Optimizing Order Control in Dual-Tasks?

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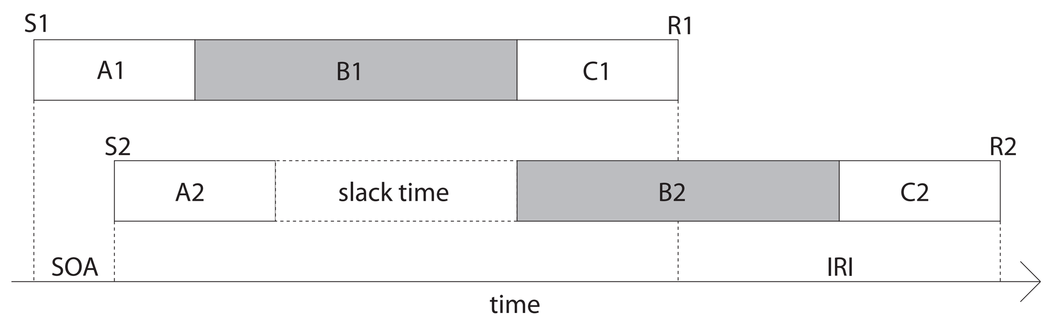
Introduction



In a psychological refractory period (PRP) experiment two stimuli (S1 and S2) are presented with a varying temporal interval, the stimulus onset asynchrony (SOA). Each stimulus involves a choice reaction time task with a corresponding response (R1 and R2). Reaction time to task 2 (RT2) typically increases progressively as SOA decreases (the PRP-effect).

This is often explained with a central bottleneck (e.g. Pashler, 1994), which causes task-2 central stages (B2) to wait until task-1 central stages (B1) are processed. The optimality account of Miller, Ulrich and Rolke (in press) suggests that this central bottleneck might be strategic with the purpose to minimize total reaction time (TRT = RT1 + RT2).

The present study examines whether the optimality account can be applied to central processing order, which the standard bottleneck model assumes to be determined on a first-come, first-served principle.

Present Approach

Research Question

Do participants interrupt task 1 and pre-draw task-2 central processing when it would be efficient in terms of TRT

A without the possibility to prepare for the upcoming SOA,

B in a paradigm where stimulus presentation order is always the same?

Paradigm and Design

Two major modifications of the standard PRP-paradigm:

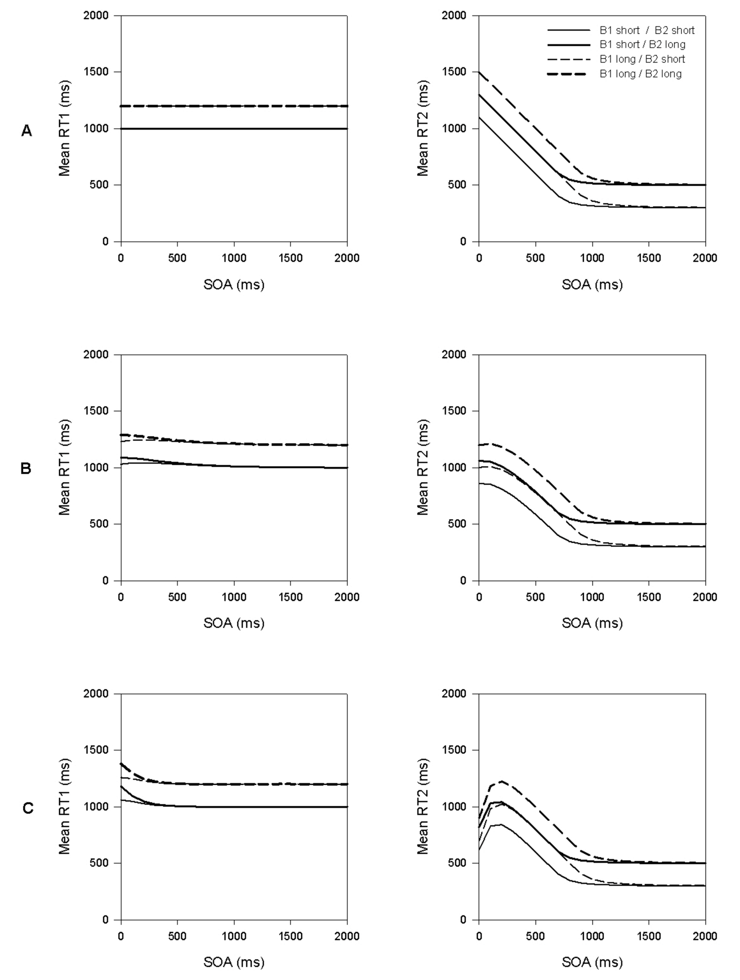
1. a very time-consuming first task with a less time-consuming second task
2. equal emphasis (by instructions and a point system).

