

The Role of Cue–Target Translation in Backward Inhibition of Attentional Set

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Backward inhibition (BI) refers to a reaction time cost incurred when returning to a recently abandoned task compared to returning to a task not recently performed. The effect has been proposed to reflect an inhibitory mechanism that aids transition from one task to another. The question arises as to precisely what aspects of a task may be inhibited and when the process takes place. Recent work has suggested a crucial role for response-related components of the task, which occur late in the typical trial structure (cue–target–response). In contrast to this suggestion, the authors present evidence that the way in which the task is cued can also modulate BI. Specifically, they find that the less transparent the cue–target relationship, the greater the level of BI. This also demonstrates that BI can be triggered at early stages of the trial structure, specifically during task preparation and prior to response processes. The authors conclude that BI is not tied to any particular component of the task structure but arises from whatever component generates the greatest intertrial conflict.

Keywords: task switching, backward inhibition, cue processing, selective attention, working memory

Cognitive control can be defined as the mechanisms by which people endogenously select and sequence mental states and related responses to realize a goal or plan (Houghton & Tipper, 1996). It is necessary to select because, in a typical environment, many objects may afford (or even provoke) a response, but most will be irrelevant or disruptive to the task a person is engaged in. Selection failure can be seen in everyday action slips and, in pathological cases, is associated with prefrontal lobe damage, for example, in utilization behavior (Lhermitte, 1983) and action disorganization syndrome (Schwartz, Reed, Montgomery, Palmer, & Mayer, 1991). Many models propose that participants activate (in working memory, WM) a selection template or target description that establishes the current relevance of perceived objects (e.g., Cooper, Schwartz, Yule, & Shallice, 2005; Duncan & Humphreys, 1989; Houghton & Tipper, 1994). Being tied to task goals, this target description naturally forms part of the participant's task set.

The second aspect of cognitive control, sequencing, can be seen as the selection problem in time. In this case, a new attentional or task set must be established against potential interference from previous sets (activated to the extent required to dominate a participant's responses). The mechanisms that permit this dominance might be expected to tend to maintain it and must be overcome to permit switching. Hence, there may exist a certain tension between the two aspects of control that we highlight here, a situation that has been referred to as the *stability–flexibility dilemma* (Goschke, 2000). This is the case in competitive queuing

models of sequential order (Burgess & Hitch, 1992; Houghton, 1990; Rumelhart & Norman, 1982), in which representations compete for control, and winners must be selectively inhibited to overcome the resulting tendency to perseverate.

In this study, we investigated this stability–flexibility dilemma when the representations that are being successively activated and deactivated specify the target objects of selective attention. Employing a cued set-switching design based on that of Mayr and Keele (2000, described below), we present evidence that active representations of attentional targets are inhibited when a switch of target is required and that the degree of inhibition is proportional to the difficulty of endogenously activating a new target. Importantly, within the paradigm presented here the task set remains constant throughout, and participants merely switch between cue–target relationships (i.e., they only switch attention).

Experimental Investigations of Set Switching

Experimentally, the mechanisms allowing efficient switching of attentional and task sets are investigated using paradigms in which participants switch between simple cognitive tasks (e.g., parity and magnitude judgments on number stimuli; see Monsell, 2003, for a review). It is a consistent finding of such studies that switching tasks incurs a performance cost (the *switch cost*): When a task (*B*) is performed following a switch (*AB*), it is slower and more prone to error than when it is repeated (*BB*). This cost has been attributed to variety of processes, such as the active reconfiguration of task set (Meiran, 1996; Rogers & Monsell, 1995), including retrieval of the currently relevant task set from long-term memory (Mayr & Kliegl, 2000, 2003). Conversely, it has been argued that task switching involves no endogenous act of reconfiguration, and the switch cost can be explained by cue-encoding benefits on task-repetition trials (Logan & Bundesen, 2003; Schneider & Logan, 2005), as task switches are often confounded with cue switches, and task repetitions are often confounded with cue repetitions (but

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see Altmann, 2006). Other authors have highlighted a role of interference from recent task performance, for instance from the aforementioned tendency of the preceding (and now irrelevant) task set to maintain its activation (Allport, Styles, & Hsieh, 1994). If this activation is overcome by some form of inhibitory mechanism, as suggested earlier, then this inhibition may in turn interfere with the reactivation of a task in the typical alternating runs procedure, with, for example, ABABA . . . or AABBA . . . task sequences (Allport & Wylie, 2000; Mayr & Keele, 2000).

Evidence for the Inhibition of Task Sets

In an influential article, Mayr and Keele (2000) investigated the role of inhibition in switching using a paradigm in which participants switched repeatedly between three tasks. This allowed a critical comparison between returning to a recently abandoned task set after one intermediate trial (lag-2 repetition or ABA sequence) and returning to the same task set when it had not appeared in the previous two trials (lag-2 nonrepetition or CBA sequence). If a task set is inhibited when being deselected, the inhibited state may persist for a short duration and hinder immediate reactivation after one intermediate trial (ABA sequence); during a CBA sequence, Task A will not have been inhibited so recently, and performance should be less affected.

To test this idea, Mayr and Keele (2000) employed a target detection paradigm, whereby four rectangular stimuli were presented with one at the center of each quadrant of the screen. On each trial, participants had to respond to the location of a target rectangle by making a spatially compatible keypress response. Three of the rectangles (randomly positioned) were potential targets, and each differed in appearance from the others along one of three dimensions: color, orientation, or movement. The target display was preceded by a verbal cue (“color,” “orientation,” “movement”) specifying the dimension on which the target deviated from the distractors. This dimension varied from trial to trial, with no immediate repetitions, permitting a contrast between ABA and CBA sequences. As each dimension had two possible deviant states (e.g., the color dimension could be a pink or purple rectangle), Mayr and Keele argued that the participant must attend to the relevant dimension rather than forming specific cue-to-target relationships.

The authors found the predicted slowing on an ABA sequence, termed the effect *backward inhibition* (BI), and provided evidence that BI could not be overcome with increased preparation time (Mayr & Keele, 2000, Experiment 1) and that it is tied to situations requiring top-down control (Experiment 4). The BI effect has been replicated in a number of studies varying in task demands (Altmann, 2007; Arbuthnott, 2005; Arbuthnott & Woodward, 2002; Bao, Li, Chen, & Zhang, 2007; Dreher & Berman, 2002; Gade & Koch, 2005, 2007, 2008; Hübner, Dreisbach, Haider, & Kluwe, 2003; Koch, Gade, & Phillip, 2004; Mayr, Diedrichsen, Ivry, & Keele, 2006; Mayr, 2002; Mayr & Keele, 2000; Phillip, Gade, & Koch, 2007; Schuch & Koch, 2003) and has been shown to selectively reduce interference from the preceding task set (Hübner et al., 2003; see also Masson, Bub, Woodward, & Chan, 2003).

