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OBSERVATION

Nonstrategic Contributions to Putatively Strategic Effects in Selective Attention Tasks

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Proportion compatible manipulations are often used to index strategic processes in selective attention tasks. Here, a subtle confound in proportion compatible manipulations is considered. Specifically, as the proportion of compatible trials increases, the ratio of complete repetitions and complete alternations to partial repetitions increases on compatible trials but decreases on incompatible trials. This confound is demonstrated to lead to an overestimation in the magnitude of the proportion compatible effect in the context of both a Stroop and a Simon task. Implications for previous research and directions for future research using proportion compatible manipulations are discussed.

Keywords: strategic control, attentional control, compatibility effects, selective attention

Participants' ability to use a nominally irrelevant stimulus as a function of its utility has become a hallmark of strategic control. This type of control is typically demonstrated in selective attention tasks by manipulating the proportion of trials on which a relevant and an irrelevant dimension of a stimulus are compatible. Increasing the proportion of compatible trials increases the predictive utility of the irrelevant dimension and, behaviorally, results in an increase in the influence of the irrelevant dimension on performance. For example, increasing the proportion of compatible trials in a Stroop task (e.g., the word *red* in red) increases the magnitude of the Stroop effect (e.g., Logan, Zbrodoff, & Williamson, 1984). According to the prevailing utilitarian account, as the proportion of compatible trials increases, participants increase their use of the irrelevant dimension (e.g., the color word in the Stroop task). That is, participants use the irrelevant dimension in a strategic fashion. In the present investigation, we demonstrate the effect of a subtle confound present in proportion compatible manipulations, which in turn casts doubt on the notion that proportion compatible effects solely reflect strategic control.

Proportion Compatible Effects

Proportion compatible effects have been demonstrated across a large number of selective attention tasks (e.g., Stroop task: Lindsay & Jacoby, 1994; Logan & Zbrodoff, 1979; Logan et al., 1984; Long & Prat, 2002; Merikle & Joordens, 1997; Simon task: Hommel, 1994; Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002; Flanker task: Gratton, Coles, & Donchin, 1992). In each case the influence of the irrelevant dimension increases as the proportion of compatible trials increases. This empirical consistency is matched by a consistency in theoretical interpretation. In all of these tasks, proportion compatible effects are held to reflect a strategy on the participant's behalf.

The Confound

Manipulating the proportion of compatible trials involves changing the relative frequency of compatible and incompatible trials. An inherent confound in this type of manipulation is that global changes in frequency also lead to local changes in the distribution of sequential transitions (e.g., Kornblum, 1969). Specifically, changes in the proportion of compatible trials alters the ratio of complete repetitions (i.e., all features of trial $N-1$ repeat on trial N) and complete alternations (i.e., all features of trial $N-1$ change on trial N) to partial repetitions (i.e., some features of trial $N-1$ change while others repeat on trial N). Figure 1 depicts the proportion of compatible and incompatible trials consisting of complete repetitions/alternations[1] and partial repetitions for a task with two levels of both the relevant and irrelevant dimension (e.g.,

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[1] In the present context, the proportion of complete trial repetitions and complete trial alternations on compatible and incompatible trials is approximately equal; thus, they are referred to together as *complete repetitions/alternations*. In a similar vein, partial repetitions are made up of two different trial types (i.e., relevant dimension repetition/irrelevant dimension change and relevant dimension change/irrelevant dimension repetition; see Table 1 for all transitions). Again, these two different types of partial repetitions occur equally on compatible or incompatible trials so they are referred to together as *partial repetitions*.

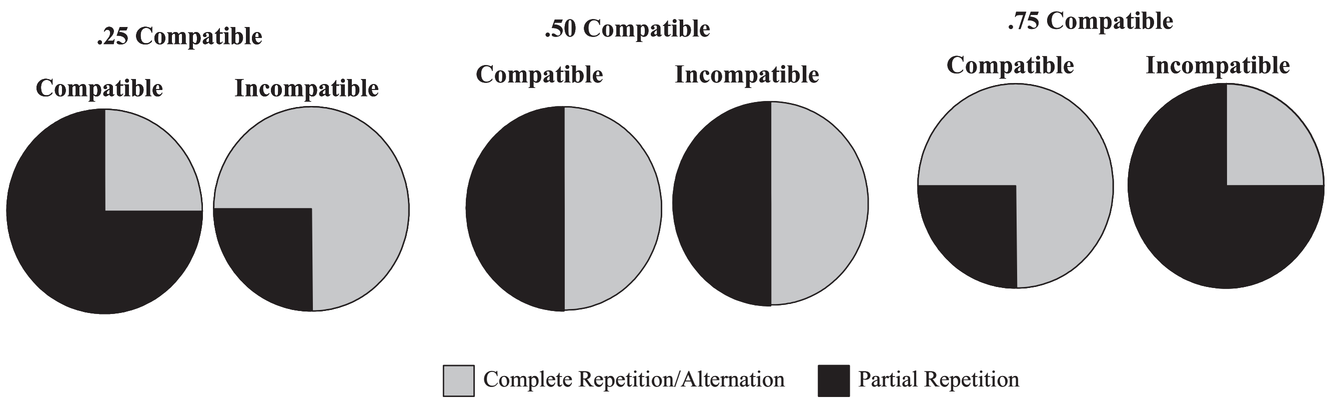

Figure 1. Proportion of trials consisting of complete repetitions/alternations and partial repetitions on compatible and incompatible trials as a function of the proportion of compatible trials in a two-choice task.

a two-choice Stroop task). As is evident from Figure 1, as the proportion of compatible trials increases, the ratio of complete repetitions/alternations to partial repetitions increases on compatible trials and decreases on incompatible trials. Thus, changes in the proportion of compatible trials are confounded with the ratio of complete repetitions/alternations to partial repetitions on compatible and incompatible trials.

