Backward Motor Crosstalk in Psychological Refractory Period Tasks

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Psychological Refractory Period Tasks

In psychological refractory period (PRP) tasks, people are presented with the stimuli for two tasks in rapid succession and required to respond to each as quickly as possible (e.g., Welford, 1952). Reaction time to the second stimulus (RT_2) typically increases dramatically when there is only a short time between stimuli (i.e., short stimulus onset asynchrony, SOA). This increase is often called the *PRP effect*.

Response-Selection Bottleneck Models

According to response-selection bottleneck models (e.g., Pashler, 1984), selection of the second response, R_2, cannot begin until selection of R_1 is finished, because the same bottleneck process is needed for both selection operations. As illustrated in Figure 1, RT_2 increases at short SOAs, relative to long SOAs, because the selection of R_2 has to wait longer for the bottleneck process to finish selecting R_1.

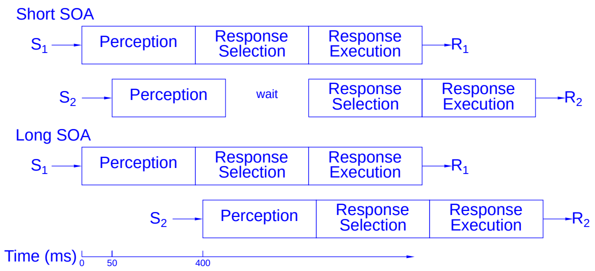

Figure 1: *Illustration of processing for the response-selection bottleneck model, in which a bottleneck stage (i.e., response selection) can only be used for one task at a time. At short SOAs, selection of R_2 must wait for selection of R_1 to finish, and RT_2 increases with the length of this waiting period. At long SOAs, selection of R_2 need not wait as long, so RT_2 is shorter.*

Backward Crosstalk

Response-selection bottleneck models suggest that the selection of R_1 should be independent of the $S_2 \rightarrow R_2$ mapping used in the same trial, because R_1 selection finishes before R_2 selection begins. Contrary to this expectation, however, several studies have shown that RT_1 can under some circumstances be affected by the trial's $S_2 \rightarrow R_2$ mapping (e.g., Hommel, 1998; Logan & Schulkind, 2000). The fact that R_1 can be affected by backward crosstalk from the second task is surprising in view of the response-selection bottleneck model's assumption that selection of R_1 must finish before selection of R_2 can begin.

Research Question

Previous demonstrations only indicate that backward crosstalk can influence task 1 during its stages of response selection (e.g., Hommel, 1998) and memory retrieval (e.g., Logan & Schulkind, 2000). The present experiments explored the generality of backward crosstalk by seeing whether it can also influence another stage.

We tested for an effect of backward crosstalk on the motor stage, during the execution of R_1. Specifically, we asked whether activation associated with the $S_2 \rightarrow R_2$ mapping could influence the forcefulness of R_1. R_1

was a choice between middle and index finger keypresses with the left hand, and R_2 was a choice between a *hard* or a *soft* keypress with the index finger of the right hand. If the forcefulness of R_1 depends on whether a hard or soft R_2 is required in the same trial, this dependence would demonstrate backward crosstalk effects on the execution of R_1.

Experiment 1

Following Hommel (1998), the first experiment used a single stimulus with two attributes to which participants made two independent responses, in order to maximize the opportunity for backward crosstalk.

Stimuli and Tasks:

In each trial participants were presented with a single colored letter: a red or green X or O. They were instructed to respond separately to the letter's color and identity according to instructions like these (with counterbalanced assignments of features to responses):

Task	Stimulus letter	Correct response
1	Red	Middle finger, left hand
	Green	Index finger, left hand
2	X	Hard keypress, index finger, right hand
	O	Soft keypress, index finger, right hand

Participants responded by pressing force-sensitive keys, and we measured both the onset latency of force generation (i.e., RT) and the peak force output in each trial. Trials with grouped responses (i.e., R_1 and R_2 force onsets within 100 ms of one another) were excluded from the analysis.

Results:

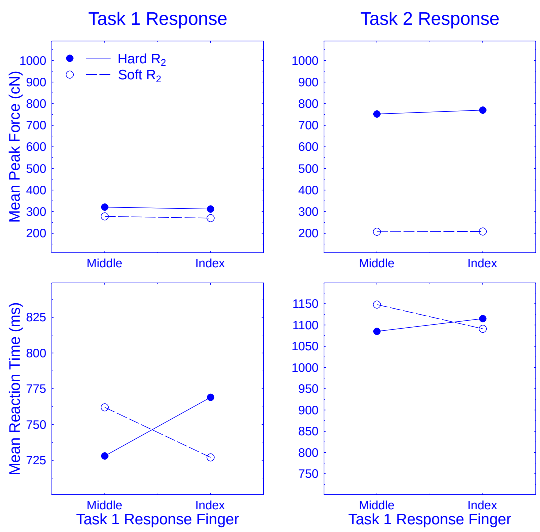

Figure 2: *Mean peak force and reaction time for each task as a function of experimental condition in Experiment 1.*

The key result is shown in the upper left panel of Figure 2: R_1 force was greater when the upcoming R_2 was to be a hard response than when it was to be a soft one ($p < .005$). Thus, activation associated with the $S_2 \rightarrow R_2$ mapping was available in time to influence the forcefulness of R_1, demonstrating backward crosstalk at the motor level.

As shown in the upper right panel of Figure 2, task-2 peak force was much larger when S_2 called for a hard response than when it called for a soft one. This simply indicates that participants were able to generate hard or soft keypresses as instructed.

