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Temporal cue–target overlap is not essential for backward inhibition in task switching

James A. Grange and George Houghton
Centre for Cognitive Neuroscience, School of Psychology, Bangor University, Bangor, Gwynedd, UK

Lag 2 repetition costs are a performance cost observed when participants return to a task after just one intervening trial of a different task, compared to returning after a longer interval (AB*A* vs. CB*A* sequences, where A, B, C are tasks). This effect is known as backward inhibition (BI) and is thought to reflect the need to overcome inhibition applied specifically to Task "A" during disengagement at trial $n - 1$. Druey and Hübner (2007) have suggested that employment of such a specific inhibitory mechanism relies upon the cue and the target of the task overlapping temporally. We provide evidence across three experiments (including a direct replication attempt) that this is not the case, and that the presence of task-specific BI relies to some extent on the need to translate the cue–target relationship into working memory. Additionally, we provide evidence that faster responses in no overlap conditions are driven by low-level perceptual differences between target displays across overlap conditions. We conclude that BI is an effective sequential control mechanism, employed equally in cases of temporally overlapping and temporally separated cues and targets.

Keywords: Task switching; Backward inhibition; Cue processing; Working memory.

The task-switching paradigm has become an increasingly popular approach to studying the mechanisms of cognitive control that permit us to change the way we respond to a given environment to produce sequences of actions (see Monsell, 2003, for a review). One mechanism frequently postulated to aid fluent shifts of action-based attention is inhibition (e.g., Houghton & Tipper, 1994, 1996). In a task-switching context, Mayr and Keele (2000) proposed that when participants expect to switch task on every trial, they will inhibit a just-completed task set to aid switching to the next one. In line with this idea, they found that response times (RTs) are increased when a task repeats after just one intervening trial (an AB*A* sequence), compared to when it

Correspondence should be addressed to James A. Grange, School of Psychology, Bangor University, Adeilad Brigantia, Penrallt Road, Gwynedd, LL57 2AS, UK. E-mail: j.a.grange@bangor.ac.uk

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doesn't (a CB*A* sequence). Mayr and Keele proposed that this lag 2 repetition cost reflects an inhibitory mechanism that serves to suppress the activation levels of a task during its disengagement, aiding a new task set to become dominant. As a result, reactivation of a task set is impaired if it has been recently abandoned (inhibited). This inhibitory mechanism has been labelled backward inhibition (BI).

Recent work in the BI paradigm has proposed that the effect depends upon response selection stages of task performance (Schuch & Koch, 2003), in particular on the use of tasks with overlapping response sets (Gade & Koch, 2007). In contrast, the role of the task cue (the way in which the participant is instructed as to which task to perform on a given trial) has received much less attention (though see Arbuthnott, 2005). This is surprising as all BI studies to date have utilized valid task cues, and it is only on the basis of the cue that the participant knows which task to prepare for. Mayr and Kliegl (2000) suggested that the task cue affords retrieval of the associated task set from long-term memory and its installation into working memory (WM), and one might well anticipate that this process of "cue-to-task translation" would be aided by the inhibition of the current contents of WM.

In this vein, a recent paper by Druey and Hübner (2007) suggested that lag 2 repetition costs only occur when the cue and the imperative stimulus (target) of the task are temporally overlapping (i.e., when the cue remains on the screen during stimulus presentation). In their experiments, lag 2 repetition costs were only found when cues and targets temporally overlapped; when the cue disappeared before the target display, no such costs were found (Experiment 1). In addition it was suggested that the temporal overlap of cue and target at the $n - 2$ trial was essential for observation of the lag 2 repetition cost (Experiment 2). On this basis, the authors suggest that in cases of nonoverlapping cues and targets, selective inhibition of the preceding task does not occur. They propose that when cues and targets are separated temporally, the current task is less salient and thus harder to discriminate; therefore "in order to select the correct task set with reasonable accuracy, interference from *both* [italics added] competing task sets must actually be reduced" (Druey & Hübner, 2007, p. 753).

