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Introduction

Can visual word recognition occur automatically, without central attention? On one hand, Stroop studies suggest that word recognition is mandatory – a type of automaticity. On the other hand, Lien, Ruthruff, Cornett, Goodin, and Allen (2008) found that people could not identify visual words on Task 2 while processing an auditory tone Task 1. Lien et al. concluded that the key obstacle to word recognition was the lack of central resources, which were devoted to Task 1. An alternative possibility, however, is that task switching prevents word recognition (see Vachon & Jolicœur, in press). We examined this issue using a Psychological Refractory Period (PRP) paradigm without task switching, using electrophysiological measures.

The Psychological Refractory Period Paradigm

In the PRP paradigm, participants make speeded responses to Task 1 and Task 2, presented with a variable stimulus onset asynchrony (SOA). The typical finding is that Task-2 response time (RT) increases as SOA decreases, known as the PRP effect. One explanation for the PRP effect is the central bottleneck model – central attention is devoted to one task at a time, creating a period of cognitive slack between the perceptual and central stages of Task 2 at short SOAs (see Figure 1).

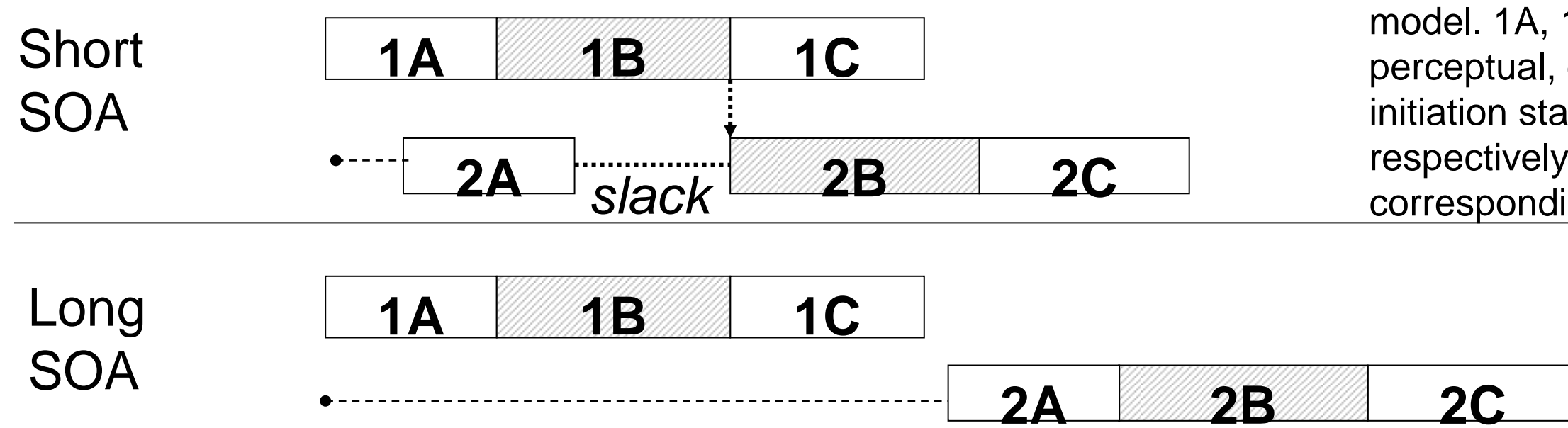
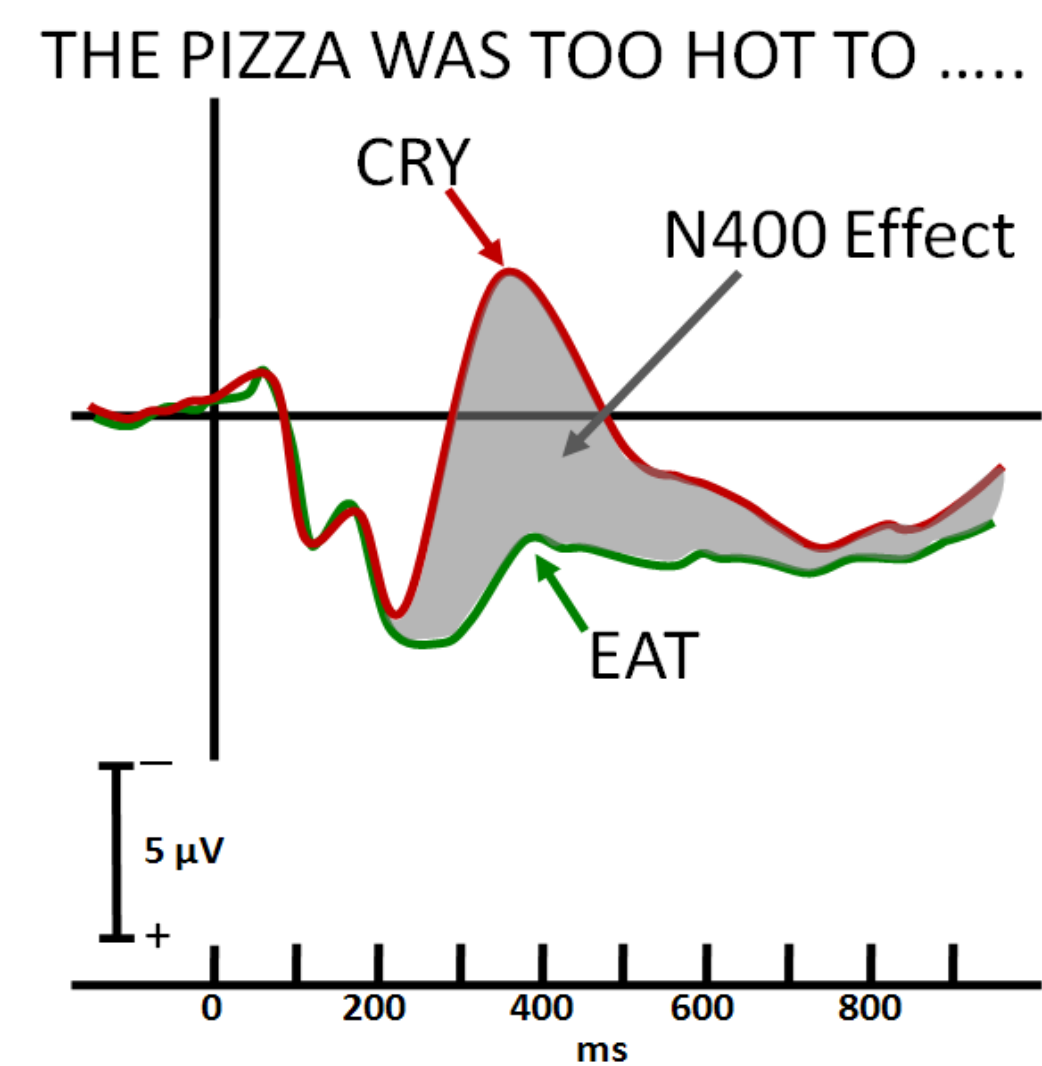