Despite the considerable progress made, it remains unclear precisely what is inhibited during disengagement from one task to allow activation of another. Mayr and Keele (2000) initially suggested that the task set as a whole is inhibited. An alternative idea

is that inhibition is more precisely targeted and is demand driven; that is, if its function in task switching is to reduce the interference caused by previously dominant representations, then it should be most clearly manifest in that aspect of the switch that generates the greatest level of between-trials conflict. This suggestion agrees with the literature showing employment of executive control processes at times of increased conflict (Botvinick, Braver, Barch, Carter, & Cohen, 2001).

Evidence for such a view comes from the work of Koch and colleagues on the role of stimulus–response (SR) mappings in generating BI. Schuch and Koch (2003) showed that BI can depend on the response selection stage of a task switch by adapting the paradigm to include a go/no-go manipulation. In an otherwise standard BI paradigm, a go/no-go signal was presented after the cue on each trial, so that participants would prepare for each trial (on the basis of the cue) but only execute a response on go trials. The authors argued that if response selection for a new task triggers inhibition of the preceding task (to reduce conflict), then no BI cost should be found for an ABA sequence if the $n - 1$ trial was a no-go task (as no response is made). The results showed the predicted effect, leading to the proposal that BI depends on the mechanisms that resolve conflict arising from persisting activation of the most recent SR rule. Gade and Koch (2007) refined this idea by suggesting that the effect requires the competing tasks to share response sets (e.g., the same left and right keypresses). In this case a switch of tasks requires suppression of the previous SR map. Further evidence for the response-centered view is provided by the finding that while BI is not reduced when participants are given longer preparation time (by extending the cue-to-stimulus interval; Mayr & Keele, 2000; Schuch & Koch, 2003), it is affected by the length of time between trials, measured by the response-to-cue interval, suggesting that inhibition is proportional to the activation levels of response rules when a task is disengaged (Gade & Koch, 2005).

Task Cues and BI

The results of Koch and colleagues (Gade & Koch, 2007; Schuch & Koch, 2003) have led to a certain focus on the role of the response selection stage in the generation of BI. However it is important to note that response competition should not have played such an important part in the original Mayr and Keele (2000) study, as the task they employed was to respond to the location of a target object by making a spatially compatible finger movement. Although the target (dimension) varied from trial to trial, the target-location-to-response mapping did not. Thus, taking the position that inhibition should be employed where there is the greatest need to reduce intertrial conflict, it is possible that other parts of the trial structure may also contribute to BI if the locus of conflict is shifted onto them. Of the major components of the trial structure, the task cue and its influence on task performance has received relatively little attention in the BI literature. The work of Arbuthnott (2005; Arbuthnott & Woodward, 2002) has provided evidence that the way in which the task is cued can modulate BI. Although Arbuthnott and Woodward (2002) found no modulation of BI due to familiarity of cue–task associations, BI was attenuated when tasks were spatially cued by the location of a row of asterisks (as opposed to a verbal cue), a finding replicated with refined methodology by Arbuthnott (2005). Arbuthnott attributed lack of

BI with the spatial cues to increased discrimination between the three tasks' category-response rules and also proposed that in the spatial cueing condition, competing task sets remain active to some degree during task performance (Arbuthnott, 2005, Experiment 2). However, in the spatially cued condition, the stimuli appeared at the cued location and hence changed position from trial to trial (unlike in the verbally cued condition). Thus, one must be wary of attributing the attenuation of BI to differences in the cues alone. Nevertheless, Arbuthnott's (2005) study does present a challenge to the suggestion that BI is exclusively generated by the use of overlapping response sets (Gade & Koch, 2007). In particular, Experiment 1 of Arbuthnott (2005) utilized univalent response sets and trivalent stimuli (i.e., a single digit that affords all three possible tasks), a condition that should not generate BI according to Gade and Koch (2007).

The Current Study

Within the framework of task switching, it can be difficult to ascertain what aspect of the trial structure is targeted by BI, as a task set comprises many components, all and any of which may have to be altered during a task switch (Schneider & Logan, 2007). In this article, we present a paradigm that enables us to focus on the contribution of the cue in generating BI, while holding all other aspects of the task set constant. We propose that when a task cue is used to retrieve elements of a task set, some form of translation must occur between the cue and those elements. In accordance with Mayr and Kliegl's (2000, 2003) model, we assume that this translation normally involves retrieval from long-term memory and application to WM. If this process is subject to conflict or interference from elements of the previous trial (still active in WM), then the latter will be a target for specific inhibition. However, if the cue is such that it requires little or no translation to establish the correct mental set, providing the desired contents of WM directly, then conflict from previous content will be minimal, and no (specific) inhibition will be required. Thus, we expected the degree of BI observed to be modulated by the degree of transparency (Logan & Schneider, 2006) of the cue-task, or cue-target, relationship.

To test this hypothesis, we have adapted the original Mayr and Keele (2000) paradigm (target location task) to employ simple one-to-one cue-target mappings. On each trial, participants first see a cue (verbal or iconic) that indicates a distinctive property of the to-be-located target. Following this cue, they see a display from which they must select the object containing the target property. Within and across experiments, we manipulated the cue-target relationship, in terms of the transparency of its relationship to the target. A transparent cue makes activation of the target description in WM relatively easy, while less transparent (or nontransparent) cues will require effortful retrieval of the target from long-term memory. Below we describe the general method used in all the experiments. Here we briefly draw attention to three details of the method:

1. Attention switching without task switching.

In all BI studies to date, participants have had to switch between different task sets (e.g., magnitude, parity, prime status judgments). In this case, many things may change from trial to trial, including the task cue, the task-relevant aspects of the stimulus display (attention switch), the response set, and the SR mapping. In

our studies, we focused on the switch of attention in isolation of everything else. Therefore, throughout all experiments presented here, the task remains constant (locate the target matching the presented cue), and participants switch between one-to-one cue-target relationships, which we take to induce a switch of selective attention. Finding BI without task switching will provide strong evidence that the mechanisms that produce BI are not tied to any particular component of a task set (or to the task set as a whole).

2. No switch of response set.

Our aim for the studies was to isolate the role of the cue-target relationship in the inhibition of attentional set, and given the previous work (cited above) showing the importance of response processes in generating BI in task switches, we deliberately chose a design in which there should be no conflict between SR mappings on successive trials.

3. No temporal cue-target overlap.

In studies of cued task switching, the cue is often visible when the target appears, removing the need for advance preparation (Verbruggen, Liefvooghe, Vandierendonck, & Demanet, 2007). Participants may even respond on the basis of cue-target compounds. We wished participants to always have to make some mental response to the cue alone, and hence it disappeared before the target was displayed. (We note here that although Druey & Hübner, 2007, have proposed that BI is affected by the temporal overlap of cue and target, we have not found this to be the case for the paradigm employed here; Grange & Houghton, in press).