The confound between the ratio of complete repetitions/alternations to partial repetitions and the proportion of compatible trials is problematic because performance on complete repetitions/alternations is better than the latter (Hommel & Colzato, 2004; Hommel, Proctor, & Vu, 2004). We return to a discussion of the mechanisms underlying this difference in performance following Experiment 2.

If performance on complete repetitions/alternations is better overall than on partial repetitions, then increasing the ratio of the former to the latter in a given condition will improve performance in that condition. Likewise, decreasing this ratio will impair performance. This is because the index of performance in a given condition is an aggregate of the different sequential transitions (unintentionally) weighted by their relative frequency. Thus, all else being equal, when there are more complete repetitions/alternations than partial repetitions, performance will be better than when there are fewer complete repetitions/alternations than partial repetitions.

Returning to the proportion compatible effect, if the proportion of compatible trials is increased, performance on compatible trials should improve (because the proportion of complete repetitions/alternations increases) and performance on incompatible trials should get worse (because the proportion of complete repetitions/alternations decreases) producing a larger compatibility effect. This is exactly the pattern that is observed. Thus, proportion compatible effects could be accounted for in terms of the distribution of sequential transitions across different proportion compatible conditions without needing to posit a utilitarian strategy.

Present Investigation

The present investigation sought to determine whether the change in the ratio of sequential transitions when the proportion of compatible trials is manipulated accounts for any portion of the proportion compatible effect. Two experiments are reported in which the proportion of compatible trials was manipulated in the context of two popular selective attention tasks: a Stroop task and a Simon task.

In each task, we first demonstrate that performance on complete repetitions/alternations is better than on partial repetitions. The presence of such an effect suggests that the confounding of the ratio of complete repetitions/alternations to partial repetitions with the proportion of compatible trials could affect the magnitude of the proportion compatible effect. To test this possibility, we estimated performance on compatible and incompatible trials using two different methods: one method that is sensitive to the ratio of complete repetitions/alternations to partial repetitions (see Figure 2B) and one method that is not sensitive to the ratio of complete repetitions/alternations to partial repetitions (see Figure 2C).

The first method weights the contribution of complete repetitions/alternations and partial repetitions according to their relative frequency. This is the standard method of estimating performance on compatible and incompatible trials and falls out of simply averaging over transition type. In Figure 2B, we demonstrate that this method of estimating performance on compatible and incompatible trials will produce a proportion compatible effect due entirely to the distribution of sequential transitions.

The second method weights the contribution of complete repetitions/alternations and partial repetitions equally. In Figure 2C, we demonstrate that, in contrast to the former method, the distribution of sequential transitions will not produce a proportion compatible effect. By comparing these estimates of performance on compatible and incompatible trials we can determine the impact of confounding the ratio of complete repetitions/alternations to partial repetitions with the proportion of compatible trials.

If the confounding of the distribution of sequential transitions with the proportion of compatible trials contributes to the proportion compatible effect, then using a method that is insensitive to the ratio of complete repetitions/alternations to partial repetitions will result in a decrease in the magnitude of the proportion compatible effect.

A

	Response Time $\frac{\sum X}{Nx}$		Proportion Compatible			
			25% Compatible		75% Compatible	
			Proportion of Trials (P)		Proportion of Trials (P)	
	Compatible	Incompatible	Compatible	Incompatible	Compatible	Incompatible
Complete Repetition/Alternation (CRA)	500	600	0.25	0.75	0.75	0.25
Partial Repetition (PR)	550	650	0.75	0.25	0.25	0.75

B

$$\text{Compatible RT} = P_{CRA}\left(\frac{\sum CRA}{N_{CRA}}\right) + P_{PR}\left(\frac{\sum PR}{N_{PR}}\right) \qquad \text{Incompatible RT} = P_{CRA}\left(\frac{\sum CRA}{N_{CRA}}\right) + P_{PR}\left(\frac{\sum PR}{N_{PR}}\right)$$

25% Compatible

Compatible RT = .25(500) + .75(550) = 537.5

Incompatible RT = .75(600) + .25(650) = 612.5

Compatibility Effect = 75

75% Compatible

Compatible RT = .75(500) + .25(550) = 512.5

Incompatible RT = .25(600) + .75(650) = 637.5

Compatibility Effect = 125

C

$$\text{Compatible RT} = average\left(\frac{\sum CRA}{N_{CRA}}, \frac{\sum PR}{N_{PR}}\right) \qquad \text{Incompatible RT} = average\left(\frac{\sum CRA}{N_{CRA}}, \frac{\sum PR}{N_{PR}}\right)$$

25% Compatible

$$\text{Compatible RT} = \frac{500 + 550}{2} = 525$$

$$\text{Incompatible RT} = \frac{600 + 650}{2} = 625$$

Compatibility Effect = 100

75% Compatible

$$\text{Compatible RT} = \frac{500 + 550}{2} = 525$$

$$\text{Incompatible RT} = \frac{600 + 650}{2} = 625$$

Compatibility Effect = 100

Figure 2. A: Example response times (RTs) for compatible complete repetitions/alternations and partial repetitions and incompatible complete repetitions/alternations and partial repetitions. Also shown are proportions of each trial type as a function of the proportion of compatible trials. B: Example of calculating estimates of performance on compatible and incompatible trials using a method sensitive to the proportion of complete repetitions/alternations and partial repetitions. This method is equivalent to averaging over transition type when calculating the average for compatible and incompatible trials. Despite the fact that there is no effect of the proportion of compatible trials proper on the compatibility effect (the underlying response times taken from Part A were equal across the two proportion compatible conditions), a proportion compatible effect is present. C: Example of calculating estimates of performance on compatible and incompatible trials using a method that is insensitive to the proportion of complete repetitions/alternations and partial repetitions. Unlike in Part B, there is no proportion compatible effect here.

