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The dark side of incremental learning: A model of cumulative semantic interference during lexical access in speech production

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ABSTRACT

Naming a picture of a dog primes the subsequent naming of a picture of a dog (repetition priming) and interferes with the subsequent naming of a picture of a cat (semantic interference). Behavioral studies suggest that these effects derive from persistent changes in the way that words are activated and selected for production, and some have claimed that the findings are only understandable by positing a competitive mechanism for lexical selection. We present a simple model of lexical retrieval in speech production that applies error-driven learning to its lexical activation network. This model naturally produces repetition priming and semantic interference effects. It predicts the major findings from several published experiments, demonstrating that these effects may arise from incremental learning. Furthermore, analysis of the model suggests that competition during lexical selection is not necessary for semantic interference if the learning process is itself competitive.

1. Introduction

Retrieving a word from memory has consequences for later retrieval. This is particularly true when retrieval occurs in a semantic memory task such as picture naming. It is well known that the second presentation of a picture to be named speeds the naming response and diminishes the chance of error. This phenomenon, known as *repetition priming*, can be explained by the fact that each retrieval event is also a learning event, and so the second retrieval benefits from the learning that occurred the first time (*e.g.* Mitchell & Brown, 1988). Somewhat less well known is the fact that repetition priming has a "dark side". Retrieving a word has *negative* consequences for the subsequent retrieval of other words from the same semantic category (*e.g.* Abdel Rahman & Melinger, 2007; Belke, 2008; Belke, Meyer, & Damian, 2005; Blaxton & Neely, 1983; Brown, 1981; Damian & Als, 2005; Damian, Vigliocco, & Levelt, 2001; Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Hsiao, Schwartz, Schnur, & Dell, 2009; Kroll & Stewart, 1994; Schnur, Schwartz, Brecher, & Hodgson, 2006; Vigliocco, Vinson, Damian, & Levelt, 2002; Wheeldon & Monsell, 1994). Following Oppenheim, Dell, and Schwartz (2007), we refer to these negative consequences as *cumulative semantic interference*. In this paper, we explain the mechanisms behind cumulative semantic interference in the domain of picture naming. This explanation takes the form of a computational model of lexical access in speech production that simulates the major phenomena in this domain. The model addresses meaning-based lexical retrieval in general, whether this is elicited by picture-naming, naming-to-definition, or spontaneous production. Our focus, however, is on persistent changes to lexical processing that result from the natural retrieval of a single word. The central theoretical point that the model implements is that repetition priming and cumulative semantic interference are two sides of the same coin. They both result from an error-based implicit learning process that tunes the language production system to recent experience.

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Although our model is formally developed only for lexical access in speech production, our theoretical goals are more general. Cumulative semantic interference is a manifestation in speech production of a set of phenomena known in the memory literature as *retrieval-induced forgetting* or RIF. Retrieval-induced forgetting studies demonstrate that the episodic memory for a word or association can be impaired by the previous retrieval of a related memory (*e.g.* Anderson, Bjork, & Bjork, 1994; but see also Anderson & Neely, 1996, for a discussion of retrieval-induced forgetting in semantic memory). Currently, the explanation for such impairment is debated, with some claiming it results from suppressing previous competitors (often termed *inhibition* or *unlearning*; *e.g.* Anderson et al., 1994; Melton & Irwin, 1940; Norman, Newman, & Detre, 2007; Postman, Stark, & Fraser, 1968) while others claim it stems from strengthening previous targets (*occlusion* or '*blocking*'[1]; *e.g.* MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003; McGeoch, 1932; Mensink & Raaijmakers, 1988). Our analysis of cumulative semantic interference in speech production will, we claim, speak to this debate. More generally, our model reflects a recent trend in cognition to link psycholinguistics with theories of learning and memory by developing accounts of how experience changes language processing (*e.g.* Chang, Dell, & Bock, 2006; Goldinger, 1998; Kraljic & Samuel, 2005).