We found this suggestion intriguing as recent work in our laboratory provides further evidence that the way task cues operate to activate the task in WM can modulate lag 2 repetition costs (Houghton, Pritchard, & Grange, in press). We suggest that in order for task retrieval to happen, some translation must occur in WM between the task cue and the task it represents. When the task set is installed into WM based on this translation, it meets with competition from the still-active cue-to-task translation used on the previous trial. This latter representation is subject to inhibition to clear WM (Mayr & Keele, 2000). Therefore, we argued that using a cue-to-task relationship that minimized the need for translation should result in reduced conflict in WM from trial to trial. This should reduce the need for inhibition, and consequently the lag 2 repetition cost should be reduced. We tested this by having participants respond to the location of a target object accompanied by three nontargets (Houghton et al., in press; see the Method section of the current article for an example of this paradigm). On each trial, a preceding cue specified a distinguishing feature of the target object, and the target changed on every trial. In a series of experiments we manipulated the cue–target relationship in terms of its "transparency"—that is, how directly the visual information provided by the cue specified what was to be looked for. For instance, if the stimuli were four ovals, each distinguished from the rest by some visual feature (see Figure 1), then a transparent cue to a target would be a shape (a rectangle) possessing the target feature. A (relatively) nontransparent cue would be a word referring to the distinguishing feature. To summarize the results of this study, we found that the size of the lag 2 repetition effect varied inversely with the degree of transparency of the cue–target relationship and was altogether absent for the most transparent cues (i.e., those most directly representing the target feature). However, in other conditions we found robust lag 2 repetition

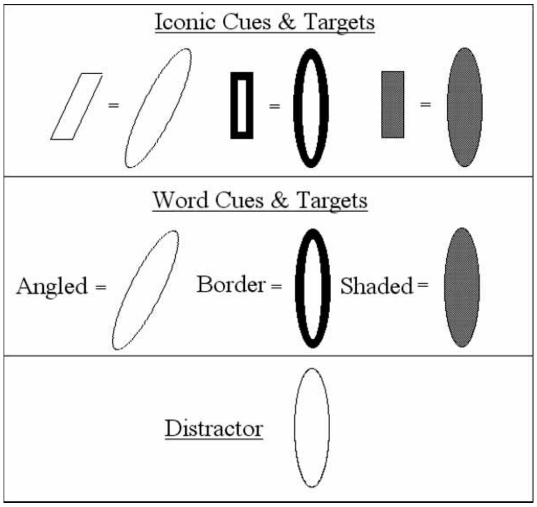

Figure 1. *Cues and targets in the two cue type conditions (icons vs. words). In each "equation", the left-hand side is the cue, and the right-hand side is the target. The "distractor" was a fourth shape that never occurred as a target. All four ovals appeared on the screen on every trial.*

costs across four experiments, and, most pertinently in the present context, in every condition cues and targets were temporally separated (with a cue–stimulus interval of 250 ms).

In addition to our findings, there are published articles reporting significant BI effects with no temporal overlap of cue and target (Altmann, 2007; Kuhns, Lien, & Ruthruff, 2007; Sinai, Goffaux, & Phillips, 2007), suggesting that overlap might not be essential to detect lag 2 repetition costs. However, given Druey and Hübner's (2007) findings, it may be that lag 2 repetition costs are simply reduced when cues and targets do not overlap. If the condition being used does not, for whatever reason, lead to very large or reliable BI effects, then the effect of lack of overlap could be enough to make them statistically unreliable. Thus in the case of our own studies referred to above, the complete absence of a lag 2 repetition cost when the cue-to-target relationship was maximally transparent may have been caused by the fact that we did not utilize temporally overlapping cues. The purpose of the present article is to investigate the relationship of temporal cue–target overlap and BI with our target detection paradigm, thus testing its generality (Experiment 1). Experiment 2 addressed the nature of lag 2 repetition costs in both overlap conditions over varying response–cue intervals (RCIs) and also investigated a possible mechanism driving the observed faster RTs for temporally separated cues and targets (see also Druey & Hübner, 2007). In Experiment 3, we attempted a direct replication of Druey and Hübner's study. To anticipate the results, across all experiments we found no evidence that lag 2 repetition costs are modulated by cue–target overlap.

EXPERIMENT 1

The purpose of the first experiment was twofold:

1. To directly test Druey and Hübner's (2007) proposal of the dependence of cue–target overlap on observing lag 2 repetition costs in a target detection paradigm, thus examining its generality. While, as mentioned above, there are published reports of lag 2 repetition costs without temporal overlap of cue and target, these studies do not examine whether such overlap affects the magnitude of these costs.
2. To investigate whether the lack of lag 2 repetition costs found in the transparently cued conditions of Houghton et al. (in press) was due to the absence of temporal overlap of cue and target, rather than the absence of the need to translate the cue–target relationship.