Experiment 1: Stroop Task

Participants performed a two-choice manual Stroop task. They were presented with the words *blue* and *red* in either blue or red. Responses on compatible trials (e.g., the word *red* in red) are typically faster than on incompatible trials (e.g., the word *red* in blue). This Stroop effect increases in magnitude as the proportion of compatible trials increases (Lindsay & Jacoby, 1994; Logan & Zbrodoff, 1979; Logan et al., 1984; Long & Prat, 2002). Two proportion compatible conditions (.25 and .75) were compared.

Method

Participants. Eighty undergraduate students were paid $4 each or received course credit for their participation. All participants reported normal or corrected-to-normal vision.

Design. Experiment 1 consisted of a 2 (compatibility: compatible vs. incompatible) × 2 (proportion compatible: .25 vs. .75) mixed design. The proportion of compatible trials was manipulated between participants. On compatible trials, the display color and the color word were the same. On incompatible trials, the display color and the color word were different. In order to determine whether performance was affected by the type of transition, we coded each trial as either a complete repetition/alternation or a partial repetition post hoc. All of the different transition types are listed in Table 1.

Apparatus. E-Prime (Psychology Software Tools, 2002) software controlled timing, presented stimuli, and logged responses. Stimuli were presented on a 17-in. (43.18 cm) monitor.

Stimuli. The stimulus display consisted of a fixation (+) at the center of the screen. The color words *blue* and *red* were presented in blue or red in Arial font. Stimuli were presented on a black background.

Procedure. Participants were instructed that on each trial a colored color word would appear and they were to respond to the

Table 1
Complete Repetitions, Complete Alternations, and Partial Repetitions for the Stroop and Simon Tasks Used in the Present Investigation

	Stroop task			
	$N-1$		N	
Trial type	Compatibility	color word–COLOR	Compatibility	color word–COLOR
	Stroop task			
Complete repetition	Compatible	blue–BLUE	Compatible	blue–BLUE
Complete repetition	Incompatible	blue–RED	Incompatible	blue–RED
Complete repetition	Compatible	red–RED	Compatible	red–RED
Complete repetition	Incompatible	red–BLUE	Incompatible	red–BLUE
Complete alternation	Compatible	blue–BLUE	Compatible	red–RED
Complete alternation	Incompatible	blue–RED	Incompatible	red–BLUE
Complete alternation	Compatible	red–RED	Compatible	blue–BLUE
Complete alternation	Incompatible	red–BLUE	Incompatible	blue–RED
Partial repetition	Compatible	blue–BLUE	Incompatible	red–BLUE
Partial repetition	Compatible	blue–BLUE	Incompatible	blue–RED
Partial repetition	Incompatible	blue–RED	Compatible	blue–BLUE
Partial repetition	Incompatible	blue–RED	Compatible	red–RED
Partial repetition	Compatible	red–RED	Incompatible	blue–RED
Partial repetition	Compatible	red–RED	Incompatible	red–BLUE
Partial repetition	Incompatible	red–BLUE	Compatible	blue–BLUE
Partial repetition	Incompatible	red–BLUE	Compatible	red–RED
	Simon task			
	$N-1$		N	
	Compatibility	stimulus–RESPONSE LOCATION	Compatibility	stimulus–RESPONSE LOCATION
Complete repetition	Compatible	right–RIGHT	Compatible	right–RIGHT
Complete repetition	Incompatible	right–LEFT	Incompatible	right–LEFT
Complete repetition	Compatible	left–LEFT	Compatible	left–LEFT
Complete repetition	Incompatible	left–RIGHT	Incompatible	left–RIGHT
Complete alternation	Compatible	right–RIGHT	Compatible	left–LEFT
Complete alternation	Incompatible	right–LEFT	Incompatible	left–RIGHT
Complete alternation	Compatible	left–LEFT	Compatible	right–RIGHT
Complete alternation	Incompatible	left–RIGHT	Incompatible	right–LEFT
Partial repetition	Compatible	right–RIGHT	Incompatible	right–LEFT
Partial repetition	Compatible	right–RIGHT	Incompatible	left–RIGHT
Partial repetition	Incompatible	right–LEFT	Compatible	right–RIGHT
Partial repetition	Incompatible	right–LEFT	Compatible	left–LEFT
Partial repetition	Compatible	left–LEFT	Incompatible	right–LEFT
Partial repetition	Compatible	left–LEFT	Incompatible	left–RIGHT
Partial repetition	Incompatible	left–RIGHT	Compatible	right–RIGHT
Partial repetition	Incompatible	left–RIGHT	Compatible	left–LEFT

color it was printed in. The *A* and *L* keys were used for responses. Response-to-target assignments were counterbalanced across participants. Each trial began with the presentation of the fixation for 500 ms. The target was presented and remained on the screen until a response was made. Participants performed 560 experimental trials preceded by 80 practice trials.

Results

Only correct trials were used in the response time (RT) analysis. A recursive outlier procedure (Van Selst & Jolicœur, 1994) was applied to the RT data and resulted in 3.8% of the RT data being discarded.

