Lexical Frequency Effects in Dual-Task Picture Naming

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Abstract

Lexical frequency effects were examined in the context of the central bottleneck (CB) model of dual-task performance. Two dual-task experiments were conducted. In Experiment 1, picture naming was the primary task and tone identification was secondary. Lexical frequency affected reaction time (RT) to both tasks similarly. In Experiment 2, task order was reversed, and, after controlling for variables including name and image agreement, frequency affected naming RT similarly at all levels of stimulus onset asynchrony. These results are consistent with prior studies localizing frequency effects in word naming to the central, response selection stage of the CB model.

Introduction

Much research in aphasiology appeals to the notion of processing resources as an explanatory construct (Blackwell & Bates, 1995; Caplan & Waters, 1996; Haarman et al., 1997; McNeil et al., 1991; Murray et al., 1997), and research into these ideas has often employed dual-task methods. An alternative model of dual-task performance, the central bottleneck (CB) model (Pashler, 1994; Telford, 1931; Welford, 1952), proposes that dual-task performance decrements result primarily from a single-channel limit on central processing operations broadly conceived as response selection. On this view, response selection processing proceeds for only one task at a time, while perceptual analysis and response execution stages of competing tasks can proceed concurrently. Many studies have demonstrated findings consistent with this model: When discrete stimulus-response tasks are presented at varying stimulus onset asynchronies (SOAs), the reaction time to the second task (RT2) slows as SOA is reduced, a phenomenon referred to as the psychological refractory period (PRP) effect (Pashler, 1994). Also, increasing the difficulty of pre-central (perceptual analysis) or central (response selection) stages of the primary task results in additive slowing of RT2 (see Figure 1) (e.g., Carrier & Pashler, 1995; Fagot & Pashler, 1992; Smith, 1969). Finally, manipulating perceptual analysis requirements of the secondary task stimulus has a smaller effect on RT2 at shorter SOAs, consistent with the hypothesis that this stage proceeds in parallel with other stages of competing tasks (see Figure 2) (e.g., Pashler, 1984; 1991; Tombu & Jolicoeur, 2005).

The few studies that have attempted to integrate the CB model with word production models have suggested that lexical frequency effects participate in the response selection bottleneck of the CB model. Ferreira and Pashler (2002) found that frequency effects in picture-naming were additive with the PRP effect on secondary-task tone identification RTs, suggesting a central or pre-central locus for frequency-sensitive lexical processing. McCann and colleagues (2000) found no interaction of frequency effects with SOA on secondary-task word naming and visual lexical decision RTs, a finding consistent with a central locus for frequency-sensitive lexical processing.

The purpose of the current study was to further investigate the temporal locus of frequency effects on picture naming in the context of the CB model, as a preliminary step toward future studies directly comparing CB and resource models' predictions of dual-task performance. Two dual-task experiments were conducted. In the first, picture naming was primary and tone identification was secondary. It was predicted that lexical frequency would affect primary and secondary-task RTs similarly. In Experiment 2, the order of tasks was reversed. Consistent with a central, response selection locus for frequency-sensitive lexical processing, it was hypothesized that lexical frequency would not interact with SOA on secondary task naming RT.

Method

Subjects were 48 university students who passed hearing, vision, and naming screens, and reported no history of communication, neurological, or psychiatric disorder. Twenty-four subjects participated in each experiment.

Picture stimuli (n=288) were taken from Szekely and colleagues (2004). Half of the pictures had target names with raw frequencies <275 in the Zeno et al. (1995) corpus, and half had names with frequencies >328. The target names were balanced on length and initial phoneme. In order to provide the largest possible set of pictures for use in subsequent studies, stimuli were not balanced on name agreement, image agreement, or object recognition time. It was assumed that, like lexical frequency, each of these variables would primarily affect the response selection stage, and thus would not affect the experimental predictions. Tone stimuli were 400 Hz, 1000 Hz, and 2500 Hz pure tones, 305 ms in length. Naming responses were collected by voice key and tone responses by keypad.

