

On the Nonautomaticity of Visual Word Processing: Electrophysiological Evidence That Word Processing Requires Central Attention

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as the SOA decreases, a phenomenon known as the PRP effect (Telford, 1931).

A large body of evidence supports the view that the PRP effect occurs largely because the central stages (e.g., decision making and response selection) for Task 1 and Task 2 do not operate in parallel (for reviews, see Lien & Proctor, 2002; Lien, Ruthruff, & Johnston, 2006; Pashler, 1994; Pashler & Johnston, 1989; see also

frequency effect at the longest SOA was 127 ms (in Experiment 2). If word processing were fully automatic and word frequency primarily affects lexical activation, then the word frequency effect could have been nearly completely absorbed into the long period of cognitive slack created by the bottleneck. Instead, the percent-

Pashler, 2001). Therefore, it is natural to suspect that Vogel et al.'s (1998) findings in the attentional blink paradigm would also apply to the PRP paradigm. That is, perhaps participants semantically process visual words in parallel with Task 1 central operations but are unable to maintain those representations during Task 1 central operations. In this case, one would expect the N400 effect to have a similar amplitude and latency at both short and long SOAs.

word frequency effects on RT can be meaningfully interpreted using locus-of-slack logic (as in previous behavioral studies and in the present Experiment 5), the same is not true for the relatedness effect. The semantic relatedness manipulation (unlike word frequency) is not intended to make word processing take more or less time. Furthermore, if there is an effect of relatedness on RT, we would not know exactly which processing stages were influenced. Note that related and unrelated responses are made with different

evidence of such a delay in the N400 effect, we calculated the time it took, at each SOA, for the total N400 effect amplitude (the area under the curve) to reach 50% of its value (i.e., the fractional area technique; see Luck, 2005) during the time window 200–1,200 ms following the onset of the Task 2 word. To determine whether the effects of SOA were significant, we submitted jackknifed latency estimates for the different SOAs to a repeated measures ANOVA; *F* values were corrected (*F*

Although the Task 2 context–target relatedness effect was numerically larger at the short SOA than at the long SOA, the interaction between SOA and Task 2 context–target relatedness was not significant, $F(2, 22) = 2.89$, $p = .0801$, $MSE = 500$, $\eta^2 = .11$.

tion of the N400 effect at the 100-ms SOA is consistent with a reduction in semantic activation for a word in the absence of central attention.

ERP analyses: A temporal shift of the N400 effect. As in Experiments 1 and 2, we conducted fractional area latency analyses to examine whether there was a temporal shift of the N400

Discussion

Experiment 3 used a category–target relatedness Task 2 rather than a context–target relatedness Task 2. Because the category name was constant within a block rather than changing trial by trial, it minimized the need to retrieve the category words from

Experiment 1. During the critical time window 300–500 ms after Task 2 word onset, the mean amplitude of the N400 effect differed across SOAs, $F(2, 34) = 39.55$, $p < .0001$, $MSE = 2.331$, $\eta^2_p = .70$. Pairwise comparison revealed that the N400 effect was more negative (i.e., larger) at the 900-ms SOA ($-5.039 \mu V$) than at the –200-ms SOA ($-1.176 \mu V$), $F(1, 17) = 46.31$, $p < .0001$, $MSE = 5.798$, $\eta^2_p = .73$, and the 100-ms SOA ($-1.064 \mu V$), $F(1, 17) = 71.21$, $p < .0001$, $MSE = 3.994$, $\eta^2_p = .81$. There was no difference in amplitude between the two shorter SOAs (–200 ms and 100 ms; $F < 1.0$). In summary, a normal N400 effect was present at the 900-ms SOA, but it was strongly attenuated at the 100-ms SOA.

P3 difference □ high-frequency words ERP

– low-frequency words ERP (2)

If lexical activation of the Task 2 word is postponed while partic-

nation is that whereas the N400 effect is sensitive primarily to the bottleneck delay, RT2 may be sensitive to the bottleneck delay plus other factors. For instance, reduced preparation at short SOAs may prolong response selection and/or response execution (see Jentzsch, Leuthold, & Ulrich, 2007; Pashler, 1994).

Possible Explanations for Incomplete Attenuation

The present experiments have shown that semantic activation (as reflected by the N400 effect) and lexical activation (as reflected by the P3 difference) were strongly attenuated while central atten-

model of context effects in letter perception: Part 1. An account of basic findings.