Complete repetitions/alternations versus partial repetitions. We conducted a repeated measures analysis of variance (ANOVA) comparing complete repetitions/alternations to partial repetitions for both RTs and errors. The data are reported in the left panel of Figure 3. Complete repetitions/alternations (404 ms) were responded to faster than partial repetitions (432 ms), $F(1, 79) = 52.23$, $MSE = 601.81$, $p < .01$, $\eta_p^2 = .40$, and more accurately (4.4% vs. 6.7%), $F(1, 79) = 43.77$, $MSE = 4.97$, $p < .01$, $\eta_p^2 = .36$.

Proportion compatible effect. Two different methods were used to determine performance on compatible and incompatible trials for each participant. The first method (*confound uncontrolled*; see Figure 2B) consisted of averaging over complete repetitions/alternations and partial repetitions. The second method (*confound controlled;* see Figure 2C) consisted of first determining performance on compatible and incompatible trials for both complete repetitions/alternations and partial repetitions, and then averaging these estimates to get an estimate of

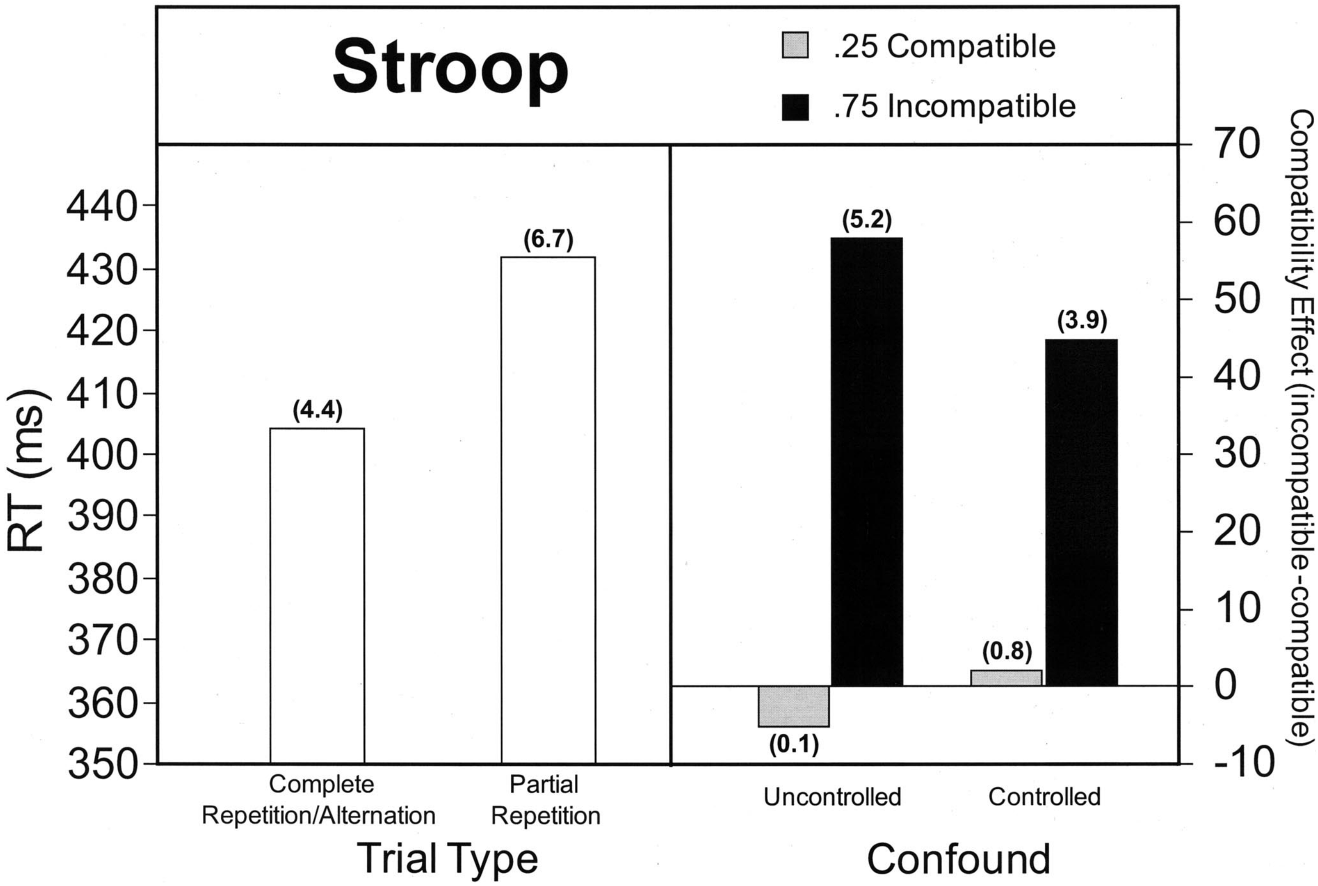

Figure 3. Left: Response time (RT; in ms) and percentage error (in parentheses) as a function of trial type. Right: Stroop effects as a function of the proportion of compatible trials (.25 vs. .75) and whether the confound was uncontrolled or controlled.

performance on compatible (i.e., the average of compatible-complete repetition/alternation and compatible-partial repetition) and incompatible (i.e., the average of incompatible-complete repetition/alternation and incompatible-partial repetition) trials. Stroop effects (incompatible – compatible) were then calculated for both RTs and errors. These Stroop effects were entered into a 2 (confound: uncontrolled vs. controlled) × 2 (proportion compatible: .25 vs. .75) mixed ANOVA, with confound as a within-subject factor.[2] Mean RT and percentage error for each condition are reported in the top panel of Table 2. Stroop effects are presented in the right panel of Figure 3.