General Method

All of the experiments reported in this article follow the same basic format that we describe here to enable us to abbreviate the descriptions of the individual experiments.

Participants

All participants were students at Bangor University, who took part in exchange for both course and printer credits. None were dyslexic and all reported normal or corrected-to-normal vision.

Task

The task required participants to make keypress responses indicating the location on the screen of a target stimulus. Four target locations were defined (upper-lower and right-left quadrant), and target position changed randomly on every trial, with all four possible target positions being filled. The target changed on every trial and was specified by a preceding cue (with a 1:1 cue-target mapping) that disappeared before the target display appeared. Depending on the experiment, the cues and targets could be words or simple visual shapes (icons).

Apparatus and Stimuli

All of the experiments were implemented using E-Prime (Psychology Software Tools, 2002) running on a PC and were presented on a 17-in. (43.18-cm) cathode ray tube monitor set at about 60 cm from the participant. Responses were made manually on a computer keyboard, using the index and middle fingers of both hands. The stimuli varied between experiments, but in every case the stimulus display consisted of four items located in the centers

of the four quadrants of the screen. Participants indicated the location of the target stimulus by making a keypress response. With the exception of Experiment 2a, the responses were spatially compatible with stimulus locations, as follows (location = key): top left = *D*; bottom left = *C*; top right = *J*; bottom right = *N*. Participants used the index and middle fingers of both hands, placed on the keys in the natural fashion.

Design and Procedure

Participants saw a series of trials consisting of a cue (verbal or iconic) followed by a target display. Cues were displayed for 500 ms, followed by a cue–stimulus interval of 250 ms (blank screen). After the cue–stimulus interval, there followed the stimulus display that remained visible until a response was made. The next trial began after a response–cue interval of 500 ms. The cue specified the visual feature to look for in the stimulus display (the target), and participants responded by identifying the position of the target by pressing the spatially compatible response key. They were asked to respond as quickly and as accurately as possible.

In every experiment, there were three possible targets, the order of which was random, except that no target was repeated twice in succession. This produced two different types of target sequence: a lag-2 repetition (ABA sequence) and a lag-2 nonrepetition (CBA sequence). Target position was randomized. Of the three other screen positions, two were occupied by the other two possible targets and the third by a distractor (Mayr & Keele, 2000). The assignment of nontargets to screen locations was also random, once the target location had been selected.

Data Analysis

Trimming

The following trimming procedure was used in all of the experiments. The first two trials of each experimental block were excluded from analysis. For the reaction time (RT) analysis, trials resulting in an error were removed. In addition, the two trials

following an error were removed, so that RTs to correct trials were not contaminated by errors at lag-2 or lag-1. Trials with RTs that were under 200 ms and over 2,000 ms were also removed.

Analysis

In general, the error data did not produce significant effects, and the *Results* sections will concentrate on the RT data. We analyzed participants' mean RTs by condition using a repeated measures ANOVA (analysis of variance), followed by planned comparisons where necessary. A factor in all experiments was the trial sequence comparison, ABA versus CBA. This will be referred to as *lag type*, with levels lag-2 repetition (ABA) and nonrepetition (CBA).

Experiment 1

Method

Participants. We recruited 31 participants as described in the General Method. One participant's data were lost due to a computer problem at the time of the experiment.

Stimuli. The target display consisted of four ovals presented as described in the General Method. Of the four ovals, three could act as targets (i.e., contain a feature specified by the preceding cue), while the other was a distractor. Each target oval was distinguished from the rest by a critical feature (angled, border, shaded; see Figure 1). All of the stimuli were 6 cm in length, and three of them had a width of 2.3 cm, while one was 3.5 cm (see Figures 1 and 2). The location of each stimulus was randomized on each trial.

The stimulus displays were preceded by a cue, which specified which visual feature to look for. There were two types of cue, verbal and iconic, which were presented in separate blocks. The three verbal cues, each disyllabic and six letters long, were "border," "angled," and "shaded" displayed in Times New Roman font in Size 15 (see Figure 1). The three icon cues were rectangular and contained a visual representation of the target feature (see Figure 1). All three iconic cues were 4 cm long; two were 1.5 cm wide and one was 2 cm wide. All cues were presented in the center of

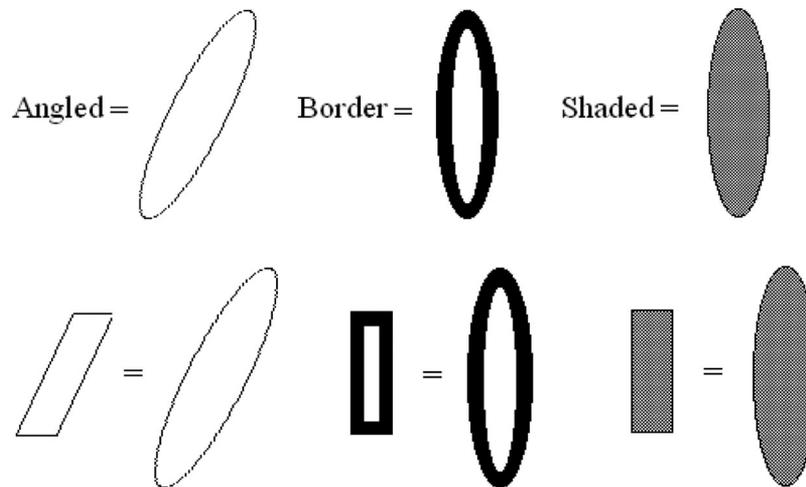


Figure 1. Verbal and icon cues and their associated target stimuli for Experiment 1. The cue is shown on the left of each pair, and the associated target is shown on the right.

