
LAKE	4	3	1	54	12	24	408	1	583	585	616	497
DISK	4	4	1	25	3	6	19	-	-	-	-	-
SEAT	4	3	1	54	10	35	713	3	597	568	574	469
GATE	4	3	1	37	10	21	311	3	540	573	545	444
PLUG	4	4	1	23	5	7	75	2	575	558	583	-

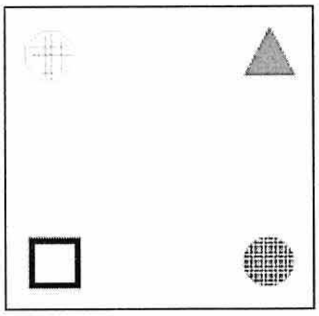
Appendix 2 - Explanation practice sheet for Experiment 5

無		海		雲		徑	
邊		雲		徑		無	
路		邊		無		雲	
徑		無		邊		徑	
邊		徑		海		路	
雲		邊		路		海	
海		徑		無		邊	
邊		海		徑		路	
海		無		路		雲	
路		海		邊		路	
徑		雲		海		邊	
邊		路		雲		無	
雲		無		徑		邊	

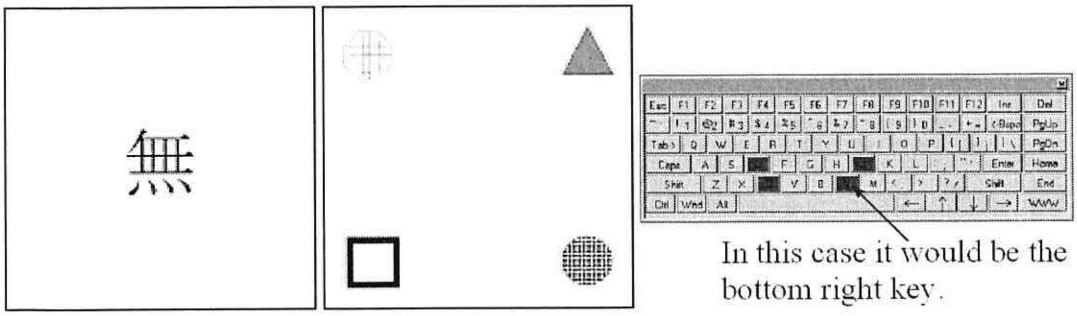
Appendix 3 - Explanation sheet for Experiment 5

1: - You will first see appear in the middle of the computer screen on of six Chinese symbols.

2: -This symbol will then disappear and four objects will then appear in the four corners of the screen.



3: -The objective of the experiment is to read the Chinese symbol, then look for the object it relates to, and identify its position by pressing the key that is corresponds to the objects position on the screen.



4: -These sequences continue to repeat themselves until the end of the experiment.