To do this we adapted Experiment 1 of Houghton et al. (in press) in which target visual icons were cued either transparently by visually similar icons (a condition within which we found no lag 2 repetition costs), or nontransparently by words referring to the target feature (a condition that produces robust lag 2 repetition effects). We crossed this contrast with whether the cues were allowed to temporally overlap with the target stimuli or not. If lag 2 repetition costs are enhanced by temporal overlap then we should find larger effects in the overlap condition; in particular, such costs may appear where we have previously failed to observe them.

Using this paradigm allows two opportunities to measure any modulation of lag 2 repetition costs with cue–target overlap: Specifically, in the first instance such costs may now occur with the iconic transparent cues, a scenario that we have reported generates none; secondly, the overlap of cue and target may increase measures of lag 2 repetition costs within a manipulation that we have reported to be present before—that is, utilizing the word cues (Houghton et al., in press). Therefore this paradigm affords a powerful and critical test of Druey and Hübner's (2007) conclusions.

Method

Participants

A total of 28 undergraduates (23 female; mean age = 21.1 years) from Bangor University were recruited from the participant pool run by the School of Psychology in exchange for partial course credit.

Apparatus and stimuli

Stimuli were presented on a 17″ CRT monitor, from a viewing distance of approximately 60 cm, and responses were made on a standard QWERTY keyboard, both connected to an IBM-compatible PC. Stimulus display consisted of four ovals (6 cm in height; three had widths of 2.3 cm, and one had a width of 3.5 cm) presented with one to the centre of each of the four quadrants on the screen (assigned randomly on each trial). Three of the ovals were potential targets whilst one was always present as a distractor. Each of the three targets had distinguishing features, and the distractor was visually neutral from the targets (see Figure 1). The target display was preceded by either a word cue or an iconic cue, dependent upon the current condition. In the word cue condition, three linguistic cues were used: "Border", "Angled", and "Shaded". Only one cue appeared in each trial centred in the PC monitor in black Times New Roman 15 font on a white background. The iconic-cue condition utilized three rectangular cues. During presentation, each iconic task cue was held constant at 4 cm in height, with a width of 1.4 cm presented in greyscale shading centred on the PC monitor with a white background. Each experimental cue in the word- and iconic-cue blocks were paired to a relevant target. For the word-cue block, each cue verbally described the visual properties of the target it was paired with, whereas the iconic cues displayed visual properties of the target it was paired with. These cue–target pairings remained fixed throughout the experiment.

Procedure

The experimental session lasted approximately 30 min. Participants were presented with four blocks of 126 trials each: (a) word cues with temporally overlapping cues and targets; (b) word cues with no temporal cue–target overlap; (c) iconic cues with temporally overlapping cues and targets; and (d) iconic cues with no temporal cue–target overlap. Each experimental block was preceded by a practice block of 26 trials. Block presentation was counterbalanced across participants.

A trial began with a blank screen for 500 ms, followed by either a word or iconic cue (dependent upon the current block). The cue was presented for 500 ms followed by a cue–stimulus interval (CSI) of 250 ms. In the no-overlap block, the CSI consisted of a blank screen; in the overlap block, the cue remained on the screen for the duration of the CSI. After the CSI, there followed the target display, with one oval to the centre of each quadrant of the screen. In the overlap block, the cue remained present in the centre of the screen; in the no-overlap block, only the targets were displayed. The participant's objective was to locate the target oval that was paired with the cue presented in the previous screen and to respond to its location by pressing the appropriate key on the keyboard as quickly and as accurately as possible. Each quadrant of the screen was assigned a spatially related key on the keyboard, with which to respond when the correct target was identified. If the relevant target appeared in the top left of the screen, participants were instructed to respond with the "D" key; if it appeared in the top right, participants responded with the "J" key; if it appeared in the bottom left, participants responded with the “C” key; and if it appeared in the bottom right of the screen, participants responded with the “N” key. Responses were made with the index and middle fingers of each hand, which were rested on the keys at all times. Incorrect responses generated no feedback from the program. After the response, the screen went blank for 500 ms (response–cue interval, RCI), after which time the cue for the next trial appeared. No task repetitions occurred.

Design

The experiment manipulated three factors, each with two levels, in a fully crossed, repeated measures design: *cue type* (icons vs. words), *cue–target overlap* (overlapping vs. nonoverlapping), and *task sequence* (AB*A* vs. CB*A*). Error rates (%) and reaction time (RT) in milliseconds (ms) served as the dependent variables.