At short SOAs, it would be especially efficient to process the shorter task-2 central stages before the longer task-1 central stages (reversed central processing), which would lead to a reversed response order.

To document reversed central processing, the length of task-1 and task-2 bottleneck stages was manipulated along with SOA. No restrictions were made concerning response order.

Factors: SOA (50/100/200/400/800/1600 ms), varying randomly from trial to trial
length of task-1 central stages, i.e. B1 (short/long)
length of task-2 central stages, i.e. B2 (short/long)

Computer Simulations



A: The precentage of trials with reversed central processing was set to 0 %. This illustrates the predictions of the standard bottleneck model.

B: The precentage of trials with reversed central processing was set to 30 % at SOA 0, declining exponentially with increasing SOA.

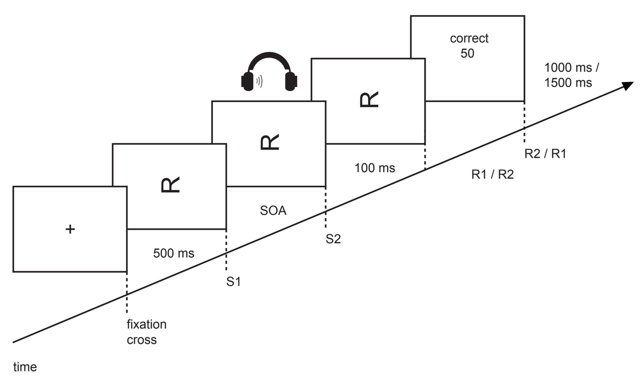
C: The precentage of trials with reversed central processing was set to 60 % at SOA 0, declining exponentially with increasing SOA.

Experiment 1

Tasks and Stimuli

1. task: Mental Rotation
The 32 participants responded to a 90 or 150°-rotated capital letter (F, G, J, L, P, Q or R) which was presented in its normal or mirror-imaged form. The task was to decide whether the letter was normal or mirror-imaged. The response was given with the index- and middle fingers of the right hand with the S-R assignment counterbalanced across participants.

2. task: Tone Discrimination
Participants were presented a 100-ms tone to the left or to the right ear via headphones. The task was to decide which ear the tone was presented to. The response was given with the left hand. S-R assignment was either compatible or incompatible and changed after half of the experiment. The order was counterbalanced across participants.

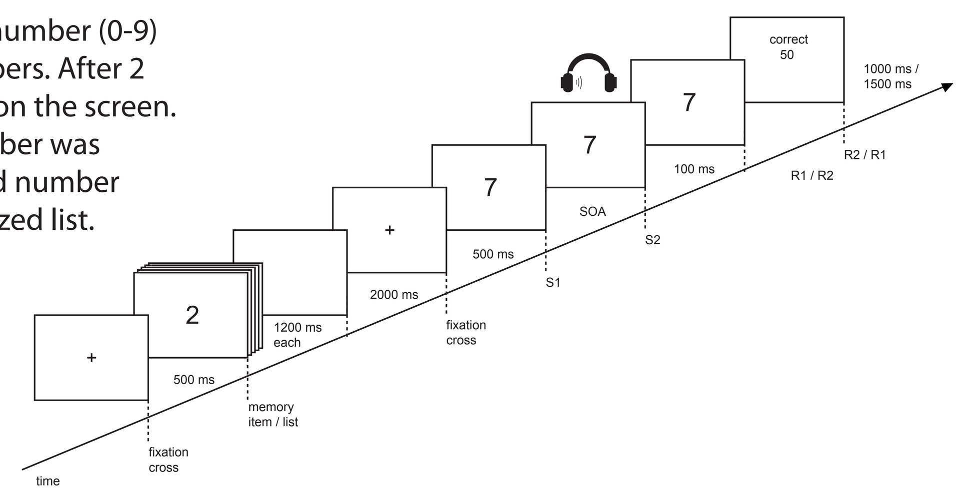


Experiment 2

Tasks and Stimuli

1. task: Memory Scanning
The 32 participants memorized a single number (0-9) or a list of 5 sequentially presented numbers. After 2 seconds a new single number appeared on the screen. The task was to decide whether this number was identical / not identical to the memorized number or included / not included in the memorized list.