Figure 1: The central bottleneck model. 1A, 1B, and 1C are the perceptual, central, and response initiation stages of Task 1, respectively. 2A, 2B, and 2C are the corresponding stages for Task 2.

N400 Effect

The N400 is a negative-going ERP wave, peaking about 400 ms after stimulus onset, that occurs when a person notices that a stimulus is incongruent with the current semantic context (see Figure 2 for an example; Kutas & Hillyard, 1980). For the present purposes, the critical thing is that this **N400 component can be elicited only when words are identified**.



$$N400 \text{ Effect} = \text{Unrelated (mismatch)} - \text{Related (match)}$$

Figure 2: Example event-related brain potentials where the target is semantically related (e.g., the word “EAT”) or unrelated (e.g., the word “CRY”) to the sentence. The N400 effect is the difference waveform between the unrelated and related target conditions. Negative is plotted upward and time zero represents target onset.

The Present Study

We examined whether central attention is necessary for word recognition using a PRP paradigm with minimal task switching. Participants were given essentially the same word task for Task 1 and Task 2 in each trial (differing only in presentation modality). The time between the stimulus onsets (the SOA) was -100, 200, or 900 ms.

EEG Recording

EEG epochs were time-locked to Task-2 stimulus onset. The N400 effect was measured from 300-500 ms after Task-2 stimulus onset, relative to a 200-ms baseline period before Task-2 stimulus onset, separately for the central (C3, Cz, and C4) and parietal (P3, Pz, and P4) electrode sites.

Predictions

If the main obstacle to word processing is task switching, and not a lack of central attention, we should see similar N400 effects for Task-2 words at all SOAs.

