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Research Report

Neural aspects of cohort-size reduction during visual gating

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ABSTRACT

In psycholinguistics, the coactivation of lexical candidates by partial input has received a lot of attention. More recently, psychophysiological studies have shed more light on this issue and identified two possible time windows in which effects of coactivation of lexical candidates can be observed in event-related potentials (ERPs). However, these studies cannot be used to disentangle effects of coactivation from the inhibition of candidates that do not match input. A new visual gating paradigm is presented, in which stimuli were visually presented letter by letter, decreasing the size of the cohort of lexical candidates as more letters are presented. Stimuli were created such that at the letter position of interest, the amount of coactivated candidates was kept constant while manipulating the size of the reduction of the cohort. The resulting ERPs indicate two components (frontal P2, and a left temporal late negativity) that scaled with cohort-size reduction. These results show that a visual gating paradigm can be used to disentangle coactivation of lexical candidates from inhibition of non-matching items, and that these processes are closely related to each other in time.

1. Introduction

It is generally assumed that, in language comprehension, partial auditory or visual input activates cohorts of lexical candidates that match this input. With more incoming information, the initial set of candidates is reduced such that only matching items remain in the cohort. The reduction process terminates when one candidate remains, at which point word recognition takes place. Cognitive models of speech and written language comprehension deal with acoustic, graphic, phonetic and phonological encoding, accompanied by semantic and syntactic activation and discourse integration (e.g., Ans et al., 1998; Coltheart et al., 1991; Cutler and Clifton, 1999; Gaskell and Marslen-Wilson, 1997; Goldinger et al., 1992; Johnson and Pugh, 1994; Marslen-Wilson, 1987; Masson, 1995; McClelland and Elman, 1986; Norris et al., 1995; Perfetti, 1999). Such models have elaborated ideas about how the activation of the initial set and the selection of the winner actually take place. These ideas differ between models, and there is still ongoing discussion about the details of word recognition. A consistent idea across the literature is that partial linguistic input can coactivate a set of several lexical items (hereafter called a 'cohort'). Coactivation of lexical items has received a lot of attention in psycholinguistics and more recently in the psychophysiological literature. To our knowledge, less work has been reported on the reduction of the cohort of activated items and the nature of the neural selection of the target word from this cohort. The goal of this paper is to focus on processes related to neural aspects of "cohort-size reduction" during word recognition.

Evidence for the coactivation of lexical candidates can be found in a variety of studies with different psycholinguistic

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paradigms. In cross-modal semantic priming studies, gated fragments of words such as *captain* are followed by a visually presented target word for lexical decision. The target word can be semantically related either to the spoken word itself (e.g., *ship*, semantically related to *captain*) or to a cohort competitor sharing the same initial sounds (e.g., *guard*, semantically related to *captive*). Typically, gated fragments like /kæpt/, that are consistent with both the actual word and its cohort competitor facilitate the processing of both the actual target and the cohort competitor compared to unrelated control targets (Zwitserlood, 1989). These results are consistent with the idea that initial form-based access activates lexical candidates and their semantic properties, allowing facilitation of a response to a semantically related word (Marslen-Wilson, 1987).

More recently, high temporal resolution methods such as eye and hand movement studies and event-related potentials (ERP) have been used to gain more insight in the time course of competition between coactivated words. For example, a general finding in eye movement studies is that when participants view arrays of pictures while hearing a target word (in a neutral context), more fixations are made to cohort competitors of the target word than to phonologically unrelated distractors (e.g. Allopenna et al., 1998; Dahan et al., 2001; Dahan and Tanenhaus, 2004). More precisely, the amount of fixations to cohort competitors starts to diverge from fixations to unrelated distractor words as early as 200 ms after word onset. Taking into account that eye movements need 150–180 ms of preparation time, these data indicate that lexical activation influences eye movements in the first 100 ms after word onset. Importantly, the number of fixations made to targets and to cohort competitors is equal until approximately 200–300 ms after enough information is present in the signal to disambiguate targets from cohort competitors, indicating that the lexical representations of both the targets and the cohort competitors are activated and considered by participants.