Much of the theoretical importance of cumulative semantic interference hinges on an alleged property of requiring a competitive mechanism for lexical selection (*e.g.* Howard et al., 2006). The most prominent theories of lexical access (*e.g.* Levelt, Roelofs, & Meyer, 1999) assume competitive lexical selection. Empirical support for this assumption has often come from picture-word interference studies (*e.g.* Schriefers, Meyer, & Levelt, 1990), in which speakers name pictures as they are presented at short offsets from distractor words. However, since Mahon, Costa, Peterson, Vargas, and Caramazza (2007) presented an analysis demonstrating that picture-word interference studies have not reliably supported the claims of competitive lexical selection, the search for empirical support has turned to a simpler task: picture naming, specifically with regards to cumulative semantic interference.

Two serial picture-naming paradigms have been particularly common in studies of cumulative semantic interference. First is the *blocked-cyclic naming paradigm* (*e.g.* Damian et al., 2001). In each block, subjects repeatedly cycle through naming a small set of pictures (*e.g.* one block might consist of four cycles through a set of six pictures). In the homogeneous condition, all the pictures in the block represent the same semantic category (*e.g.* farm animals), and in the mixed condition each picture represents a different semantic category. Cumulative semantic interference is indexed by greater difficulty naming pictures in the homogeneous condition relative to the mixed condition (the *semantic blocking effect*). Typically, the semantic blocking effect is not present in the first cycle and grows over subsequent cycles (*e.g.* Belke et al., 2005). The second important serial picture-naming paradigm, used by Brown (1981, Experiment 4) and Howard et al. (2006), can be called the *continuous paradigm*. In this method, pictures drawn from several categories (*e.g.* animals, vehicles) are named without repeating any item, but with multiple exemplars from each category. Here, cumulative semantic interference is demonstrated by naming times that increase linearly as a function of the number of previously named pictures in that category. Importantly, the number of interspersed pictures between each category exemplar is irrelevant to the effect (Howard et al., 2006). For example, in the sequence *GOAT, CAR, TOMATO, TRUCK, HORSE*, the naming time for *HORSE* would be slower than that for *GOAT*, and would be unaffected by the number of unrelated intervening items.

1.1. The nature of cumulative semantic interference: Howard et al.'s principles

Howard et al. (2006) argued that three specific properties of the lexical retrieval process must interact to produce cumulative semantic interference in naming latencies: shared activation, competitive selection, and priming. The idea is that each time a target word is activated, semantically related competitors are also activated (*shared activation*), and strongly activated competitors slow down the selection of target words (*competitive selection*). Retrieving a word once primes its future retrieval (*priming*), making it a stronger competitor when related words are retrieved in subsequent trials, thereby causing those subsequent target words to be retrieved more slowly. We will use these three properties to structure our review of the phenomenon and its implications for lexical retrieval.

1.1.1. Shared activation

When a target word such as DOG is activated during its attempted retrieval, its semantic relatives such as GOAT are also activated, thereby setting the scene for lexical competition. This principle of *shared activation* for semantically related words is what makes cumulative semantic interference specifically *semantic* in nature.

While the idea of shared activation is compatible with most current theories of semantic representation, it arises naturally from the use of distributed (or feature-based) semantic representations such as those commonly employed in connectionist models (see McClelland & Rogers, 2003, for a review). Distributed mechanisms would predict graded effects of semantic similarity, and indeed blocked-cyclic picture naming studies have demonstrated that more closely related items generate stronger interference effects than those more distant (Vigliocco et al., 2002). So, for the purpose of understanding cumulative semantic interference, it may be useful to think of shared activation arising from shared semantic features rather than all-or-none category membership. That is how shared activation is implemented in our model.

As noted by Howard et al. (2006), however, shared semantic activation does not require distributed representations. It may occur with non-decomposed (localist) lexi-

[1] The term 'blocking' carries a quite different meaning in the retrieval-induced forgetting literature, where it refers to a hypothesis of competitor-based interference, than in the cumulative semantic interference literature, where it tends to refer to the structure of an experimental design (i.e. pictures may be presented in semantically homogeneous blocks).