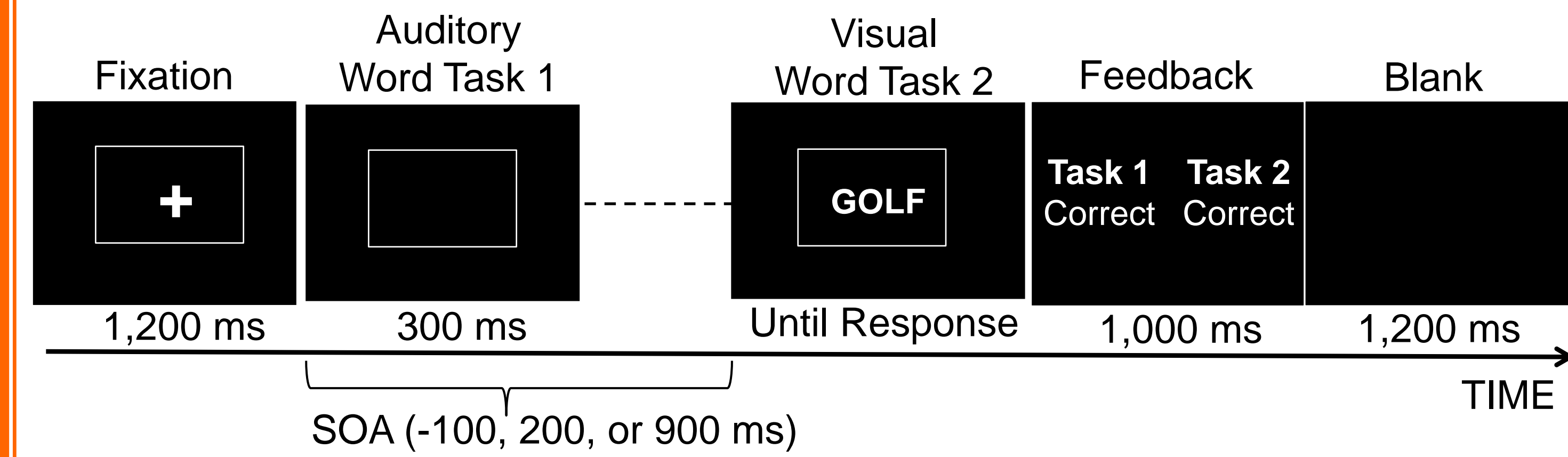
Experiment 1:

Each participant received 22 different categories (e.g., “sports”) in separate 36-trial blocks, each containing 18 related words and 18 unrelated words.

Auditory Word Task 1: Depress the left foot pedal for related words, and the right foot pedal for unrelated words.

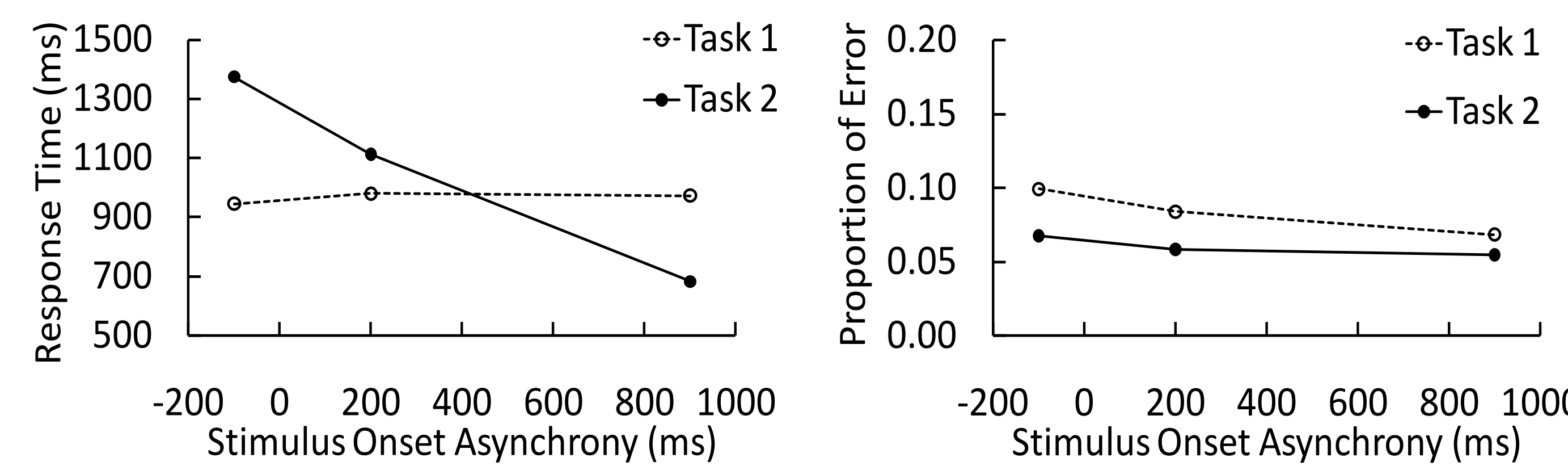
Visual Word Task 2: Press the left key (“1”) for related, the right key (“5”) for unrelated.