Similarly, in a study in which participants were required to make a PC mouse movement towards a picture depicting a spoken word, the trajectory of the mouse movement was found to be influenced by the presence of a cohort competitor (Spivey et al., 2005). The trajectory of the mouse followed an equidistant path to both pictures for a longer time when the distractor picture was a cohort competitor. This was interpreted as being consistent with "a description of two nearly equibiased attractors initially pulling the system toward their shared midpoint" (p. 10394). Only when enough information was present in the speech signal to disambiguate the two stimuli, the target became a stronger attractor, pulling the movement of the mouse towards it.

Psychophysiological evidence that the meaning of several potential candidates is activated comes from a study by van Petten et al. (1999). In an ERP study, participants listened to sentences that ended with contextually congruous words, incongruous words that shared the same initial phonemes (cohort incongruous words), or words that rhymed with the congruous words (rhyme incongruous words). The target ERP component in this study was the N400, which is usually observed when participants are presented with semantically incongruous words in a sentence, indicating that it reflects semantic integration (Kutas and Hillyard, 1980, 1984). The critical finding in this study was that the N400 amplitude for rhyme incongruous words deviated from that of congruous words and cohort incongruous words as early as 200 ms before the isolation point (i.e., the moment when enough information was present to have one lexical candidate left). Moreover, the N400 amplitudes of the congruous words and the cohort incongruous words diverged from each other at a later time point, namely after the isolation point. These data clearly indicated that the meaning of alternative lexical candidates was at least partially activated and that the moment of selection depended on the amount of onset phonemes that were shared between target and competitor. These data have been replicated in a subsequent study by van den Brink et al. (2006), who also showed that the onset of the N400 effect occurs before the isolation point. Furthermore, the onset latency of the N400 was not influenced by the exact timing of the isolation point, which implies that semantic integration takes place before a unique word candidate has been selected.

In a cross-modal priming task, Friedrich (2005) showed that visual targets that are fully congruent with previously presented auditory primes lead to most negative ERP amplitudes at centro-temporal electrodes, followed by targets that were only partially congruent and targets that were fully incongruent, respectively. The amplitude differences caused by prime–target congruency were reflected in a P350 component which peaked at left-hemispheric scalp sites at around 350 ms. Based on these results and those of a previous study in which the P350 was also observed in a unimodal priming task (Friedrich et al., 2004), the P350 was interpreted as an index for the activation of matching words in a modality-independent mental lexicon. In this respect, the P350 shares similarities with the M350 component observed in MEG studies (e.g., Pylkkänen et al., 2002, 2004, 2006; Stockall et al., 2004). The latency of the M350 has been found to vary with phonotactic probability of written words (Pylkkänen et al., 2002; Stockall et al., 2004). Words with high phonotactic probabilities led to lower M350 latencies than words with low probabilities. Similar to the previously mentioned P350, the M350 was interpreted to reflect lexical activation, and the decreased latency for high-probability words was a result of facilitated lexical activation.

Further evidence for the activation of multiple lexical candidates in written words came from an ERP study by Holcomb et al. (2002). Participants read words and pseudowords that belonged to small or large lexical neighborhoods while performing either a lexical decision task or a semantic categorization task. The authors found an enhanced N400 component for both words and pseudowords with a high amount of orthographic neighbors. This N400 pattern was interpreted as supportive for the view that printed strings belonging to large neighborhoods lead to increased levels of activation at either the form representation level, or the semantic representation level. Interestingly, in the semantic categorization task, effects of neighborhood size could already be observed in the 150- to 350-ms time window. Along similar lines, Barber et al. (2004) and Hutzler et al. (2004) reported an N400 component varying with syllable frequency (higher N400 for high syllable frequency stimuli), supporting the idea that high-frequency syllables trigger the activity of many lexical