As shown in the lower two panels of Figure 2, RTs were much longer for task 2 than for task 1, consistent with the idea that R_2 selection cannot begin until R_1 selection is finished. The RT data for both tasks also show an unexpected interaction: Responses were relatively fast in trials with a middle finger R_1 and a hard R_2 or with an index finger R_1 and a soft R_2, whereas they were relatively slow in the other two combinations. This may be an additional sign of crosstalk between tasks, but it was not replicated in Experiment 2.

Experiment 2

Perhaps backward motor-level crosstalk was obtained in Experiment 1 only because a single stimulus was used for both tasks (i.e., only because we maximized the opportunity for crosstalk). This experiment was conducted to see whether the effect would generalize to a more typical PRP task in which S_1 and S_2 were physically separate and presented at varying SOAs.

Stimuli and Tasks:

In each trial participants were presented with two stimuli separated by an SOA of 50, 150, or 400 ms. S_1 was a red or green rectangle to the left of fixation, and S_2 was a white X or O to the right of fixation. As in Experiment 1, participants were instructed to respond to stimulus color with the left hand and to letter identity with the right, in a pattern like this (with counterbalancing):

Task	Stimulus	Correct response
1	Red rectangle	Middle finger, left hand
	Green rectangle	Index finger, left hand
2	X	Hard keypress, index finger, right hand
	O	Soft keypress, index finger, right hand

Results:

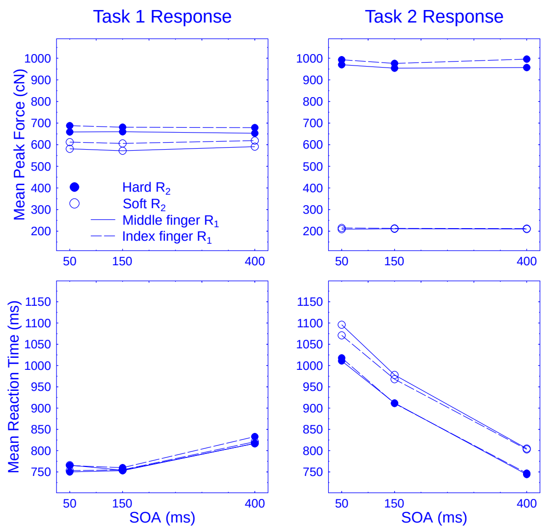

Figure 3: *Mean peak force and reaction time for each task as a function of experimental condition in Experiment 2.*

The key result is shown in the upper left panel of Figure 3: R_1 force was again greater when the upcoming R_2 was to be a hard response than when it was to be a soft one ($p < .001$). This demonstrates an influence of backward crosstalk at the motor level in a PRP task with separated S_1 and S_2. Interestingly, the effect diminishes little if at all across the range of SOAs used here.

As shown in the upper right panel of Figure 3, task-2 peak force was again much larger when S_2 called for a hard response than when it called for a soft one.

As shown in the lower two panels of Figure 3, RT_2 was substantially elevated at short SOAs, replicating the standard PRP effect.

Conclusions

- In a PRP situation, the motor dynamics of R_1 can be influenced by response-related processing associated with the second task.
- Response-selection bottleneck models must be elaborated to account for the effects of the $S_2 \rightarrow R_2$ mapping on the forcefulness of R_1.
- Three possible elaborations of response-selection bottleneck models to account for backward motor-level crosstalk are shown in Figure 4. The three accounts differ in which stage of task-2 produces the activations that influence the forcefulness of task-1 responses: perception (bottom panel), response selection (middle panel), or response execution (top panel).
  - The *execution source* account seems implausible because activations produced during R_2 execution would probably be too late to generate effects on R_1 force.
  - The *perception source* account seems implausible because effects on R_1 force would probably depend on SOA if they were produced by activations produced during the perceptual analysis of S_2.
  - The *selection source* account seems most consistent with the timing of the task-2 effects on R_1 force.

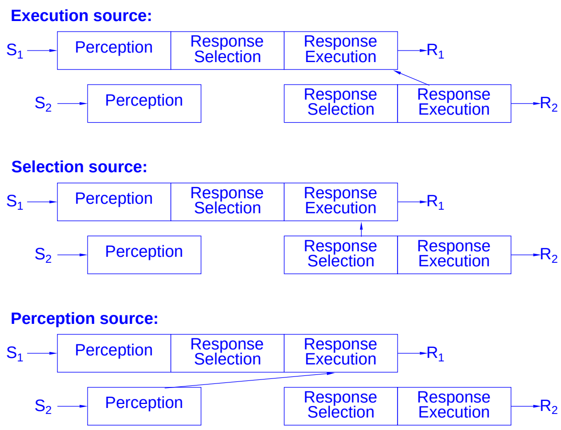

Figure 4: *Three elaborations of the response-selection bottleneck model capable of accounting for motor-level crosstalk.*

References

Hommel, B. (1998). Automatic stimulus-response translation in dual-task performance. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 1368–1384.

Logan, G. D., & Schulkind, M. D. (2000). Parallel memory retrieval in dual-task situations: I. Semantic memory. *Journal of Experimental Psychology: Human Perception and Performance, 26,* 1072–1090.

Pashler, H. E. (1984). Processing stages in overlapping tasks: Evidence for a central bottleneck. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 358–377.

Welford, A. T. (1952). The "psychological refractory period" and the timing of high-speed performance — A review and a theory. *British Journal of Psychology, 43,* 2–19.