The main effect of confound was marginal in RTs, $F(1, 78) = 2.80$, $MSE = 121.10$, $p = .10$, $\eta_p^2 = .03$, and percentage error, $F(1, 78) = 3.39$, $MSE = 1.42$, $p = .07$, $\eta_p^2 = .04$. The main effect of proportion compatible was significant in both RTs, $F(1, 78) = 24.50$, $MSE = 4588.06$, $p < .05$, $\eta_p^2 = .24$, and percentage error, $F(1, 78) = 19.83$, $MSE = 33.87$, $p < .05$, $\eta_p^2 = .20$. Critically, the interaction between confound and proportion compatible was significant in RTs, $F(1, 78) = 34.28$, $MSE = 121.10$, $p < .05$, $\eta_p^2 = .30$, and errors, $F(1, 78) = 29.66$, $MSE = 1.42$, $p < .05$, $\eta_p^2 = .27$.

The proportion compatible effect (Stroop effect 75% compatible condition – Stroop effect 25% compatible condition) when the confound was uncontrolled was 63 ms in RTs, $F(1, 78) = 32.72$, $MSE = 2441.36$, $p < .05$, $\eta_p^2 = .29$, and 5.1% in errors, $F(1, 78) = 29.66$, $MSE = 17.71$, $p < .05$, $\eta_p^2 = .28$. When the confound was controlled, the proportion compatible effect was 43 ms in RTs, $F(1, 78) = 16.17$, $MSE = 2267.80$, $p < .05$, $\eta_p^2 = .17$, and 3.1% in errors, $F(1, 78) = 10.72$, $MSE = 17.59$, $p < .05$, $\eta_p^2 = .12$.

Discussion

Experiment 1 demonstrated that, in the Stroop task, the proportion compatible effect was reduced once the distribution of sequential transitions was controlled. Thus, confounding the ratio of complete repetitions/alternations to partial repetitions with propor-

[2] Given that the observations contributing to the compatible and incompatible means are the same, the present test is very powerful. We also conducted a more conservative test wherein the observations contributing to the compatible and incompatible means were different. This was achieved by dividing each participant's observations into two independent sets (i.e., odd vs. even trials) and calculating compatible and incompatible means for each set according to the given method of calculation (e.g., even set confound uncontrolled vs. odd set confound controlled). Thus, each participant would have a compatibility effect for each method of calculation, with each based on independent observations. This analysis yielded the same pattern of results.

Table 2
Mean Response Time (RT) and Percentage Error (%ER) as a Function of Compatibility, Proportion Compatible, and Whether the Confound Between Ratio of Complete Repetitions/Alternations to Partial Repetitions and Proportion Compatible Was Uncontrolled or Controlled

	Confound							
	Uncontrolled				Controlled			
	25% compatible		75% compatible		25% compatible		75% compatible	
Compatibility	RT	%ER	RT	%ER	RT	%ER	RT	%ER
			Stroop task					
Incompatible	396	5.9	475	8.6	400	6.4	468	7.4
Compatible	401	5.8	417	3.4	398	5.6	423	3.5
Compatibility effect	−5	0.1	58	5.2	2	0.8	45	3.9
			Simon task					
Incompatible	427	2.5	465	10.2	436	3.2	453	7.5
Compatible	451	6.6	389	1.2	437	5.1	401	1.6
Compatibility effect	−24	−4.1	76	9.0	−1	−1.9	52	6.0

tion compatible results in an overestimation of the magnitude of the proportion compatible effect in the Stroop task. Experiment 2 determined whether the same was true in another popular selective attention task: the Simon task.

Experiment 2: Simon Task

In a Simon task, participants typically discriminate between two targets that are presented on either the left or right side of a display using response keys that are located on the left or right. Despite the fact that location is irrelevant to their task, participants respond faster when the stimulus appears on the same side as the required response (i.e., a compatible trial) than when the stimulus appears on the side opposite the required response (i.e., an incompatible trial). This effect is typically referred to as the Simon effect (e.g., Hommel, 1994). The Simon effect increases in magnitude as the proportion of compatible trials increases (Hommel, 1994; Stürmer et al., 2002).

We present a reanalysis of an experiment reported by Borgmann, Risko, Stolz, and Besner (2007) where the proportion of compatible trials was manipulated in the context of a typical Simon task. Participants discriminated between an *X* and an *O* presented to the left or right of a central fixation. Responses were located on the left and right of the keyboard. We present data from the .25 and .75 proportion compatible conditions.

Method

Participants. Forty undergraduate students were paid $2 each or received course credit for their participation. All participants reported normal or corrected-to-normal vision.

Design. Experiment 2 consisted of a 2 (compatibility: compatible vs. incompatible) × 2 (proportion compatible: .25 vs. .75) mixed design. The proportion of compatible trials was manipulated between participants. On compatible trials, the target appeared on the same side as the required response, and on incompatible trials, the target appeared on the opposite side of the required response. Transition type was determined in the same fashion as in Experiment 1.

Stimuli. The stimulus display consisted of a fixation (+) at the center of the screen. Either an *X* or an *O* was presented 3.8 cm to the left or the right of fixation. All stimuli were presented in black on a white background.

Procedure. Participants were instructed that on each trial an *X* or an *O* would be presented and they were to respond by pressing the assigned key. The *A* and *L* keys were used as responses. Response-to-target assignments were counterbalanced across participants. Each trial began with the presentation of the fixation for 500 ms. The target was then presented and remained on the screen until a response was made. Participants performed 240 experimental trials preceded by 80 practice trials.

Results

Only correct RTs were used. RTs greater than 1,000 ms were considered outliers[3] and their removal resulted in 0.9% of the RT data being discarded.