On each trial, subjects were presented with a picture and a tone, and asked to name the picture and press a button identifying the tone as low, medium or high. In Experiment 1 trials, pictures were presented first and tone stimuli were presented after a 50, 150, or 900 ms delay. There were four blocks of 72 trials each. The order of conditions was pseudorandomized. Tone stimuli were balanced across lexical frequency and SOA conditions, and pictures were presented an approximately equal number of times in each condition across subjects. Instructions required subjects to respond to the stimuli in the order presented and emphasized the speed of RT1, although both responses were speeded. Before the experimental trials, subjects practiced each task individually and completed 36 dual-task practice trials. Experiment 2 was identical to Experiment 1 except that the order of the tasks was reversed.

Trials containing response order errors (1%), voice key failures (3%), incorrect responses (18%), or RT outliers (3%) were excluded from analysis. Experiment 1 RTs were entered into an ANOVA ($\alpha=0.05$) with three repeated factors: task (naming, tone ID), lexical frequency (low, high), and stimulus onset asynchrony (50, 150, 900 ms). Experiment 2 naming RTs were entered into an ANOVA ($\alpha=0.05$) with two repeated factors: frequency and SOA.

Follow-up analyses of Experiment 1 and 2 data were also conducted. In these analyses, a subset of the naming stimuli (99 LF, 99 HF) balanced on length, name agreement, image agreement, and object recognition time was identified and submitted to ANOVAs identical to those described above.

Results

In Experiment 1, average RTs on low-frequency naming trials were significantly slower than RTs for high-frequency trials, by 121 ms for naming and 137 ms for tone identification (see Figure 3). Neither the task-by-frequency nor the SOA-by-frequency interaction was significant. Follow-up analysis of the balanced stimulus lists, presented in Figure 4, obtained similar results. Lexical frequency had a 61-ms effect on naming RTs and a 62-ms effect on tone RTs, averaged across SOA conditions.

In Experiment 2, secondary-task low-frequency naming RTs were longer than high-frequency RTs by 122 ms in the long SOA condition, 56 ms in the medium SOA condition, and by 55 ms in the short SOA condition (see Figure 5). Both main effects and the interaction were significant. The follow-up analysis of balanced stimuli obtained frequency effects of 58 ms, 26 ms, and 31ms, in the long, medium, and short SOA conditions, respectively (Figure 6). The main effects of lexical frequency and SOA were again significant, but the interaction was not ($p = 0.20$).

Discussion

Experiment 1 demonstrated that lexical frequency affected primary-task naming RTs and secondary-task tone RTs similarly. As shown in Figure 1, this result, consistent with Ferreira and Pashler (2002) suggests a central, response selection locus for frequency-sensitive lexical processing in picture naming. The result is also consistent with a pre-central locus for frequency effects, and experiment 2 was conducted to rule out that possibility. In experiment 2, the initial analysis found a significant frequency-by-SOA interaction, suggesting a pre-central locus for at least some of the frequency effect, as operationalized in the stimulus lists employed. In the follow-up analysis using lists balanced on a larger set of potentially confounding variables, frequency did not interact with SOA on secondary-task picture-naming RTs. This result is consistent prior findings in word-naming (McCann et al., 2000), and provides further evidence for a response selection locus of frequency effects in naming. It is concluded that the balanced stimulus sets identified in this study can be productively used to directly compare CB and resource models in their ability to predict dual-task naming performance.