Results

The first 2 trials from each block were removed from data analysis. Trials in which an error occurred, and the 2 trials immediately following an error, were also excluded. Response times faster than 200 ms or slower than 2,500 ms were removed as outliers. Data trimming left 87.07% of the raw data to be submitted for further analysis.[1]

Trimmed RTs and error data were submitted to separate three-way repeated measures analysis of variance (ANOVA), with the factors as described above in the *Design* section. In the error analysis only the main effect of cue type was reliable, $F(1, 27) = 9.87$, $p < .01$, $\eta_p^2 = .27$, with more errors being committed with word cues (4.47%) than iconic cues (3.44%). Therefore, the results focus on RT data. Means by condition, errors, and lag 2 repetition costs are shown in Table 1.

In the RT analysis, all three factors produced significant main effects: *cue type*—icon-cued trials ($M = 501$ ms; $SE = 15$ ms) were faster than word-cue trials ($M = 599$; $SE = 17$), $F(1, 27) = 64.99$, $p < .001$, $\eta_p^2 = .71$; *cue–target overlap*—RTs in the nonoverlapping condition ($M = 528$; $SE = 16$) were faster than those in the overlapping condition ($M = 572$; $SE = 16$), $F(1, 27) = 19.96$, $p < .001$, $\eta_p^2 = .43$; *task sequence*—AB*A* sequences ($M = 555$; $SE = 16$) produced slower RTs than CB*A* sequences ($M = 545$; $SE = 15$), $F(1, 27) = 6.05$, $p < .05$, $\eta_p^2 = .18$.

The main effects were accompanied by a significant interaction of cue type and sequence type, $F(1, 27) = 12.13$, $p < .01$, $\eta_p^2 = .31$. This interaction was investigated using planned comparison paired *t* tests, which showed that lag 2 repetition costs were only apparent for word cues: AB*A* sequences ($M = 610$; $SE = 18$) were significantly slower than CB*A* sequences ($M = 589$; $SE = 16$), $t(27) = 3.39$, $p < .01$. For iconic cues, AB*A* sequences ($M = 500$; $SE = 16$) did not differ from CB*A* sequences ($M = 501$; $SE = 15$), $t(27) = -0.13$, $p = .8$, thus replicating the findings of our earlier work (Houghton et al., in press). Of most importance, the overlap factor did not interact with sequence type, nor was there a three-way interaction of overlap, sequence, and cue. In summary, lag 2 repetition costs were only found when targets were cued verbally, and this was not affected in any way by whether cues overlapped with targets or not (Table 1).

Discussion

The results from Experiment 1 clearly challenge the proposal that specific inhibition of a recently abandoned task during task switching is dependent upon the cue and target overlapping temporally, as suggested by Druey and Hübner (2007). Additionally, lag 2 repetition costs were only present when some degree of translation was required between the cue and the target it

[1] Retaining 87.07% of the raw data still left on average 110.58 trials per block, equating to an average of 55.29 trials per lag 2 comparison for each block submitted for analysis.

Table 1. *Mean reaction time for ABA and CBA sequences in Experiment 1 across both cue types and cue–target overlap*

		Sequence						
		ABA			*CBA*			
Cues		*M*	*SD*	*% errors*	*M*	*SD*	*% errors*	*Lag 2 repetition cost (ms) (ABA − CBA)*
Icon	CT overlap	520	93	3.25	519	78	3.46	1
	No CT overlap	481	95	3.16	483	92	3.90	−2
Word	CT overlap	636	108	4.04	614	96	4.59	22
	No CT overlap	584	98	4.97	564	91	4.29	20

Note: Reaction times in ms. CT overlap = cue–target overlap.

represented (i.e., the word cue condition), thus replicating our recent work (Houghton et al., in press). If task-specific BI depended on cue–target overlap alone, then we should have observed lag 2 repetition costs for the iconic cues within this manipulation; this was not the case (see also Altmann, 2007; Kuhns et al., 2007; Sinai et al., 2007).

Our paradigm is a powerful test of the effect of overlap on lag 2 repetition costs in that it allows two scenarios within which their modulation with temporal cue–target overlap can appear: It was possible that lag 2 repetition costs may have appeared where we had previously failed to find it with the iconic cues; secondly, within the word cue manipulation (a scenario where we have found lag 2 repetition costs previously; Houghton et al., in press) lag 2 repetition costs may have been greater when the cue and target overlapped. However, both of these scenarios failed to find any modulation with overlap. Druey and Hübner's suggestion that both irrelevant tasks are inhibited when the cues and target are separated cannot explain our findings, and as such we suggest that task-specific BI does occur in cases of overlapping and nonoverlapping cues and targets.