Complete repetitions/alternations versus partial repetitions. We conducted a repeated measures ANOVA comparing complete repetitions/alternations with partial repetitions for both RTs and percentage errors. The data are reported in the left panel of Figure 4. Complete repetitions/alternations (400 ms) were responded to faster than partial repetitions (455 ms), $F(1, 39) = 192.26$, $MSE = 302.99$, $p < .01$, $\eta_p^2 = .83$, and more accurately (1.4% vs. 6.9%), $F(1, 39) = 96.94$, $MSE = 6.18$, $p < .01$, $\eta_p^2 = .71$.

Proportion compatible effects. We calculated Simon effects (incompatible – compatible) for both RTs and percentage error using the two different methods described earlier. These Simon effects were entered into a 2 (confound: uncontrolled vs. controlled) × 2 (proportion compatible: .25 vs. .75) mixed ANOVA, with confound as a within-subject factor. Mean RT and percent error for each condition are reported in the bottom panel of Table 2. Simon effects are presented in the right panel of Figure 4.

[3] The same outlier procedure that was applied in Borgmann et al.'s (2007) study was used here, rather than the Van Selst and Jolicœur (1994) procedure used in Experiment 1.

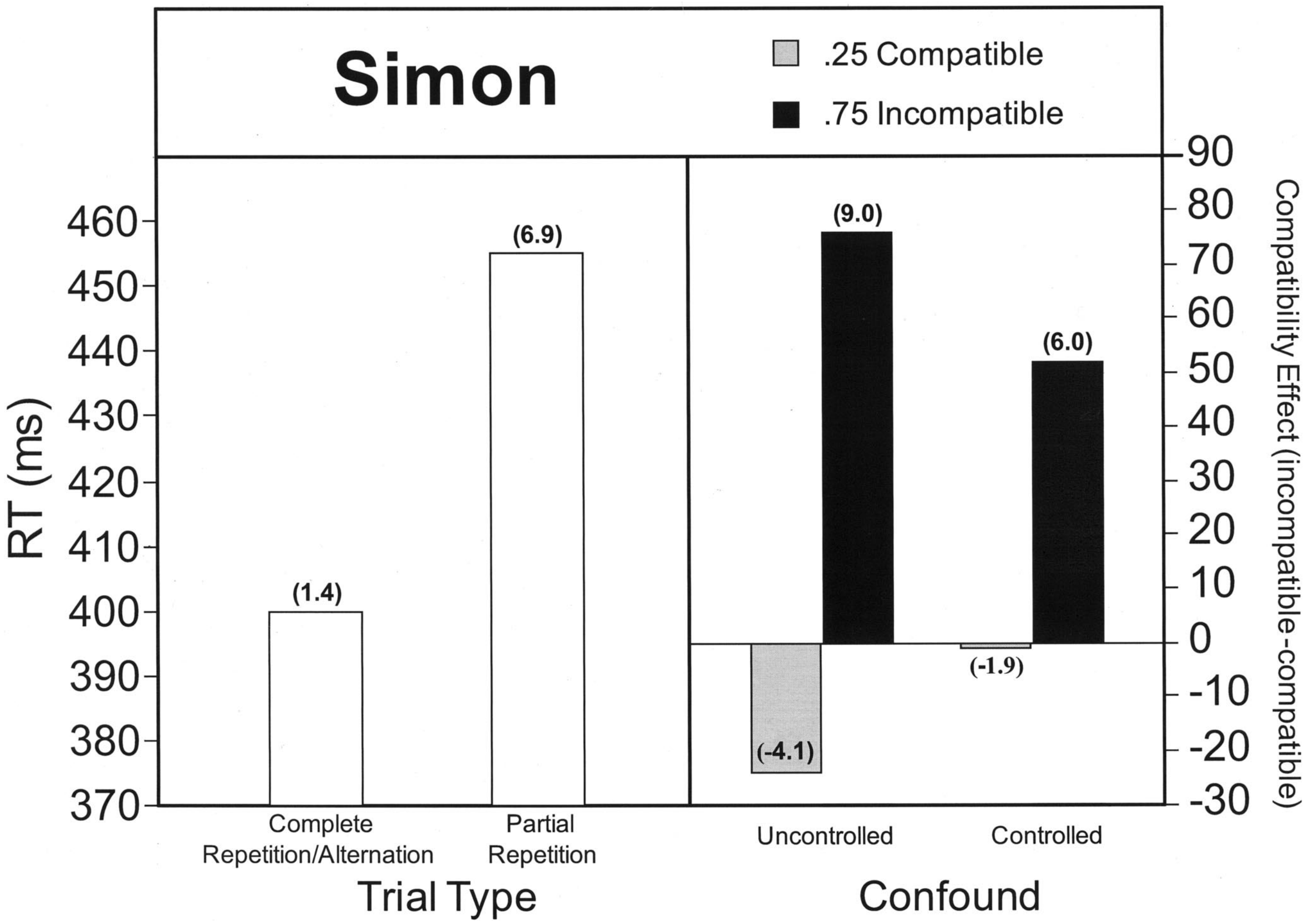

Figure 4. Left: Response time (RT; in ms) and percentage error (in parentheses) as a function of trial type. Right: Simon effects as a function of the proportion of compatible trials (.25 vs. .75) and whether the confound was uncontrolled or controlled.

The main effect of confound was not significant in either RTs or percentage error (both Fs < 1.6; $\eta_p^2 = .04$). The main effect of proportion compatible was significant in both RTs, $F(1, 38) = 95.86$, $MSE = 1207.11$, $p < .05$, $\eta_p^2 = .72$, and percentage error, $F(1, 38) = 58.89$, $MSE = 37.26$, $p < .05$, $\eta_p^2 = .61$. Critically, the interaction between confound and proportion compatible was significant in RTs, $F(1, 38) = 175.11$, $MSE = 60.86$, $p < .05$, $\eta_p^2 = .82$, and percentage error, $F(1, 38) = 65.13$, $MSE = 2.20$, $p < .05$, $\eta_p^2 = .63$.