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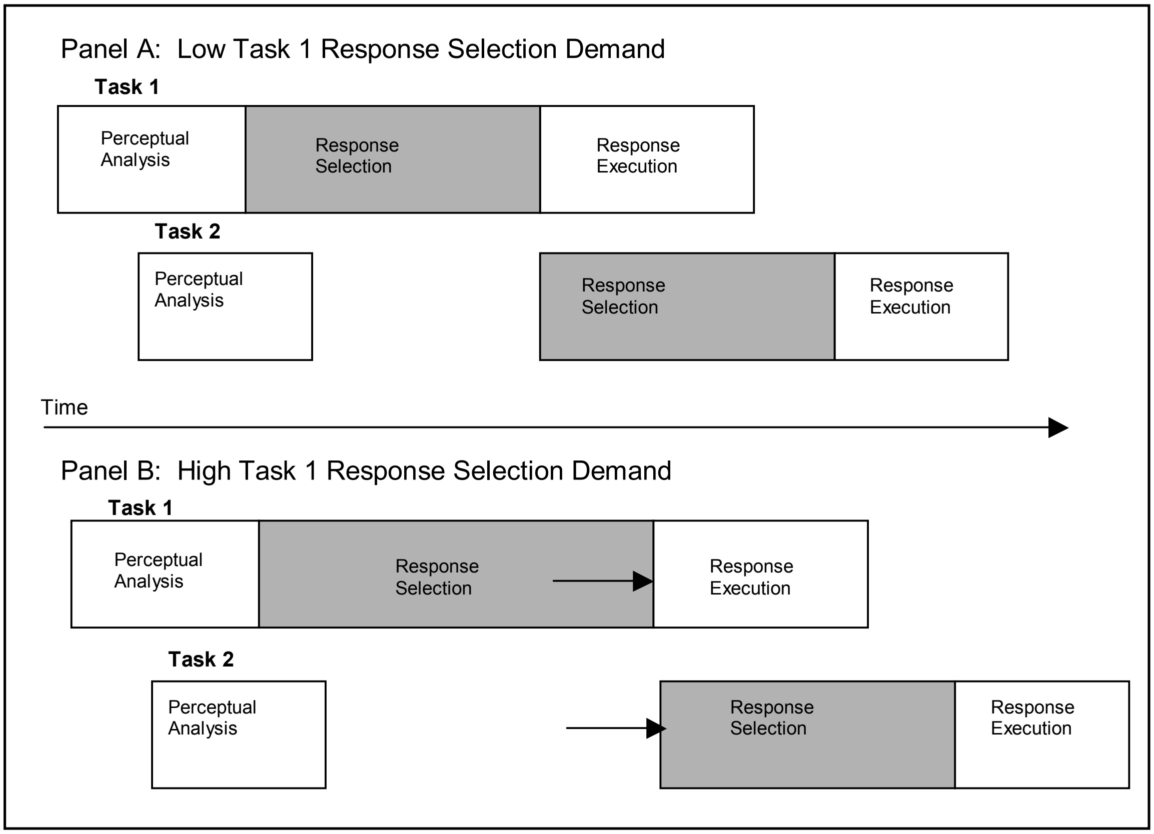

Figure 1. Schematic time diagram of the central bottleneck model. Time is represented in the horizontal dimension. Processing for each task proceeds in three serial stages and, in the short stimulus onset asynchrony condition represented, task 2 response selection is postponed until completion of task 1 response selection. The increase in task 1 response selection demand from panel A to panel B results in equal increases in reaction times to both tasks.