Event Sequence: See below for an example based on the “sports” category.



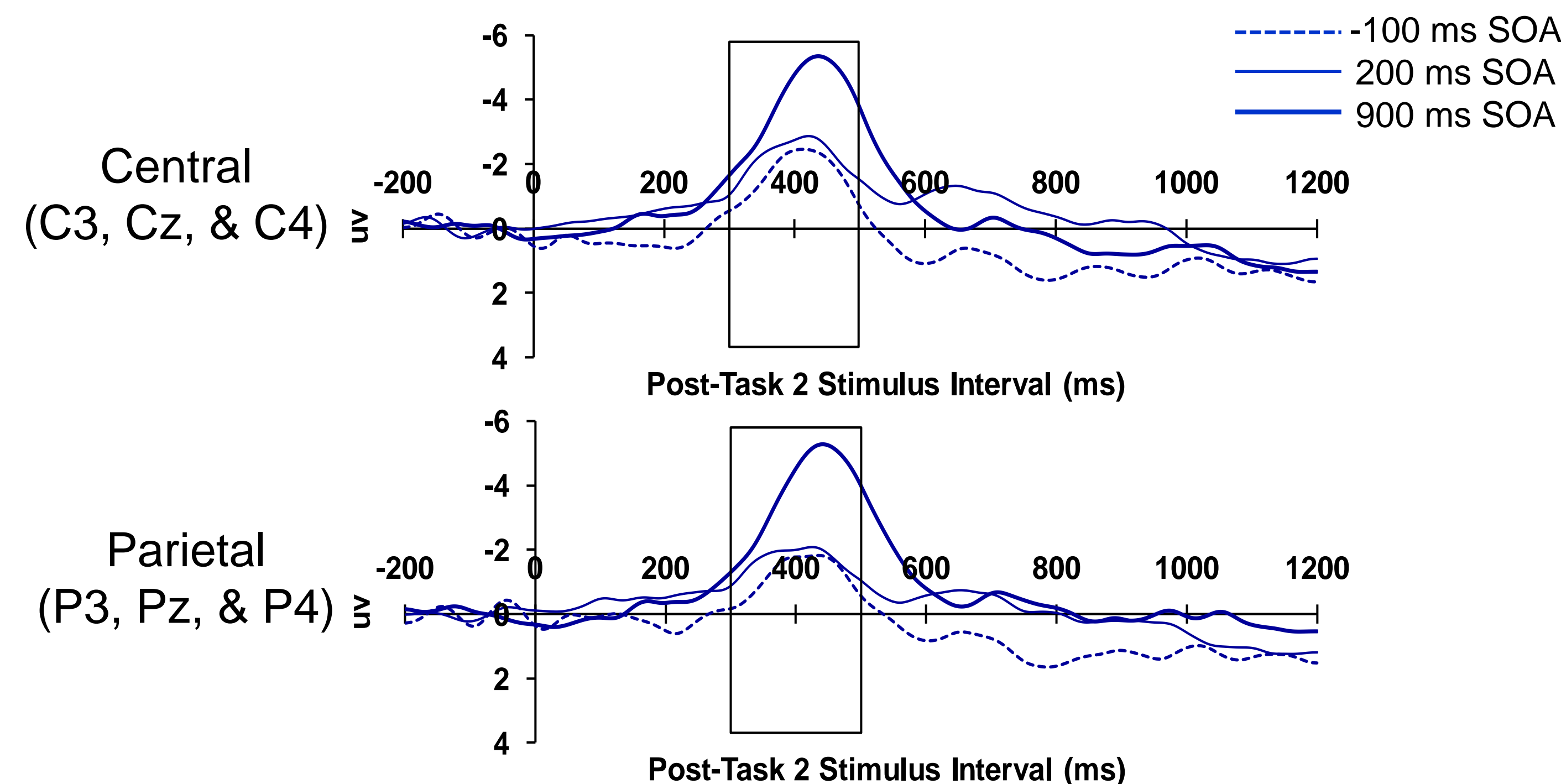
Results (N=18)

Behavioral Data (RT and PE):



A large PRP effect of 693 ms on RT was obtained, $F(2,34)=10.21, p<.001$, replicating previous PRP studies.