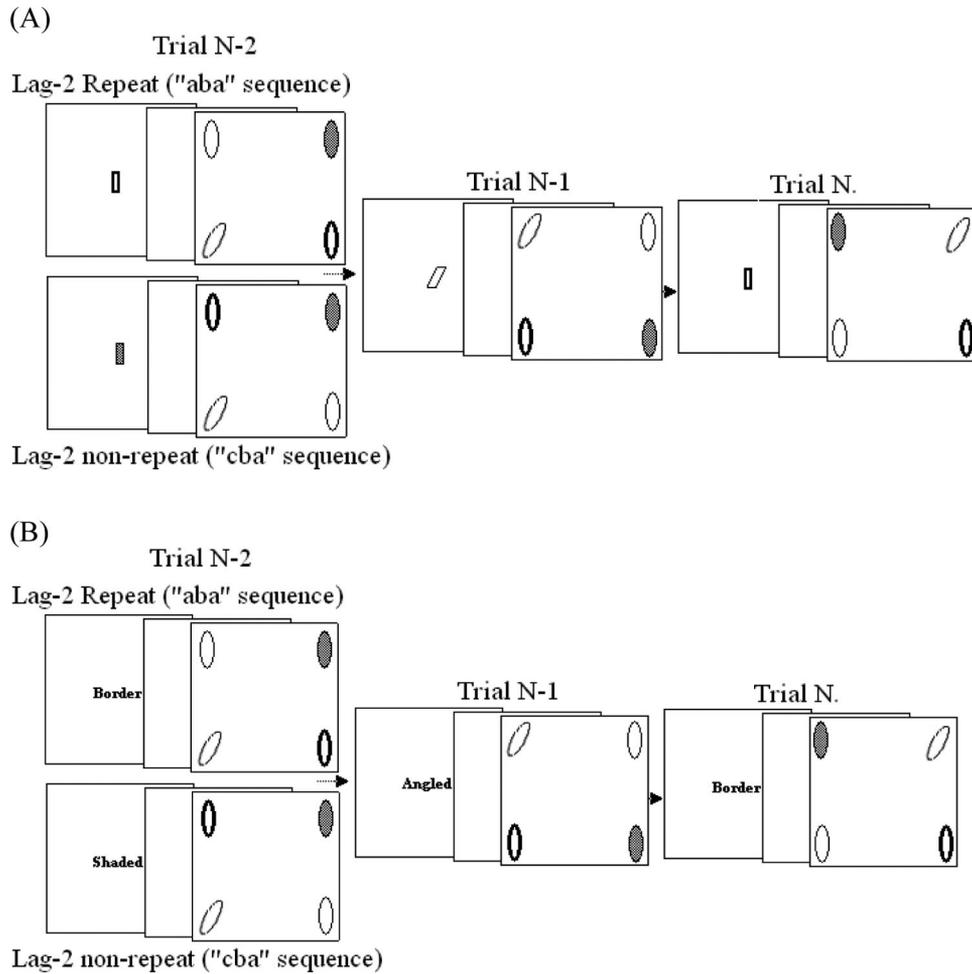


Figure 2. Example of ABA and CBA trial sequences with visual (iconic) cues (A) and with verbal cues (B).

the screen. In terms of transparency, we considered the icon cues to be maximally transparent, as they provided a direct visual representation of the target feature (albeit in a different shape). The verbal cues, though meaningfully associated with the visual targets, were less transparent, as they would still require an act of translation to bring the target feature into WM.

Design and procedure. Participants saw a series of trials as described in the General Method. The ABA and CBA sequences are illustrated in Figure 2.

The experiment consisted of two blocks of trials, one with icon cues and the other with verbal cues. The order of the blocks was counterbalanced across participants. Before each block of trials, the participants were shown a pictorial representation of the relationship between the cues and targets and then carried out a practice run of 30 trials prior to completing an experimental block of 126 trials. The experimenter stayed in the room while the participant practiced, then left the room when the participant carried out the experimental block.

Results

Analysis of the errors revealed no significant effects; hence, we report only the RT data. RT data were trimmed as described in the

General Method, resulting in 10% of trials being excluded. We analyzed the remaining data using a 2 × 2 repeated measures ANOVA for the factors cue type (verbal vs. iconic cue) and lag type (lag-2 repetition vs. lag-2 nonrepetition; see Table 1). There were significant main effects of both cue, $F(1, 29) = 44.67, p < .001$, and lag repetition, $F(1, 29) = 9.07, p = <.01$, and a significant interaction between the two factors, $F(1, 29) = 8.5, p < .01$. The main effect of cue was due to participants responding faster to icon than to word cues. We further analyzed the interac-

Table 1
Mean Reaction Times in Milliseconds Across ABA and CBA Sequences for Both Cue Types in Experiment 1

Sequence	Cue type	
	Iconic cues	Word cues
ABA	493 (78)	591 (104)
CBA	492 (79)	567 (96)
Backward inhibition (ABA – CBA)	1	24

Note. Standard deviations are in parentheses. ABA = lag-2 repetition; CBA = lag-2 nonrepetition.

tion using planned comparisons. For word cues, there was a significant BI effect of 24 ms, $t(29) = 3.4$, $p < .005$. For iconic cues, there was a nonsignificant effect of 1 ms (see Table 1).

Discussion

The results of this experiment showed a clear dissociation between the two cueing conditions with respect to BI. When the targets were verbally cued, a highly reliable BI effect of 24 ms was found, whereas the effect was completely absent for the transparent icon cues. This clearly suggests that the way in which the target is being activated in WM affects the process of inhibition. We assumed that the verbal cues must be translated in some manner to retrieve a useable representation of the target feature (i.e., one that can be directly compared to the stimulus display), whereas the icon cues provide this information directly. Thus, BI appears to vary inversely with the degree of transparency of the cue–target relationship.

Before testing this idea in more detail, we first addressed a possible confound in the first study. As well as showing greater BI with verbal cues, participants were also much slower overall. It is possible then that the emergence of robust BI is affected by overall task difficulty; participants on average spend longer on each trial when a verbal cue is used, and this relative difficulty and increased time on task may increase the likelihood of inhibition being used and/or its effects observed. In the following two experiments, we addressed this by producing a more difficult (slower) version of the icon cue condition (Experiment 2a) and an easier (faster) version of the verbal cue condition (Experiment 2b). If overall task difficulty plays a role, then we would expect BI to emerge when the icon cue task is made more difficult and to be reduced or disappear when the verbal cue task is made easier. The results of Experiments 2a and 2b will be discussed together following Experiment 2b.

Experiment 2a

The aim of this experiment was to repeat the icon cue condition of Experiment 1 but to include a version that was more difficult, ideally at least as difficult (as measured by RTs) as the verbal cue condition in Experiment 1. To this end, each participant performed the task with two different SR mappings; one was the spatially congruent arrangement used in Experiment 1, while the other was left–right reversed (spatially incongruent). We predicted that the incongruent SR mapping would increase the difficulty of the task and the average time taken on each trial. If this is a factor in producing BI, then the incongruent condition should show more BI than the congruent one.

Method

Participants. We recruited 16 new students at Bangor University as described in the General Method.

Stimuli, design, and procedure. Apparatus, testing conditions, and stimuli were all identical to the icon cue condition of Experiment 1. However, participants performed two different SR mappings, congruent and incongruent. In the congruent condition, the SR assignment was the same as that used in Experiment 1. In the incongruent condition, the responses were left–right reversed with

respect to the locations of the targets; thus, pressing the *D* and *C* keys (left hand) represented top and bottom right, respectively, while pressing the *J* and *N* keys (right hand) represented top and bottom left, respectively. The two SR mappings were performed in separate blocks, the order of which was counterbalanced across participants. All other parameters (timing, block length, practice, etc.) were identical to Experiment 1.

Results

The error analysis showed only a significant main effect of SR mapping, $F(1, 15) = 4.5$, $p = .05$, with participants making more errors in the incongruent condition. Trimming of RT data (General Method) resulted in the loss of 15% of trials. The remaining data was subject to a 2×2 repeated measures ANOVA, with factors lag type (repetition vs. nonrepetition) and SR mapping (congruent vs. incongruent). Means and standard deviations of RTs are shown in Table 2. The only significant effect was the main effect of SR mapping, as participants were considerably slower using the incongruent than the congruent mapping (663 ms v. 470 ms), $F(1, 15) = 91.7$, $p < .001$. No BI was observed whatever the mapping used.