When the confound was uncontrolled, the proportion compatible effect (Simon effect in the 75% compatible condition – Simon effect in the 25% compatible condition) was 100 ms in RTs, $F(1, 38) = 144.51$, $MSE = 680.25$, $p < .05$, $\eta_p^2 = .79$, and 13.1% in errors, $F(1, 38) = 69.48$, $MSE = 24.89$, $p < .05$, $\eta_p^2 = .65$. When the confound was controlled, the proportion compatible effect was 53 ms in RTs, $F(1, 38) = 47.75$, $MSE = 587.73$, $p < .05$, $\eta_p^2 = .56$, and 7.9% in errors, $F(1, 38) = 41.75$, $MSE = 14.57$, $p < .05$, $\eta_p^2 = .52$.

Discussion

As in Experiment 1, the magnitude of the proportion compatible effect was strongly reduced once the distribution of sequential transitions was controlled. Thus, confounding the ratio of complete repetitions/alternations to partial repetitions with proportion compatible results in an overestimation of the magnitude of the proportion compatible effect in the Simon task.

Sequential transitions. In the main analyses, performance was collapsed across complete trial repetitions and complete trial alternations and the two types of partial repetitions (relevant repeat – irrelevant change; relevant change – irrelevant repeat). However, performance differences do exist between these transition types. To demonstrate this fact, we conducted an analysis of both Experiment 1 (Stroop) and Experiment 2 (Simon) comparing the four different types of transitions (see Table 3).

In the Stroop task, performance was best on complete repetitions (379 ms, 4.0%), ts > 2.06, ps $< .05$, for all paired comparisons. In RTs, for partial repetitions when the relevant dimension repeated (414 ms) responses were faster than on complete alternations (428 ms), $t(79) = 3.26$, $SED = 4.29$, $p < .05$. In errors, the reverse pattern of performance was observed, such that for partial repetitions when the relevant dimension repeated (6.3%) more errors occurred than on complete alternations (4.0%), $t(79) = 2.91$, $SED = 0.54$, $p < .05$. Performance was worst on partial repetitions when the irrelevant dimension repeated (450 ms, 7.1%), ts > 5.00,

Table 3
Mean Response Time (RT) and Percentage Error (%ER) as a Function of Repetition Type for Experiment 1 (Stroop) and Experiment 2 (Simon)

	Repetition type							
	Relevant repetition				Relevant change			
	Irrelevant repetition		Irrelevant change		Irrelevant repetition		Irrelevant change	
Task	RT	%ER	RT	%ER	RT	%ER	RT	%ER
Stroop	379	4.0	414	6.3	450	7.1	428	4.8
Simon	389	1.0	439	5.6	470	8.2	411	1.8

*p*s < .05, for all paired comparisons except between the two types of partial repetitions in errors.

There was a similar pattern in the Simon task: Performance was best on complete repetitions (389 ms, 1.0%), *t*s > 2.60, *p*s < .05, for all paired comparisons. Performance was better in both RTs and errors on complete alternations (411 ms, 1.8%) than on partial repetitions when the relevant dimension repeated (438 ms, 5.6%), $t(39) = 5.02$, $SED = 5.64$, $p < .05$, $t(39) = 5.49$, $SED = 0.69$, $p < .05$, for RTs and errors, respectively. Performance was worst on partial repetitions when the irrelevant dimension repeated (470 ms, 8.2%), *t*s > 3.4, *ps* < .05, for all paired comparisons.

Various features of this pattern of results have been explained by recourse to a variety of mechanisms (e.g., feature binding, Hommel & Colzato, 2004; negative priming, Neill, 1977; response priming, Keele, 1973). For example, Hommel and Colzato (2004) explained the difference between complete repetitions and complete alternations and partial repetitions in terms of feature integration. When there is incomplete overlap between features of consecutive trials (i.e., partial repetitions), the repeated feature primes the previous trial's event code (i.e., an integrated representation of the previous trial event) resulting in competition that impairs feature integration and thus performance on the current trial. An additional benefit for response repetition may also be required because performance on complete repetitions (response repetition) is better than on complete alternations (response alternation) despite the lack of competition between integrated event codes in both cases. In addition, performance is better on partial repetitions when the relevant dimension repeats (response repetition) than on partial repetitions when the irrelevant dimension repeats (response alternation) despite the presence of competition between integrated event codes in both cases. Thus, an account in terms of feature integration and response priming can account for the pattern of results across the various transitions present in the current study.

Conflict adaptation. Thus far, we have focused on sequential transitions in terms of stimulus–response transition. Another explanation can be couched in terms of condition transitions. Specifically, Gratton et al. (1992) demonstrated that compatibility effects are smaller following incompatible trials than following compatible trials. This has been explained in terms of conflict adaptation (Ullsperger, Bylsma, & Botvinick, 2005). An incompatible trial signals conflict in information processing, which leads to an increase in top-down control on the following trial and vice versa in the case of a compatible trial. When the proportion of compatible trials is increased, the proportion of trials preceded by a compatible trial increases, which should increase the magnitude of the compatibility effect overall. Thus, the proportion compatible effect may be due to the accumulated effects of local sequential conflict adaptation effects.