It remains to address possible reasons why Druey and Hübner (2007) did not find such a lag 2 repetition effect when the cue and target did not overlap temporally. An important difference is that Druey and Hübner used a relatively large RCI of 1,000 ms, whereas we used one of 500 ms. It has been shown that the lag 2 repetition cost decreases as the RCI increases (Mayr & Keele, 2000). Gade and Koch (2005) proposed that this is due to decay of the activation levels of competing tasks during the RCI, which in turn reduces the level of inhibition required to fully suppress them. The extended RCI may have altered the as yet unexplored dynamics of activation levels and subsequent inhibition between cue overlap conditions. This question was addressed in Experiment 2.

EXPERIMENT 2

For Experiment 2 we repeated the word cue condition from Experiment 1, with the addition of manipulating the RCI between blocks. If our finding of lag 2 repetition costs with separated cues and targets was specifically caused by a peculiarity tied to shorter RCIs, then we should not find such costs at longer response cue intervals. This manipulation is also important theoretically, as to our knowledge no study has manipulated the RCI with temporally separated cues and targets in a BI paradigm.

A further change was made for Experiment 2 to address a possible cause for the reduced RTs for nonoverlapping cues and targets (see also Druey & Hübner, 2007). Druey and Hübner suggested possible reasons for this reduction, including the need to divide attention between cue and target in the overlapping condition and a possible rechecking process to activate the correct task. Another possible cause is that the removal of the cue before target onset encourages advanced task preparation, as participants cannot simply wait until the target arrives before deciding what they should do, as they can when the cue remains visible throughout a trial (De Jong, 2000; Verbruggen, Liefooghe, Vandierendonck, & Demanet, 2007). Such higher level influences are feasible, but a low-level perceptual difference between overlapping and separated conditions may also affect performance. The target display within our paradigm and Druey and Hübner differs significantly between the two overlap conditions at a perceptual level, as there is no cue visible in the separated condition. This low-level difference may be significant, as it has been shown in the perception literature that saccades (and spatially compatible manual responses) to peripheral targets are speeded if a central fixation stimulus is removed 200 ms before target onset as compared to when the fixation remains visible throughout a trial. This "gap-effect" (Gómez, Atienza, Vázquez, & Cantero, 1994) has, among other mechanisms, been attributed to the relative ease of disengaging covert attention from the centre of a display to the peripheral target in gap conditions (Fischer & Weber, 1993) resulting in so-called express saccades. This "attentional release" is especially relevant in our paradigm as participants must disengage covert attention from the central cue to search for peripheral targets. Therefore, in Experiment 2 during the no-overlap condition, instead of presenting a blank screen in between the cue and target display, the cue was replaced with a mask consisting of a string of *x*s, which remained visible during target display; thus the low-level features of target display are now matched between overlap conditions. If the speeded RTs in the no-overlap condition were due to the need for dividing attention between target and meaningful cue, a rechecking process, or enhanced preparation, then the presence of the mask should not affect the main effect of overlap. However, if the speeded RTs are caused by an "attentional release" generated by low-level presence of a central stimulus akin to the gap effect, the two overlap conditions should now produce equivalent RTs.

Method

Participants

A total of 28 undergraduates (18 female; mean age = 24.1 years) from Bangor University were recruited from the same pool as that in Experiment 1. None had participated in Experiment 1.

Apparatus and stimuli

The apparatus, word cues, and target displays were identical to those in Experiment 1.

Procedure

In this experiment, cue–target overlap (CTO, 2 levels) was crossed with response–cue interval (RCI, 2 levels). The levels of CTO were the same as those in Experiment 1 (overlap, no overlap); the levels of RCI were 100 ms (short) and 900 ms (long). This produced four conditions: (a) overlap, short; (b) overlap, long; (c) no overlap, short; (d) no overlap, long. The cue presentation times and CSI were unchanged from Experiment 1. However, during the CSI in the no-overlap condition, the cue was replaced by a central string of 6 *X*s in the same font as the word cues. This mask remained present during target display.

Each condition was presented in its own block of 130 trials, each block being preceded by a practice block of 26 trials. Block presentation was counterbalanced across participants, but with the constraint that overlap only changed from Block 2 to Block 3 (i.e., Blocks 1–2 then 3–4; Blocks 2–1 then 4–3; Blocks 3–4 then 1–2; or Blocks 4–3 then 2–1).

Design

The experiment manipulated three factors with two levels each in a repeated measures design: *RCI* (short vs. long); *cue–target overlap* (overlap vs. no overlap); and *task sequence* (AB*A* vs. CB*A*). All three factors were manipulated within participants. Error rates (%) and RT (ms) served as the dependent variables.