Comparing Experiment 2a with the results from Experiment 1, the mean RTs for the congruent conditions were similar (470 ms vs. 497, respectively). The mean RT for the incongruent condition of Experiment 2a was even slower than that to the verbal cue condition of Experiment 1 (663 ms vs. 587, respectively).

Experiment 2b

In this experiment, we tested whether we could reduce or eliminate the BI effect produced by verbal cues in Experiment 1, by making the overall task easier (without changing its basic nature). To this end, we replaced the feature localization task used in Experiment 1 with a verbally cued color localization task. In pilot studies using this manipulation, we found that participants could perform color localization relatively quickly. (We assumed that this is because color targets are more salient than the visual targets of Experiment 1. However, it is also likely that the semantic association between color words and colors is greater than that between the verbal cues and targets of Experiment 1. If this is so, then the verbal cues used in this experiment should be considered somewhat more transparent than those used in Experiment 1).

Table 2
Mean Reaction Times in Milliseconds for Experiments 2a and 2b

Sequence	Experiment 2a		Experiment 2b
	Congruent SR	Incongruent SR	
ABA	469 (89)	666 (136)	476 (99)
CBA	472 (87)	661 (147)	464 (93)
Backward inhibition (ABA – CBA)	–3	5	12

Note. Standard deviations are in parentheses. SR = stimulus–response; ABA = lag-2 repetition; CBA = lag-2 nonrepetition.

Method

Participants. We recruited 32 new students at Bangor University according to the General Method.

Stimuli and procedure. The experiment had exactly the same structure, timing parameters, and SR rules as the verbal cue condition of Experiment 1. However, the stimuli consisted of four colored (filled) ovals of the same dimensions and arrangement as in Experiment 1; the targets were colored red, blue, or green, and the distractor oval was orange. The target was cued by the words *red*, *blue*, and *green*, displayed as in the verbal cue condition of Experiment 1. All participants received instructions as in the previous experiments followed by a practice block of 32 trials. They then completed a single experimental block of 126 trials.

Results

No significant effects were found in the errors. For the RT analysis, trimming (General Method) resulted in the loss of about 7% of trials. A comparison of lag-2 repetition versus lag-2 non-repetition revealed a significant BI effect of 12 ms, $t(31) = 2.7$, $p = .011$.

Discussion—Experiments 2a and 2b

In Experiment 2a, we attempted to produce BI with icon cues by slowing overall RTs using a spatially incongruent SR mapping. While this produced the desired slowing, it was found to have no effect at all on BI. Hence, it does not appear to be the case that BI is more likely to emerge as a task simply becomes more difficult. Experiment 2b employed the converse logic, whereby we attempted to speed up the verbally cued task by using a more salient visual feature (color). In this case, mean RTs were similar to (indeed slightly faster) than those to the icon-cued condition of Experiment 1, but significant BI was still observed. Thus, these two experiments have provided a double dissociation between task difficulty and BI, turning the RT relationship between the verbally and visually cued conditions of Experiment 1 on its head while maintaining the overall pattern of BI. We conclude then that the BI difference between the two cueing conditions found in Experiment 1 was not simply a function of the relative ease with which the tasks could be carried out.

We return then to the idea that BI of attentional set depends on a translation in WM between the form in which the cue is presented and the mental instantiation of the search target. If this is so, then the effect should not depend on the fact that the cue is verbal and the target visual, as has been the case in the conditions

producing BI so far. Hence, in Experiments 3 and 4, we aimed to show BI when there is no change of modality between the cue and the target. Experiment 3 involved a visual (icon) cue to a visual target, while in Experiment 4 we looked at verbal cues to verbal targets.

Experiment 3

In this experiment, we exactly repeated the design of Experiment 1, comparing visual (icon) and verbal cues, but in the icon-cued condition the cues did not resemble the targets (see Figure 3). The logic was that if the absence of BI in the icon-cued conditions of Experiments 1 and 2a is due to the lack of a need to translate between cue and target, then the use of visual cues that do not resemble the target should produce BI, as participants will not be able to simply use the cue directly to identify the target. Indeed, we suggested that the new abstract icon cues (see Figure 3) will be even harder to translate (as they are less transparent) than the meaningful verbal cues of Experiment 1. Therefore, we expected overall RTs to be slower for the icon-cued condition, due to the extra retrieval difficulty. We also predicted this extra translation needed to interpret the cue would generate even more conflict in WM at the time of a switch and with it greater inhibitory control. Thus, we now predicted the reverse findings from Experiment 1 (i.e., that the visual [icon] cues should generate more BI than the verbal cues, though the latter condition will still produce BI).

Method

Participants. We recruited 28 new participants as described in the General Method. Data from 1 participant were lost due to a computer failure.

Stimuli and procedure. The experiment was identical in structure to Experiment 1, comparing BI in verbally versus visually cued target searches. The verbally cued condition was identical in all respects to the corresponding condition in Experiment 1. In the visually cued condition, we used visual cues that had no direct relationship to the target stimuli (see Figure 3). All participants performed two blocks of 126 trials, one block for each cue type. The relationship between the cues and targets was explained before each block, and participants performed a block of practice trials before starting each experimental block. The order of blocks was counterbalanced across participants.

Results

Trimming of the RT data (General Method) resulted in the loss of about 16% of trials. We analyzed the remaining data using a 2 ×

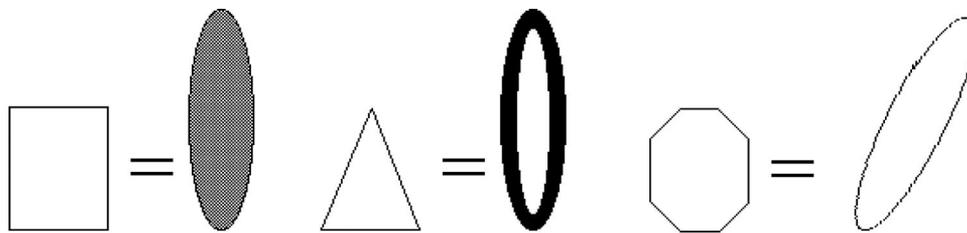


Figure 3. Visual cues and targets used in Experiment 3. The cue is shown on the left of each pair, and the associated target is shown on the right.