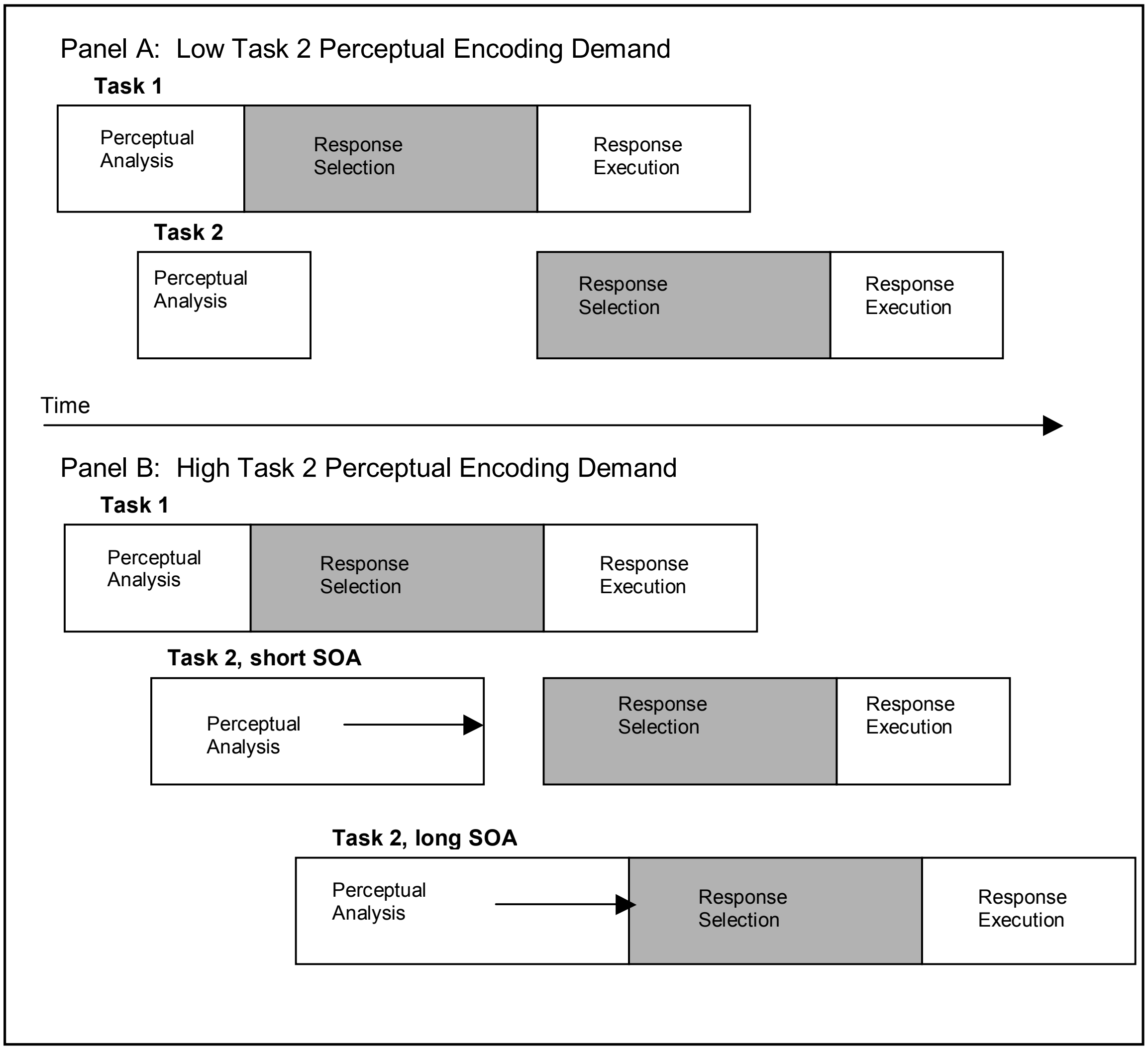

Figure 2. Schematic time diagram of the central bottleneck model. In the short stimulus onset asynchrony condition (SOA), the increase in task 2 perceptual encoding demand from panel A to panel B does not affect task 2 reaction time because of the delay in response selection processing imposed by the central bottleneck. In the longer SOA condition, task 2 response selection is not postponed and the increase in perceptual analysis demand lengthens task 2 reaction time.

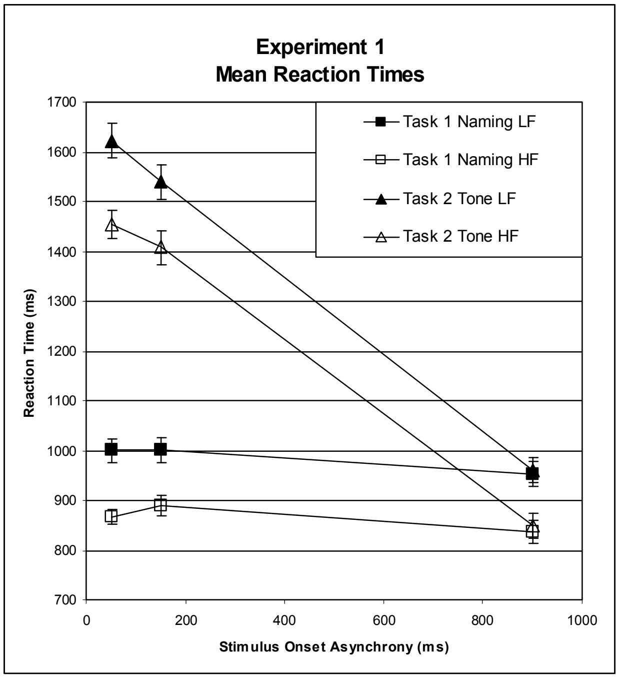

Figure 3. Mean reaction times in milliseconds from Experiment 1 by task and condition. Error bars indicate 1 standard error.