Results

Data trimming (see Experiment 1) left 92.2% of the raw data to be submitted to further analysis.

Trimmed RT and error (%) were submitted to separate three-way repeated measures ANOVAs, with the factors as described in the *Design* section. There were no significant effects in the error rates, so the results section focuses on RT. Means by condition, errors, and lag 2 repetition effects are shown in Table 2.

There was a main effect of RCI, with the short RCI ($M = 650$; $SE = 31$) producing slower RTs than the long RCI condition ($M = 608$; $SE = 30$), $F(1, 27) = 16.94$, $p < .001$, $\eta_p^2 = .39$. There was also a main effect of task sequence, with AB*A* sequences ($M = 640$; $SE = 30$) producing slower RTs than CB*A* sequences ($M = 618$; $SE = 30$), $F(1, 27) = 10.28$, $p < .01$, $\eta_p^2 = .28$. There was no main effect of overlap, $F(1, 27) = 1.09$, $p > .3$, showing that the masking slowed the RTs in the no-overlap conditions to be equivalent to those in the overlap conditions.

Task sequence interacted with RCI, $F(1, 27) = 12.49$, $p < .01$, $\eta_p^2 = .32$, replicating the finding of reduced lag 2 repetition costs at longer RCIs (Gade & Koch, 2005). This interaction was investigated using planned comparison paired *t* tests. At the short RCI, AB*A* sequences ($M = 668$; $SE = 32$) were significantly slower than CB*A* sequences ($M = 632$; $SE = 31$), $t(27) = 3.86$, $p < .01$. At the long RCI, AB*A* sequences ($M = 612$; $SE = 29$) did not differ significantly from CB*A* sequences ($M = 603$; $SE = 30$), $t(27) = 1.43$, $p > .16$.

Most importantly for the current context, lag 2 repetition costs were again not modulated by cue–target overlap, nor was any other interaction involving overlap significant.

Discussion

As in Experiment 1, we found no interaction of overlap on the BI effect. As a further test of the effect of cue–target overlap on BI, we manipulated the RCI, which showed the usual pattern of reduced lag 2 repetition costs at longer RCIs for both overlap conditions (Gade & Koch, 2005), thus supporting our argument that backward inhibition is equivalent in nature in both overlap conditions.

Furthermore, we found that the speeded RTs in the no-overlap conditions of Experiment 1 were likely due to low-level perceptual differences between target displays across overlap conditions, with the presence of a central stimulus in the overlap condition perhaps impeding attentional disengagement from cue to target display, an effect akin to the gap effect (Fischer & Weber, 1993; Gómez et al., 1994). Such an effect presents more evidence against the hypothesis that cue–target overlap can affect high-level mechanisms, such as BI (Druey & Hübner, 2007).

Across two experiments we have demonstrated that the conclusions of Druey and Hübner (2007) do not generalize to our target detection paradigm. For purposes of clarification whether the failure to generalize these conclusions is specific to our paradigm, or a more general replication failure, for Experiment 3 we sought to replicate the relevant

Table 2. *Mean reaction time for ABA and CBA sequences in Experiment 2 across both RCI types and cue–target overlap*

		Sequence						
		ABA			*CBA*			
Cues		*M*	*SD*	*% errors*	*M*	*SD*	*% errors*	*Lag 2 repetition cost (ms) (ABA − CBA)*
Short RCI (100 ms)	CT overlap	672	190	3.07	644	186	2.54	28
	No CT overlap	663	154	3.3	620	146	2.5	43
Long RCI (900 ms)	CT overlap	612	158	1.95	608	174	1.99	4
	No CT overlap	613	158	2.64	599	155	2.95	14

Note: Reaction times in ms. RCI = response–cue interval. CT overlap = cue–target overlap.

aspects of Druey and Hübner's (2007) original design of their Experiment 1.

EXPERIMENT 3

Method

Participants

A total of 28 participants (18 female; mean age = 23.4 years) from Bangor University were recruited from the same pool as that in Experiments 1 and 2; none had participated in either of these experiments.

Apparatus and stimuli

Stimuli were presented and responses collected by the apparatus from Experiment 1. The task stimuli were the numbers 1 to 9, excluding 5, and were presented centrally in white on a black background. Task cues were shapes, with one cue per task: square, diamond, and a circle (each approximately 6 cm in height and width). Shapes were also presented in white.