N400 Effects Elicited by Task-2 Words:



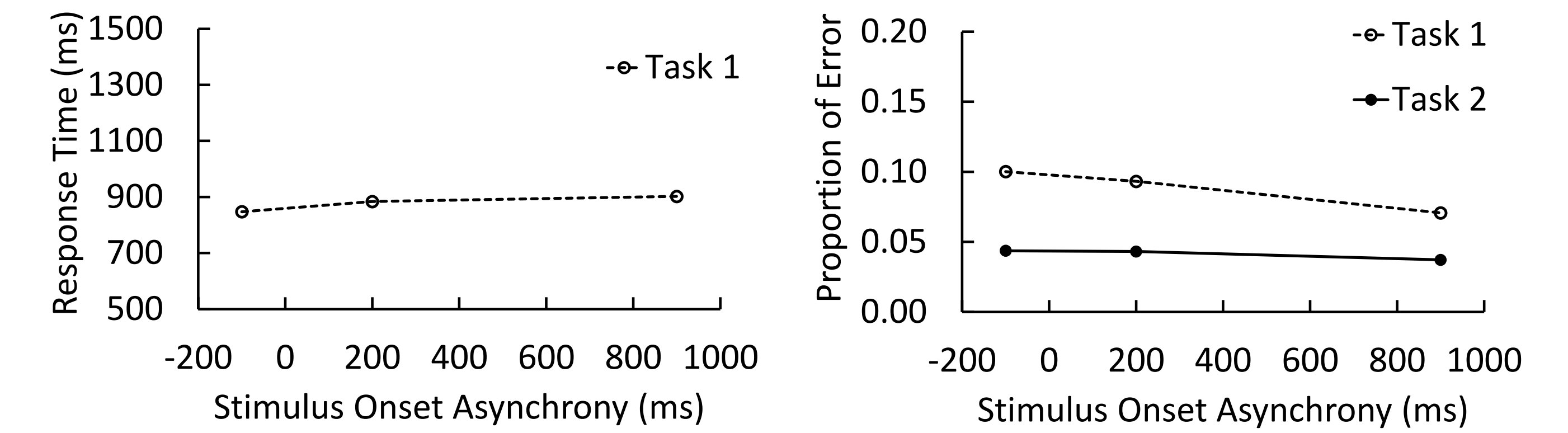
The N400 effect elicited by the Task-2 word was strongly attenuated at short SOAs relative to long SOAs, $F_s(1,17) \geq 5.85, p_s < .05$, suggesting that Task-2 word recognition is depressed while central attention is devoted to Task 1.

Experiment 2:

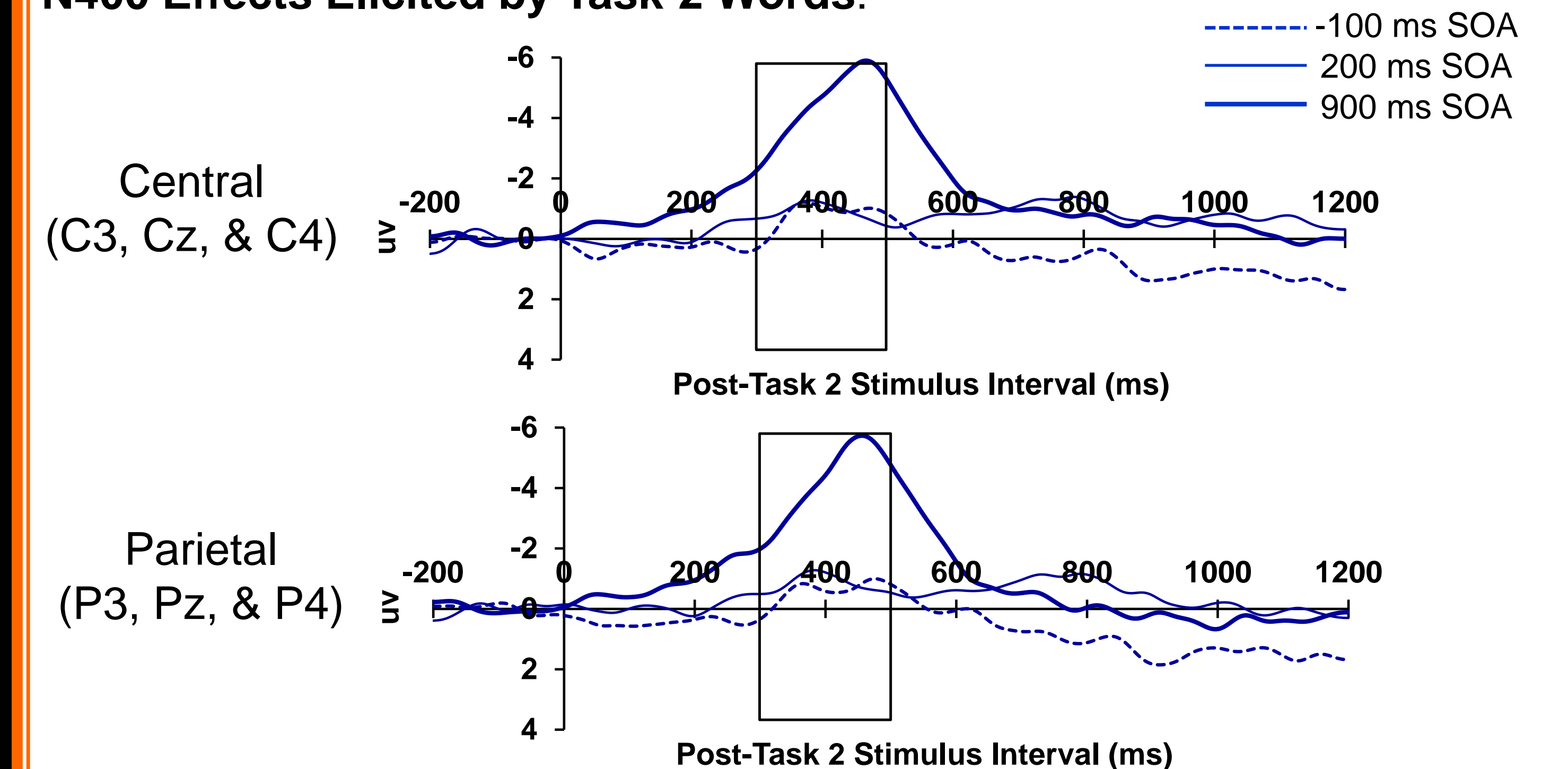
Experiment 1 used different response modalities (foot vs. manual) to reduce output interference between tasks. But the need to change response modalities might induce some task switching, which in turn prevents word recognition. Experiment 2, therefore, used manual keypresses for both Task 1 and Task 2. To prevent response conflicts, Task 2 was unsped and delayed (responding allowed only after a question mark appeared) while Task 1 was speeded as in Experiment 1.

Results (N=17)

Behavioral Data (RT and PE):



N400 Effects Elicited by Task-2 Words:



Replicating the findings in Experiment 1, the N400 effect elicited by Task-2 words was sharply attenuated at short SOAs relative to long SOAs, $F_s(1,16) \geq 12.15, p_s < .01$. Task-2 word recognition is blocked while central attention is devoted to Task 1, even with highly similar tasks that require minimal task switching.

Conclusions

We used a dual-task paradigm to determine whether word processing requires central attention. We tried to eliminate any need for task switching by using essentially the same judgment for both Task 1 and Task 2. The critical finding was that, at short SOAs (where central resources were still devoted to Task 1), the N400 effect elicited by Task-2 words was strongly attenuated (62% and 84% reductions in Experiments 1 and 2, respectively). This finding was obtained when using different response modalities (to reduce output interference) and when using identical response modalities (to minimize task switching). We conclude that, without access to central attention, word processing is greatly diminished.

References

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science*, 207, 203–205.
 Lien, M.-C., Ruthruff, E., Cornett, L., Goodin, Z., & Allen, P. A. (2008). On the non-automaticity of visual word processing: Electrophysiological evidence that word processing requires central attention. *Journal of Experimental Psychology: Human Perception and Performance*, 34, 751–773.
 Vachon, F., & Jolicœur, P. (in press). On the automaticity of semantic processing during task switching. *Journal of Cognitive Neuroscience*.