2. task: Tone Discrimination
This task was identical to Experiment 1.



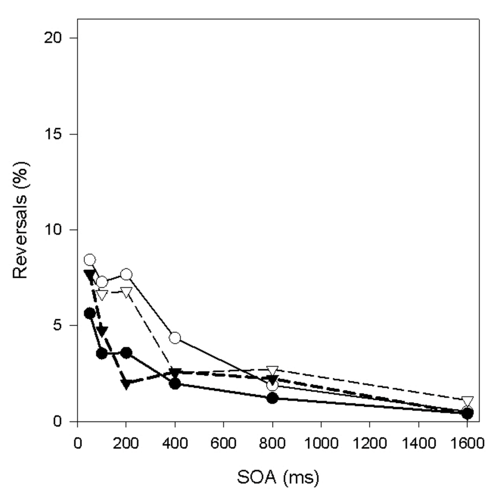
Hypotheses

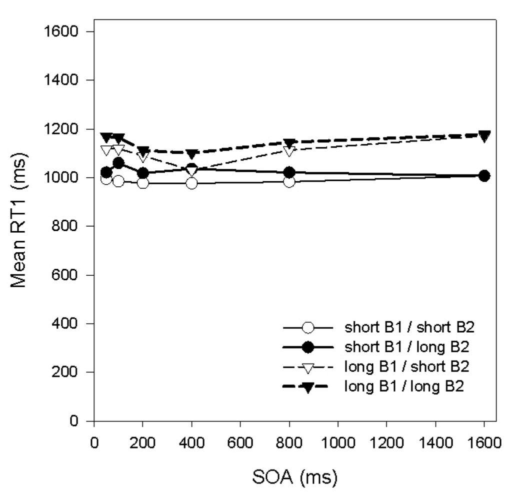
According to the optimality account (Miller et al., in press) we expected an increasing percentage of reversed responses (i.e. R2 before R1) with decreasing SOA.
Due to reversed central processing, RT1 and RT2 shoud be modulated as illustrated in the computer simulations.

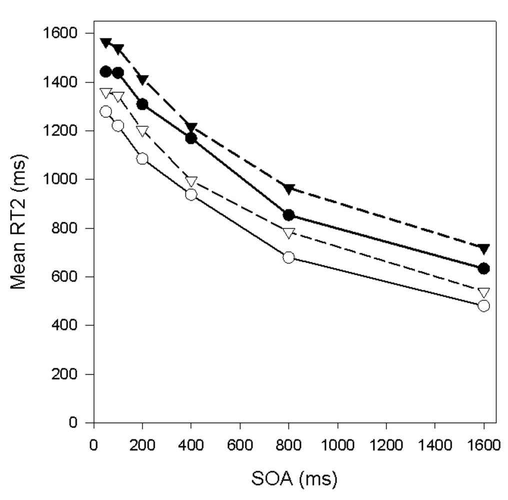
Data Analyses

Reaction times to the two tasks (RT1 and RT2) as well as their accuracy rates (PC1 and PC2) and the percentage of response reversals were analyzed using an ANOVA with the within-subjects factors SOA, rotation angle / memory list length (length of B1) and compatibility (length of B2).
Trials with an inter-response interval (IRI) > -100 ms and < 100 ms were regarded grouped and excluded from the analyses, trials with an IRI < -100 ms were regarded reversed.

Results (Experiment 1)