Procedure

Participants were asked to classify the central digit according to one of three possible tasks, dependent upon the cue presented on the current trial: A square indicated a parity judgement (odd/even); a diamond indicated a magnitude judgement (higher/lower than 5); and the circle indicated a position judgement (position on the number line of 1 to 9—central (3, 4, 6, 7)/peripheral (1, 2, 8, 9). Of the four possible blocks in Druey and Hübner (2007) Experiment 1, we only manipulated cue−target overlap. In their Experiment 1 they also manipulated whether the stimuli were spatially integrated within the cue (i.e., central) or nonintegrated (i.e., one stimulus either side of the cue). Results found significant lag 2 repetition costs only with centrally placed, spatially integrated stimuli. Therefore we utilized integrated, central stimuli throughout. This is also the strategy that Druey and Hübner used for their Experiment 2.

Responses were made on the QWERTY keyboard, using two keys: the "V" key was pressed for "even", "less than 5", and "central", and the "N" key was pressed for "odd", "higher than 5", and "peripheral" responses.

A trial began with the presentation of a central cue, selected randomly with the restriction of no task repetitions being allowed. In the no-overlap condition, the cue was presented for 400 ms, before being removed for 100 ms (blank screen) after which the stimulus appeared on its own. The stimulus remained on screen until a response was registered, after which a blank screen was presented for 1,000 ms (response−cue interval). In the overlap condition, the cue was presented for 500 ms, after which time the stimulus appeared centrally within the cue. The cue remained on screen during stimulus display. Both cue and stimulus disappeared after a response was registered. The RCI was also 1,000 ms for this condition.

Cue−target overlap was manipulated between blocks in the same experimental session, with the order of condition presentation counterbalanced across participants. Druey and Hübner (2007) repeated the experimental procedure over two sessions for each participant. However, all BI studies to date have only utilized one experimental session for each participant, so in order to simplify generalization, we only ran one session for each participant. Additionally, across just one session there are ample trials per lag 2 condition (approximately 190 per overlap condition). For each overlap condition, participants were first exposed to two practice blocks of 48 trials each, after which four experimental blocks were presented, consisting of 96 trials each. The experimental session lasted approximately 60 minutes.

Design

The experiment was a 2 × 2 repeated measures design, with the factors *cue−target overlap* (overlap vs. no overlap), and *sequence* (AB***A*** vs. CB***A***). Reaction time (ms) and error rates (%) served as the dependent variables.

Results

The first two trials from each experimental block were removed, as were errors and trials following errors. The RT trimming differed to that of Experiments 1 and 2 to align with Druey and Hübner's (2007) analysis, which consisted of removing the fastest 5% and the slowest 5% of RTs from each condition (R. Hübner, personal communication, August 29, 2008). Trimmed RT and error (%) were submitted to separate two-way repeated measures ANOVAs, with the factors as described in the *Design* section. Means by condition, errors, and lag 2 repetition costs are shown in Table 3.

Error rates showed no main effect of overlap, $F(1, 27) = 1.05$, $p > .3$. There was a main effect of sequence, $F(1, 27) = 4.49$, $p < .05$, $\eta_p^2 = .14$, with more errors being committed on AB*A* sequences (4.02%) than on CB*A* sequences (3.41%). Critically, there was no interaction of overlap on sequence, $F(1, 27) < 1$, $p > .7$.

RT analyses showed no main effect of overlap, $F(1, 27) = 0.4$, $p > .53$, or sequence, $F(1, 27) = 0.35$, $p > .55$. Most importantly in the present context, cue–target overlap did not interact with task sequence, $F(1, 27) = 0.33$, $p > .56$. For the overlap condition, the lag 2 repetition cost was 7 ms, $t(27) = 0.77$, $p = .45$; for the no-overlap condition, the cost was 1 ms, $t(27) = 0.2$, $p = .85$. To investigate the null interaction further, we calculated individual lag 2 repetition costs for each participant for both cue–target overlap manipulations. If cue–target overlap does produce larger lag 2 repetition costs, then we would expect to see this pattern within the individual lag 2 repetition scores, even though the group means did not reach significance. However, there was no clear pattern of overlap affecting the lag 2 repetition costs. A total of 9 participants showed positive lag 2 repetition costs in both overlap conditions. Regarding the interaction of overlap on the lag 2 repetition costs, 13 participants showed numerically greater lag 2 repetition costs for overlapping cues and targets than for separated cues and targets (as would be expected by the hypothesis of Druey & Hübner, 2007). However, 13 participants showed a trend in the opposite direction, with numerically greater lag 2 repetition costs for separated cues and targets than for overlapping cues and targets.[2] Such distributional trends cannot be accounted for by the hypothesis proposed by Druey and Hübner (2007).