2 repeated measures ANOVA comparing cue type (verbal vs. visual) against lag-2 (repetition vs. nonrepetition). Means and standard deviations by conditions are shown in Table 3. There were significant main effects of both cue, $F(1, 26) = 40.1, p < .001$, and lag-2 repetition, $F(1, 26) = 23.7, p < .001$. The main effect of cue was due to participants responding faster to word than to icon cues, the reverse effect to that found in Experiment 1. The global BI effect was 35 ms, but this was qualified by a significant interaction with cue type, $F(1, 26) = 7.6, p = .011$. We further analyzed the interaction using planned comparisons. For the verbal cues, there was a significant BI effect of 14 ms, $t(27) = 2.1, p = .049$. As predicted for the visual cues, the BI effect was even greater reaching 57 ms, $t(27) = 4.3, p < .001$.

Discussion

Experiment 3 confirmed the prediction that visual cueing of a visual target would produce BI if the cue did not resemble the target, thereby requiring translation of the cue information in order to establish a visual target description. However, the results actually reversed those of Experiment 1, with the visual cues now producing significantly greater BI than the verbal cues. (Note that although the visual cues also slowed participants down globally, the RTs were similar to those in the incongruent condition of Experiment 2a; hence, we do not believe that the effect is due to general task difficulty.) For now, it suggests that when there is no change in modality from cue to target, and the cue is not similar to the target, then there is an even greater need to suppress the contents of WM (either the cue and/or target information) when a switch is made. If this is so, then the same result should be found for verbal cues to verbal targets. This possibility was investigated in Experiment 4.

Experiment 4

The aim of this experiment was to establish whether the high level of BI found in the visual cue condition in Experiment 3 could be replicated with verbal cues and targets. In one condition, participants saw a verbal cue (e.g., *Milk*) and then had to report the location of an unrelated target word (e.g., *Disk*). This is analogous to the visually cued condition of Experiment 3. Participants cannot keep the cue word in verbal WM, as it must be replaced by a specification of the target word. Similarly the target word itself may need to be suppressed to process the next verbal cue. Hence, we predicted an even higher level of BI than we have previously

Table 3
Mean Reaction Times in Milliseconds Across ABA and CBA Sequences for Both Cue Types in Experiment 3

Sequence	Cue type	
	Iconic cues	Word cues
ABA	753 (176)	599 (121)
CBA	697 (162)	585 (126)
Backward inhibition (ABA – CBA)	56	14

Note. Standard deviations are in parentheses. ABA = lag-2 repetition; CBA = lag-2 nonrepetition.

found when using a verbal cue to a visual target. As this latter condition has been now been run three times in the current series of experiments (Experiment 1, 2a, 3), we decided not to repeat it here; instead we took the opportunity to include a verbal analogue of the visually cued condition from Experiments 1 and 2a. In this condition, participants saw a cue word and then looked for the identical word in the target display. It was predicted that this condition would produce no BI, as the cue supplies the target description directly, without the need for translation or the endogenous control of WM.

Method

Participants. We recruited 28 new participants as described in the General Method.

Stimuli and procedure. All participants completed two blocks of trials with the same structure and timing parameters used in all the previous experiments. The cue was always a word, and each block comprised one of two cueing conditions: identical versus unrelated. In the identical condition, the cue and target words were the same (viz., *milk–milk*, *coal–coal*, and *lake–lake*). In the unrelated condition, the three words used in the identical condition were paired with the nonassociated words, *disk*, *seat*, and *gate*. For half the participants, *milk*, *coal*, and *lake* were cue words, while for the other half, they were targets (and *desk*, *seat*, and *gate* were the cues). The order of blocks (identical vs. unrelated cues) was counterbalanced across participants. Each cueing condition was explained and practiced separately before the beginning of the relevant experimental block of 126 trials.

Results

Trimming (General Method) removed 19% of trials. We analyzed the remaining RT data using a 2×2 repeated measures ANOVA, comparing cue type (identical vs. unrelated) against lag-2 (repetition vs. nonrepetition). Means and standard deviations by conditions are shown in Table 4.

There were significant main effects of both cue (identical vs. unrelated), $F(1, 26) = 84, p < .001$, and lag-2 (repetition vs. nonrepetition), $F(1, 26) = 9.9, p = .004$. The main effect of cue was due to participants responding more slowly in the unrelated condition, while the lag-2 effect reflected a global slowing in the repetition condition. Most importantly, there was a significant interaction between the two factors, $F(1, 26) = 7.1, p = .013$. In follow-up tests, we found the main effect of lag to be entirely due to the unrelated condition, which produced a 50-ms BI cost, $t(26) = 3.1, p = .004$. No BI was found in the identical condition (see Table 4).

Discussion

The experiment confirmed the predictions that the finding of BI with verbal cues depended entirely on the cue–target relationship. When the target was identical to the cue, no BI was observed. When cue and target were unrelated, a substantial BI cost of 50 ms was observed, notably higher than that found for verbally cued icon targets, and similar to the level of BI produced by visual cues to dissimilar targets.

Table 4
Mean Reaction Times in Milliseconds Across ABA and CBA Sequences for Both Types of Cue–Target Relationships in Experiment 4

Sequence	Cue–target relationship	
	Identical	Unrelated
ABA	638 (109)	850 (189)
CBA	638 (113)	800 (162)
Backward inhibition (ABA – CBA)	0	50

Note. Standard deviations are in parentheses. ABA = lag-2 repetition; CBA = lag-2 nonrepetition.

General Discussion

For ease of comparison between the experiments presented here, we summarize the results in Table 5, in terms of the cue–target relationships and the level of BI observed.

Across five experiments, we have provided evidence that BI can be caused by cue-related processing, involving installation of the relevant attentional set into WM. Importantly, across all experiments the task set and the response set were held constant across trials. In Experiment 1, verbal cues to visual targets generated greater BI than transparent iconic cues, which displayed the relevant target properties in a direct fashion, removing the need for translation. In Experiment 2a, we demonstrated that the observed effect was not caused by increased task difficulty for verbal cues, as increasing the task difficulty for the icon-cued trials did not generate BI. We suggest this manipulation did not produce BI, as the increased difficulty did not introduce the need to translate the cue; conversely, making the verbally cued task easier without removing the need for translation did not remove BI (Experiment 2b). This finding suggests that the levels of BI we observed are independent from aspects of task difficulty not related to cue processing. Experiment 3 (abstract icons) demonstrated that BI can occur even with no change in modality between the cue and the target. Due to the abstractness of the iconic cue in this condition, we propose that additional translation was required, leading to the increased levels of BI compared to the word-cue condition of Experiment 1. In Experiment 4, we generalized the previous results to the case in which the target was a word as opposed to a geometric figure. This manipulation still produced BI but only when the cue and target words were unrelated and thus requiring effortful translation for successful task performance. The unrelated words condition was analogous to the condition in Experiment 3 in that icon targets were cued by visually dissimilar icons, and these two conditions produced the highest observed levels of BI (around 50 ms). Taken together, the results show that (a) BI can be observed without a task switch in the usual sense, (b) BI can be caused by cued switches in attentional set alone, and (c) the more difficult the cue is to interpret (i.e., the more translation required to establish the appropriate contents of WM) the greater the degree of BI observed.