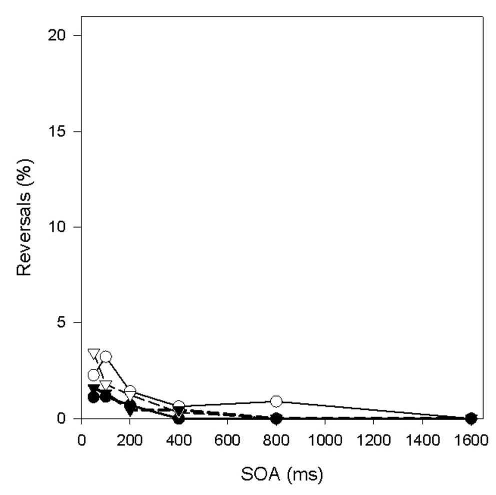


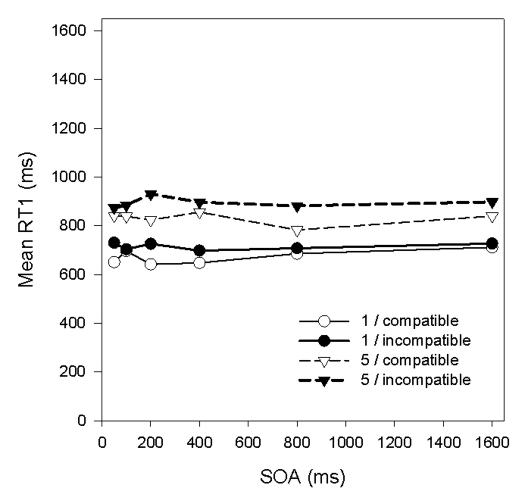
Reversed Responses
Response reversals occurred in 7.37 % of the trials at the shortest SOA. As predicted by the optimality account the percentage decreased significantly with increasing SOA ($F(5,155)=13.108$, $p<.001$). Additionally, reversals at short SOA were more frequent when task 2 was compatible ($F(5,155)=2.343$, $p<.05$).

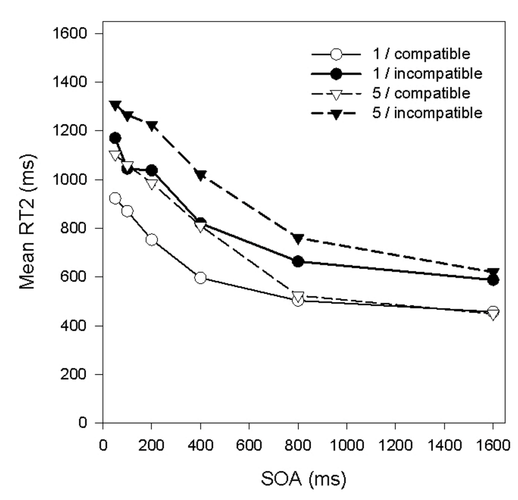
RT1
Consistent with the standard bottleneck model, SOA did not affect RT1. There was a main effect of rotation angle ($F(1,31)=73.006$, $p<.001$), but no effect of compatibility. Unpredictedly, rotation angle varied with SOA ($F(5,155)=2.955$, $p<.05$).

RT2
As predicted by the standard bottleneck model, there was an effect of SOA ($F(5,155)=417.31$, $p<.001$), of rotation angle ($F(1,31)=66.070$, $p<.001$) and of compatibility ($F(1,31)=15.774$, $p<.001$). Not in line with the central bottleneck model rotation angle did not interact with SOA.

Results (Experiment 2)







Reversed Responses
Response reversals occurred in 2.10 % of the trials at the shortest SOA. As predicted by the optimality account the percentage decreased significantly with increasing SOA ($F(5,155)=2.988$, $p<.05$). Reversals were also more frequent when task 2 was compatible ($F(5,155)=4.225$, $p<.05$).

RT1
In line with the standard bottleneck model, SOA did not affect RT1. There was a main effect of set size ($F(1,31)=77.914$, $p<.001$), but no effect of compatibility. Unpredictedly, set size interacted with SOA ($F(5,155)=2.838$, $p<.05$).

RT2
Consistent with the standard bottleneck model, there was an effect of SOA ($F(5,155)=329.06$, $p<.001$), set size ($F(1,31)=119.53$, $p<.001$) and compatibility ($F(1,31)=20.384$, $p<.001$, as well as an interactive effect of SOA and set size ($F(5,155)=21.508$, $p<.001$). Unexpectedly compatibility also interacted with SOA ($F(5,155)=2.791$, $p<.05$).

Conclusion

The results of the two experiments favour the notion of the central bottleneck model that the two tasks are processed on a first-come, first-served principle. In the present paradigm where (A) SOA was random and (B) stimulus presentation order was constant, participants did not usually interrupt task 1 and pre-drawed task-2 central processing at short SOAs which speaks against the optimality account.

In Experiment 1, the percentage of reversed responses increased significantly with decreasing SOAs as predicted by the optimality account. However, reversed responses occurred only seldom at short SOAs. In Experiment 2, The percentage of reversed responses was also diminished with increasing SOA. But the percentage of reversed responses was even smaller than in Experiment 1. Reaction times seems to be accordable with the standard bottleneck model, too.

It remains to be investigated whether the specific conditions of the present experiments contributed to this finding. Former studies on this topic (De Jong, 1995; Luria & Meiran, 2003) point out the role of preparation for order control. Additionally, constant stimulus presentation order could influence the processing order of the participants. Therefore, ongoing research employs paradigms with (A) the possiblity for SOA anticipation and (B) varying stimulus presentation orders.

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