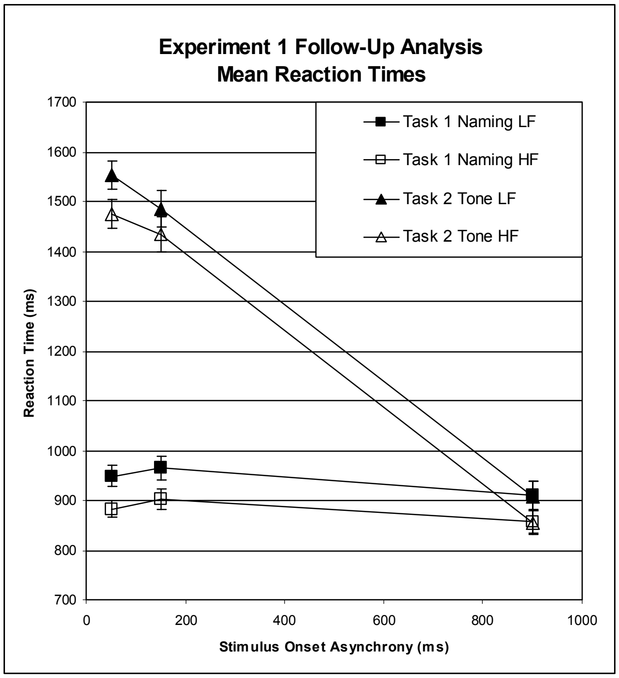

Figure 4. Mean reaction times from Experiment 1 follow-up analysis by task and condition.

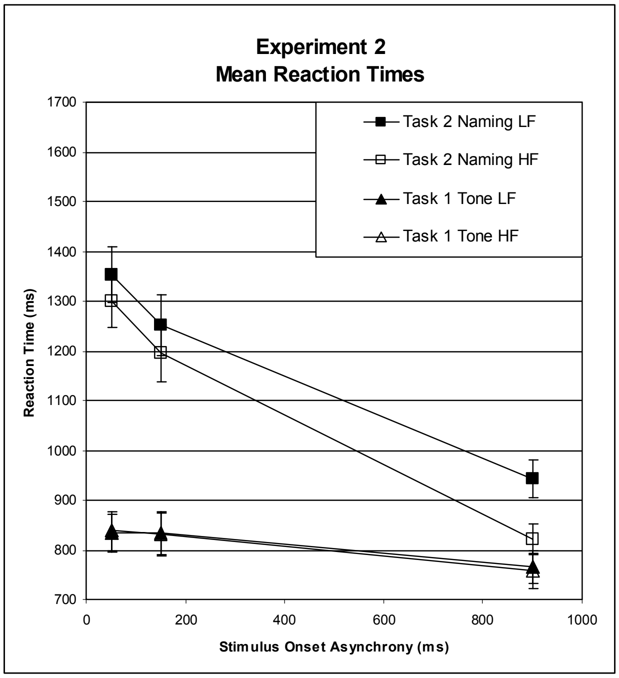

Figure 5. Mean reaction times from Experiment 2 by task and condition.

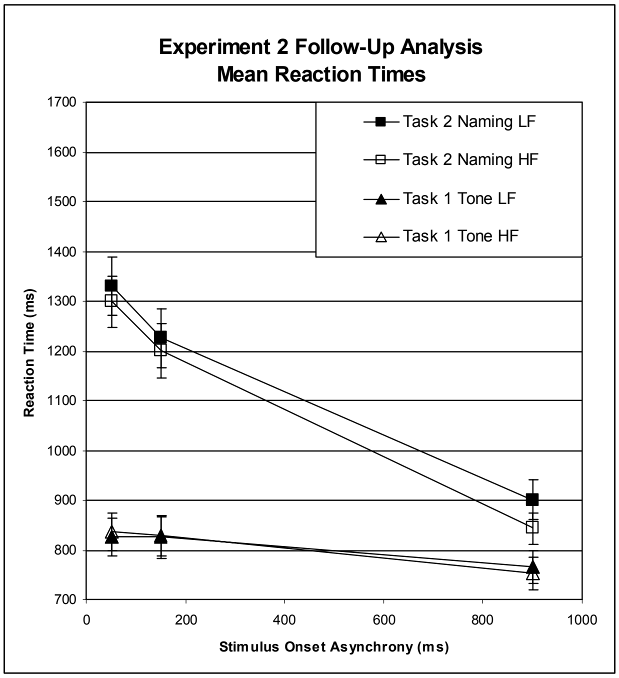

Figure 6. Mean reaction times from Experiment 2 follow-up analysis by task and condition.