Discussion

The present experiment aimed to directly replicate that of Druey and Hübner (2007) to determine whether the findings from Experiments 1 and 2 indicated a failure to generalize their findings to a new paradigm, or a more general replication failure. However, we failed to replicate their critical results. Indeed, the finding of no lag 2 repetition cost for RT in either overlap condition suggests that the experimental procedure used does not produce reliable BI effects. If the procedure does not produce such reliable "baseline" BI effects, then any manipulation added to it (such as cue–target overlap) is susceptible to producing effects that are equally unreliable.

It is possible that our replication failure may be due to only exposing participants to one experimental session, whereas Druey and Hübner (2007) used two. We only used one session as this has been the norm within the BI literature to date, and as such we wanted to retain consistency allowing generalization to this literature. It remains possible that one can obtain the interaction of Druey and Hübner under such narrow, albeit atypical, conditions. We see no theoretical reason why adding a second session should introduce this interaction, although this may be an avenue for future research.

The finding of no interaction of overlap on task sequence here suggests that our findings from

[2] Breakdown of this interaction only totals 26 participants as lag 2 repetition costs from 2 participants were equivalent between overlap conditions.

Experiments 1 and 2 are more than a generalization failure to other paradigms. This experiment, taken together with the reported findings of significant lag 2 repetition effects with no cue–target overlap from other laboratories, strongly supports our assertion that cue–target overlap is not essential to observe lag 2 repetition costs in task switching.

GENERAL DISCUSSION

The present set of results has directly challenged the proposal of Druey and Hübner (2007) that the cue and target must be copresent in order to observe task-specific inhibition (BI, as measured by lag 2 repetition costs). Experiment 1 found lag 2 repetition costs for both temporally overlapping and nonoverlapping cues and targets. Furthermore, we extended our previous findings of no lag 2 repetition costs with maximally transparent cue–target relationships in cases of temporally overlapping cues and targets (Houghton et al., in press). Experiment 2 demonstrated that lag 2 repetition costs showed the same pattern of being reduced at longer RCIs (Gade & Koch, 2005). Experiment 3 attempted a direct replication of critical features of their paradigm, but again the lag 2 repetition cost was not modulated by cue–target overlap. Taken together we suggest that the difference in experimental design is not the cause of our failure to generalize Druey and Hübner's findings to a new paradigm, and that the necessity of cue–target overlap for task-specific BI to occur can be seriously called into question.

Additionally we have taken steps in addressing the possible mechanisms behind faster RTs in no-overlap conditions. Experiment 2 suggests that the speeded RTs are possibly due to passive low-level differences between overlap displays and thus "release" of attention from a central stimulus, thus facilitating redeployment of attention to the target display. Such a result suggests that the facilitation in no-overlap conditions is not caused by higher level functions such as rechecking or advanced preparation. However, it is slightly problematic for this line of reasoning that our replication of Druey and Hübner's (2007) study found no main effect of overlap; however, we note that there was a slight trend for faster RTs in the no-overlap condition (Table 3). One difference is apparent between the presented paradigms that may account for this, that our target detection paradigm requires a shift of attention from a central cue to peripheral stimuli (as in saccade tasks producing the "gap-effect", Fischer & Weber, 1993; Gómez et al., 1994), whereas Druey and Hübner's (2007) paradigm requires withdrawing attention from the outline of a larger central cue to a smaller central stimulus, which could be considered withdrawing attention from a peripheral cue to a central target (see also Verbruggen et al., 2007). Future research might attempt to manipulate the direction of attentional disengagement empirically to determine its necessity to observe speeded RTs.

In conclusion, the absence of modulation of lag 2 repetition costs and the finding of equivalent RTs when low-level perceptual differences are controlled provide strong evidence against the hypothesis of Druey and Hübner (2007) that

Table 3. *Mean reaction time for ABA and CBA sequences in Experiment 3 across cue–target overlap*

	Sequence						
	ABA			*CBA*			
	M	*SD*	*% errors*	*M*	*SD*	*% errors*	*Lag 2 Repetition Cost (ms) (ABA − CBA)*
CT overlap	865	205	3.92	858	195	3.23	7
No CT overlap	838	221	4.13	837	222	3.59	1

Note: Reaction times in ms. CT overlap = cue–target overlap.

temporal cue–target overlap influences such a high-level mechanism as backward inhibition.

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