These results constitute novel findings regarding BI, as previously little attention has been paid to the influence of task cues on BI (though see Arbutnott, 2005) or to the possibility of observing BI without a classical task switch. Indeed, much recent work has

emphasized the importance of response stages rather than preparatory stages of task performance on BI (Gade & Koch, 2007; Koch et al., 2004; Schuch & Koch, 2003). Hence, these new results are of some theoretical importance more generally, as all published BI studies have used instructional cues: either verbal cues (e.g., “odd/even”; Mayr, 2002; Mayr et al., 2006; Mayr & Keele, 2000) or abstract cues requiring an extra stage of translation (e.g., a square screen frame; Druey & Hübner, 2007; Gade & Koch, 2005, 2007; Koch et al., 2004; Phillip et al., 2007; Schuch & Koch, 2003). Although these studies used more conventional task-switching designs (compared to our attention-switching paradigm), it is possible that the nature of the cue–task relationship employed may influence the results.

The Locus of Inhibition in BI: Preparation Versus Response

From the data presented in the current article, inhibition does not appear to exclusively target response related stages. It is important to note that in all conditions presented (for conditions that generated BI and those that did not), identical response parameters were implemented: A response was expected on every trial, and thus response selection and execution was required with 100% certainty (cf. Schuch & Koch, 2003). The response set was held constant throughout the experiments, with participants simply having to make (in all but one case) a spatially compatible response to a target location. Under these circumstances, it seems unlikely that the response set would be inhibited from one trial to the next (cf. Gade & Koch, 2007) and that the degree of response inhibition used would be affected by the way in which the target was cued.

Therefore, something other than response processes must determine the degree of BI found in the various conditions; this, we argue, is the role translation plays in interpreting the cue. As mentioned in the introduction, this view is consistent with Mayr and Kliegl’s (2000, 2003) two-stage model of task-set selection, whereby the cue aides recovery of the relevant task set from long-term memory. We argue that during this retrieval stage, the translation result for the current task (attentional set, in our studies)

Table 5
Summary of the Results in Terms of Cue–Target Relationships and Observed Backward Inhibition in Milliseconds

Experiment and cue	Target	Cue–target relationship	Backward inhibition
1			
Verbal	Icon	Semantic	24**
Icon	Icon	Similar	1
2a			
Icon	Icon congruent	Similar	–3
Icon	Icon incongruent	Similar	5
2b			
Verbal	Icon	Semantic	12*
3			
Verbal	Icon	Semantic	14*
Icon	Icon	Unrelated	57**
4			
Verbal	Verbal	Identical	0
Verbal	Verbal	Unrelated	50**

* $p < .05$. ** $p < .01$.

will meet with competition from the recently performed translation result in WM (from $n - 1$); this competition will induce conflict in the cognitive system, thus triggering control mechanisms (Botvinick et al., 2001; Houghton & Tipper, 1994). Note that we suggest this process occurs during cue presentation and before target presentation (and therefore before response processes). This view is in line with the proposal that BI reflects a mechanism by which WM is cleared, making it available for a new task set to be installed (Mayr & Keele, 2000).

On the face of it, this proposal is contradicted by Schuch and Koch's (2003) finding that BI was abolished when trial $n - 1$ in an ABA sequence was marked as no go following the cue (i.e., the $n - 1$ cue would have been processed as usual). One problem in interpreting this result is that researchers do not really know what happens when participants encounter a no-go signal. Clearly they produce the usual type of response, but it is also possible that some more general cognitive resetting takes place that disrupts all ongoing WM process (including cue processing). A related possibility is that the result of the cue translation generates most conflict (and with it greater BI) when it is actually applied to a stimulus (the second stage of Mayr & Kliegl's, 2003, model). This always occurred in our experiments but was abolished on no-go trials in Schuch and Koch's study. In this vein, one might even interpret the use of no-go trials as interleaving a fourth task, as participants have to remember what the no-go cue means and react appropriately.

Bottom-Up Versus Top-Down Activation of a Task Set

Mayr and Keele (2000, Experiment 3) proposed that BI is tied to top-down, endogenous acts of control. Thus, it may be that where we found no BI at all (highly similar-identical cues and targets), it was because no top-down control was employed. The previous study most relevant to this question is Mayr and Keele's (2000) Experiment 3, which contrasted bottom-up (uncued) with top-down (cued) selection of targets. In the bottom-up condition, participants could identify the target from the stimulus display alone but could not make advance preparation as there was no cue. In the top-down condition, participants saw the same stimulus displays (with only one object having target properties) but also saw a valid word cue beforehand, allowing them to prepare in advance. BI was only found in the top-down condition, in which overall RTs were also faster (i.e., participants used the cues). This finding supports the idea that translation of a cue determines BI. In the top-down condition, the cue is translated to form a representation of the target, leading to inhibition of the previous target. In contrast to Mayr and Keele's (2000) bottom-up condition, in our studies selection could never be made without the aid of the cue. Thus, some act of top-down control (attending to the cue, remembering it, matching it to the display) was always needed, however transparent the cue.

BI in the Absence of Task Switching

In the experiments presented here, we have found BI in scenarios that do not require task switching per se. Across all conditions, those that generated BI and those that did not, the task remained constant (search for the cued target), and participants switched attentional set between target properties. As BI can be modulated by cue transparency alone, it remains to be investigated to what

degree the effects found in other studies of BI are due to cue translation processes. We do not claim on the basis of our results that all BI reported to date is caused exclusively by cue-target (task) translation processes. Indeed, as so much changes when a new task is installed into WM, many more conflicts than cue-target translation may arise, thus triggering inhibition. Future research might parametrically introduce more conflict into the trial structure of our paradigm in a systematic manner to investigate whether BI increases additively as a function of the conflict.

Conclusion

We have presented evidence in favor of the existence of a demand-driven inhibitory mechanism in task switching employed during increased intertrial conflict (Botvinick et al., 2001; Mayr & Keele, 2000). Rather than being tied exclusively to response-related processes of task performance (or the task set as a whole), the mechanism is employed wherever and whenever the locus of conflict appears. In the current context, we have shown that some degree of conflict arises during cue-processing stages, likely caused by the need to translate the cue efficiently enabling successful retrieval of the relevant task set from long-term memory and implementation into WM.