Distinguishing between an account in terms of stimulus–response transitions (e.g., feature integration and response priming) and condition transitions (e.g., conflict adaptation) is difficult, as these transition types overlap considerably. For example, in the two-choice tasks used here, the fact that a compatible trial preceded by a compatible trial (CC) is faster than a compatible trial preceded by an incompatible trial (CI) could be due to conflict adaptation. But, it could also be due to the fact that compatible trials preceded by compatible trials are always complete repetitions or complete alternations, and compatible trials preceded by incompatible trials are always partial repetitions (see Table 1). In fact, a number of researchers have claimed that conflict adaptation effects are simply feature integration or priming effects (Hommel et al., 2004; Mayr, Awh, & Laurey, 2003), but this remains an active area of debate (Ullsperger et al., 2005). Critically, the issue at hand is that global manipulations of the proportion of compatible trials are confounded with changes in the distribution of sequential transitions and that controlling that confound reduces the magnitude of the proportion compatible effect.

General Discussion

The present experiments demonstrate that proportion compatible manipulations in both Stroop and Simon tasks index more than just strategic control. Proportion compatible effects also index the effect of changing the distribution of sequential transitions on compatible and incompatible trials. We turn now to a brief discussion of the implications of the present work for previous and future research using proportion compatible manipulations.

Implications for Previous Research

There exist a large number of studies that have used proportion compatible manipulations as an index of strategic control in Stroop and Simon tasks. Given the present results, it is likely that the proportion compatible effects reported in these studies are overestimated. In addition, the problem present in the use of proportion compatible manipulations in Stroop and Simon tasks is likely not limited to those tasks (see also Cohen, Fuchs, Bar-Sela, Brumberg, & Magen, 1999). Manipulations analogous to the proportion of compatible trials, and thus open to the confound discussed here, are often used in other paradigms (e.g., the covert orienting paradigm).

Implications for Future Research

Given the large effect of the proportion compatible manipulation remaining once the distribution of sequential transitions was controlled, should researchers be concerned about this confound? The answer, of course, is yes. If researchers plan to use proportion compatible manipulations as a measure of strategic control, the relative purity of the measure should be foremost in their minds. If the confound between the distribution of sequential transitions and the proportion of compatible trials is ignored, then the proportion compatible effect no longer exclusively indexes strategic control, leaving the results of experiments using this manipulation open to alternative explanations.

Conclusion

The confounding of the proportion of compatible trials with the distribution of sequential transitions on compatible and incompatible trials leads to an overestimation of the magnitude of the proportion compatible effect across two widely studied tasks. Thus, the strong view that proportion compatible effects exclusively reflect strategic control is no longer tenable.

References

Borgmann, K. W. U., Risko, E. F., Stolz, J. A., & Besner, D. (2007). Simon says: Reliability and the role of working memory and attentional control in the Simon task. *Psychonomic Bulletin and Review, 14,* 313–319.

Cohen, A., Fuchs, A., Bar-Sela, A., Brumberg, Y., Magen, H. (1999). Correlational cuing as a function of target complexity and target-flanker similarity. *Perception & Psychophysics, 61,* 275–290.

Gratton, G., Coles, M. G. H., & Donchin, E. (1992). Optimizing the use of information: The strategic control of the activation of responses. *Journal of Experimental Psychology: General, 121,* 480–506.

Hommel, B. (1994). Spontaneous decay of response code activation. *Psychological Research, 56,* 261–268.

Hommel, B., & Colzato, L. S. (2004). Visual attention and the temporal dynamics of feature integration. *Visual Cognition, 11,* 483–521.

Hommel, B., Proctor, R. W., & Vu, K.-P. L. (2004). A feature-integration account of sequential effects in the Simon task. *Psychological Research, 68,* 1–17.

Keele, S. W. (1973). *Attention and human performance*. Pacific Palisades, CA: Goodyear.

Kornblum, S. (1969). Sequential determinants of information processing in serial and discrete choice reaction time. *Psychological Review, 76,* 112–131.

Lindsay, D. S., & Jacoby, L. L. (1994). Stroop process dissociations: The relationship between facilitation and interference. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 219–234.

Logan, G. D., & Zbrodoff, N. J. (1979). When it helps to be misled: Facilitative effects of increasing the frequency of conflicting stimuli in a Stroop-like task. *Memory & Cognition, 7,* 166–174.

Logan, G. D., Zbrodoff, N. J., & Williamson, J. (1984). Strategies in the color-word Stroop task. *Bulletin of the Psychonomic Society, 22,* 135–138.

Long, D. L., & Prat, C. S. (2002). Working memory and Stroop interference: An individual differences investigation. *Memory & Cognition, 30,* 294–301.

Mayr, U., Awh, E., & Laurey, P. (2003). Conflict adaptation effects in the absence of executive control. *Nature Neuroscience, 6,* 450–452.

Merikle, P. M., & Joordens, S. (1997). Parallels between perception without attention and perception without awareness. *Consciousness and Cognition, 6,* 219–236.

Neill, W. T. (1977). Inhibition and facilitation processes in selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 3,* 444–450.

Psychology Software Tools. (2002). E-Prime (Version 1.1) [Computer software]. Pittsburgh, PA: Author.

Stürmer, B., Leuthold, H., Schröter, H., Soetens, E., & Sommer, W. (2002). Control over location-based response activation in the Simon task: Behavioral and electrophysiological evidence. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 1345–1363.

Ullsperger, M., Bylsma, L. M., & Botvinick, M. M. (2005). The conflict adaptation effect: It's not just priming. *Cognitive, Affective, & Behavioral Neuroscience, 5,* 467–472.

Van Selst, M., & Jolicœur, P. (1994). A solution to the effect of sample size on outlier elimination. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 47*(A), 631–650.

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