References

- Allport, D. A., Styles, E. A., & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks. In C. Umiltà & M. Moscovitch (Eds.), *Attention and performance XV: Conscious and nonconscious information processing* (pp. 421–452). Hillsdale, NJ: Erlbaum.
- Allport, D. A., & Wylie, G. (2000). Task-switching, stimulus-response bindings, and negative priming. In S. Monsell & J. S. Driver (Eds.), *Control of cognitive processes: Attention and performance XVIII* (pp. 35–70). Cambridge, MA: MIT Press.
- Altmann, E. (2006). Task switching is not cue switching. *Psychonomic Bulletin & Review*, *13*, 1016–1022.
- Altmann, E. (2007). Cue-independent task-specific representations in task switching: Evidence from backward inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 892–899.
- Arbuthnott, K. (2005). The influence of cue type on backward inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*, 1030–1042.
- Arbuthnott, K., & Woodward, T. (2002). The influence of cue-task association and location on switch cost and alternating-switch cost. *Canadian Journal of Experimental Psychology*, *56*, 18–29.
- Bao, M., Li, Z., Chen, X., & Zhang, D. (2007). Backward inhibition in a task of switching attention within verbal working memory. *Brain Research Bulletin*, *69*, 214–221.
- Botvinick, M., Braver, T., Barch, D., Carter, C., & Cohen, J. (2001). Conflict monitoring and cognitive control. *Psychological Review*, *108*, 624–652.
- Burgess, N., & Hitch, J. G. (1992). Towards a network model of the articulatory loop. *Journal of Memory and Language*, *31*, 429–460.
- Cooper, R. P., Schwartz, M., Yule, P., & Shallice, T. (2005). The simulation of action disorganisation in complex activities of daily living. *Cognitive Neuropsychology*, *22*, 959–1004.
- Dreher, J., & Berman, K. F. (2002). Fractioning the neural substrate of cognitive control processes. *Proceedings of the National Academy of Sciences, USA*, *99*, 14595–14600.
- Druey, M., & Hübner, R. (2007). The role of temporal cue-target overlap in backward inhibition under task switching. *Psychonomic Bulletin & Review*, *14*, 749–754.

- Duncan, J., & Humphreys, G. W. (1989). Visual search and stimulus familiarity. *Psychological Review*, *96*, 433–458.
- Gade, M., & Koch, I. (2005). Linking inhibition to activation in the control of task sequences. *Psychonomic Bulletin & Review*, *12*, 530–534.
- Gade, M., & Koch, I. (2007). The influence of overlapping response sets on task inhibition. *Memory & Cognition*, *35*, 603–609.
- Gade, M., & Koch, I. (2008). Dissociating cue-related and task-related processes in task-inhibition: Evidence from using a 2:1 cue-to-task mapping. *Canadian Journal of Experimental Psychology*, *62*, 51–55.
- Goschke, T. (2000). Intentional reconfiguration and involuntary persistence in task set switching. In S. Monsell & J. Driver (Eds.), *Control of cognitive processes: Attention and performance XVIII* (pp. 331–355). Cambridge, MA: MIT Press.
- Grange, J. A., & Houghton, G. (in press). Temporal cue–target overlap is not essential for backward inhibition in task-switching. *Quarterly Journal of Experimental Psychology*.
- Hübner, M., Dreisbach, G., Haider, H., & Kluwe, R. H. (2003). Backward inhibition as a means of sequential task-set control: Evidence for reduction of task competition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*, 289–297.
- Houghton, G. (1990). The problem of serial order: A neural network model of sequence learning and recall. In R. Dale, C. Mellish, & M. Zock (Eds.), *Current research in natural language generation* (pp. 287–319). London: Academic Press.
- Houghton, G., & Tipper, S. P. (1994). A model of inhibitory mechanisms in selective attention. In D. Dagenbach & T. Carr (Eds.), *Inhibitory mechanisms in attention memory and language* (pp. 53–112). San Diego, CA: Academic Press.
- Houghton, G., & Tipper, S. P. (1996). Inhibitory mechanisms of neural and cognitive control: Applications to selective attention and sequential action. *Brain and Cognition*, *30*, 20–43.
- Koch, I., Gade, M., & Phillip, A. (2004). Inhibition of response mode in task switching. *Experimental Psychology*, *51*, 52–58.
- Lhermitte, F. (1983). Utilisation behaviour and its relation to lesions of the frontal lobes. *Brain*, *106*, 237–255.
- Logan, G. D., & Bundesen, C. (2003). Clever homunculus: Is there an endogenous act of control in the explicit task-cuing procedure? *Journal of Experimental Psychology: Human Perception and Performance*, *29*, 575–599.
- Logan, G. D., & Schneider, D. W. (2006). Interpreting instructional cues in task switching procedures: The role of mediator retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 347–363.
- Masson, M. E. J., Bub, D. N., Woodward, T. S., & Chan, J. C. K. (2003). Modulation of word-reading processes in task switching. *Journal of Experimental Psychology: General*, *132*, 400–418.
- Mayr, U. (2002). Inhibition of action rules. *Psychonomic Bulletin & Review*, *9*, 93–99.
- Mayr, U., Diedrichsen, J., Ivry, R., & Keele, S. W. (2006). Dissociating task-set selection from task-set inhibition in the prefrontal cortex. *Journal of Cognitive Neuroscience*, *18*, 14–21.
- Mayr, U., & Keele, S. W. (2000). Changing internal constraints on action: The role of backward inhibition. *Journal of Experimental Psychology: General*, *129*, 4–26.
- Mayr, U., & Kliegl, R. (2000). Task-set switching and long-term memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 1124–1140.
- Mayr, U., & Kliegl, R. (2003). Differential effects of cue changes and task changes on task-set selection costs. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*, 362–372.
- Meiran, N. (1996). Reconfiguration of processing mode prior to task performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*, 1423–1442.
- Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences*, *7*, 134–140.
- Phillip, A., Gade, M., & Koch, I. (2007). Inhibitory processes in language switching: Evidence from switching language-defined response sets. *European Journal of Cognitive Psychology*, *19*, 395–416.
- Psychology Software Tools. (2002). E-Prime (Version 1.1) [Computer software]. Pittsburgh, PA: Author.
- Rogers, R. D., & Monsell, S. (1995). The cost of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General*, *124*, 207–231.
- Rumelhart, D. E., & Norman, D. A. (1982). Simulating a skilled typist: A study of skilled cognitive-motor performance. *Cognitive Science*, *6*, 1–36.
- Schneider, D. W., & Logan, G. D. (2005). Modeling task switching without switching tasks: A short-term priming account of explicitly cued performance. *Journal of Experimental Psychology: General*, *134*, 343–367.
- Schneider, D. W., & Logan, G. D. (2007). Defining task-set reconfiguration: The case of reference point switching. *Psychonomic Bulletin & Review*, *14*, 118–125.
- Schuch, S., & Koch, I. (2003). The role response selection for inhibition of task sets in task shifting. *Journal of Experimental Psychology: Human Perception and Performance*, *29*, 92–105.
- Schwartz, M. F., Reed, E. S., Montgomery, M. W., Palmer, C., & Mayer, N. H. (1991). The quantitative description of action disorganization after brain damage: A case study. *Cognitive Neuropsychology*, *8*, 381–414.
- Verbruggen, F., Liefoghe, B., Vandierendonck, A., & Demanet, J. (2007). Short cue presentations encourage advance task preparation: A recipe to diminish the residual switch cost. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 342–356.

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