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Brief article

The paca that roared: Immediate cumulative semantic interference among newly acquired words

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ABSTRACT

With 40,000 words in the average vocabulary, how can speakers find the specific words that they want so quickly and easily? Cumulative semantic interference in language production provides a clue: when naming a large series of pictures, with a few mammals sprinkled about, naming each subsequent mammal becomes slower and more error-prone. Such interference mirrors predictions from an incremental learning algorithm applied to meaning-driven retrieval from an established vocabulary, suggesting retrieval benefits from a constant, implicit, re-optimization process (Oppenheim et al., 2010). But how quickly would a new mammal (e.g. paca) engage in this re-optimization? In this experiment, 18 participants studied 3 novel and 3 familiar exemplars from each of six semantic categories, and immediately performed a timed picture-naming task. Consistent with the learning model's predictions, naming latencies revealed immediate cumulative semantic interference in all directions: from new words to new words, from new words to old words, from old words to new words, and from old words to old words. Repeating the procedure several days later produced similar-magnitude effects, demonstrating that newly acquired words can be immediately semantically integrated, at least to the extent necessary to produce typical cumulative semantic interference. These findings extend the Dark Side model's scope to include novel word production, and are considered in terms of mechanisms for lexical selection.

1. Introduction

People know a lot of words (e.g. Nagy & Herman, 1987), but what does it mean to 'know' a word? Is a person's vocabulary merely a static collection of the words that they know, or something more dynamic?

Cumulative semantic interference in picture naming provides a clue: as a person names a series of a hundred pictures, with a few mammals interspersed, each successive mammal becomes persistently harder to name than the previous (e.g. Brown, 1981). This interference accumulates with each semantically related retrieval (Navarrete, Mahon, & Caramazza, 2010), persists over time and irrelevant experience (Howard, Nickels, Coltheart, & Cole-Virtue, 2006), and does not require explicit memory for previous exemplars (Oppenheim, Barr, & Tainturier, 2016), precisely as if an implicit learning algorithm were operating on the task of mapping shared semantic features to individual words in a neural network, incrementally overwriting competing associations (Navarrete et al., 2010; Oppenheim, Dell, & Schwartz, 2007; Oppenheim, Dell, & Schwartz, 2010): naming a picture of a tiger strengthens the semantic connections that support *tiger* ([mammal]→*tiger*), and weakens any that erroneously activate its competitors ([mammal]→*hedgehog*), thereby making *hedgehog* harder to retrieve when cued later. Remarkably, this interference has typically been demonstrated using very well-known words (e.g. *tiger, hedgehog*), leading to a theoretical claim that speakers continually learn and unlearn even words that they have 'known' for decades (Oppenheim et al., 2010).

If established vocabularies show such plasticity, how quickly would a novel word, like *paca* (a large burrowing rodent, native to South America) become semantically integrated enough to engage in this re-optimization process? Predictions may depend on the role of online competition in determining the timecourse of word retrieval in general, and creating cumulative semantic interference in particular. Oppenheim et al. (2010)'s Dark Side model, described above, emphasizes the error-driven unlearning of competing associations: retrieving *paca* should weaken the [mammal]→*hedgehog* connection to the extent that it erroneously activates *hedgehog*, thereby rendering *hedgehog* harder to retrieve in the future. But other accounts (Abdel Rahman & Melinger, 2009; Belke, 2013; Howard et al., 2006; Roelofs, 2018) have long assigned online competition a more central role in turning repetition priming or residual activation into semantic interference: *hedgehog* should grow less accessible only insofar as the nascent *paca*

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gets in the way.

A decade of word-learning research offers the general conclusion that novel words can be quickly 'configured' for retrieval—for instance allowing successful picture naming—but require more time, practice, and/or sleep before dynamically engaging with other vocabulary (Leach & Samuel, 2007). Thus novel words tend not to compete immediately with familiar words, perhaps because their slower and less automatic processing does not activate them in time to do so (Davis & Gaskell, 2009). Whereas familiar words can be retrieved quickly though strong and direct neocortical mappings, novel words initially depend more on weaker, slower, hippocampal routes. Pattern reinstatement during sleep may consolidate hippocampal traces into neocortical mappings (Davis & Gaskell, 2009), or simply strengthen them (Kumaran, Hassabis, & McClelland, 2016), yielding more efficient retrieval that allows competition effects to emerge. A novel wordform, like *cathedruke*, therefore typically requires sleep-based consolidation before competing with established phonological neighbors, like *cathedral* (Gaskell & Dumay, 2003 *et passim*), and semantic effects including picture-word interference (Clay, Bowers, Davis, & Hanley, 2007) have invariably required similar delays (Coutanche & Thompson-Schill, 2014; Tamminen & Gaskell, 2013; van der Ven, Takashima, Segers, & Verhoeven, 2015). Therefore, if online competition is central to cumulative semantic interference in production, *paca* should not impair *hedgehog* retrieval until after consolidation.

Whether retrieving *tiger* or *yapok* (a web-footed Central American marsupial) should interfere with *paca* similarly depends on theory. The Dark Side model assumes incremental semantic-to-lexical learning and unlearning from the moment a new word is established, implying *paca*'s immediate vulnerability to interference from both. But Complementary Learning Systems theories propose an additional, sparser, means of storing novel associations (hippocampal conjunctive coding), trading semantic richness for representational independence that prevents it from overwriting or being overwritten by other concepts that share its features (e.g. McClelland, McNaughton, & O'Reilly, 1995). If such sparse storage introduces a sparse route for novel word retrieval—retrieving *paca* via its conjunctive code instead of shared semantic features—it could plausibly insulate novel words from both competitive selection (retrieving *paca* without engaging *tiger* or *yapok*) and 'competitive' unlearning (by making *paca* less dependent on input from the shared [mammal] feature, essentially bypassing the semantic-to-lexical mapping). The same mechanism that prevents new memories from catastrophically interfering with old ones may thereby provide an interference-resistant route for retrieving them.

Thus, it is unclear whether or how the scope of an incremental lexical learning model should extend to novel word production. The Dark Side model offers predictions for cumulative semantic interference involving novel words, but they hinge on the uncertain contributions of semantically rich retrieval and competitive lexical selection. Therefore, the current study considers, for the first time, the emergence of a well-studied semantic effect (cumulative semantic interference) as a way to assess this possible extension, consider the cognitive mechanisms underlying the behavioral effect, and more generally assess the timecourse of novel words' semantic integration.

1.1. Method

1.1.1. Participants

Eighteen native-English Bangor University students (11 female) received £12 or course credit for participation. All provided informed consent, reporting normal or corrected-to-normal vision and hearing and no known language disorders. Additional participants were replaced due to technical difficulties (2), excessive omissions (> 25%) (3), or prior familiarity with too many novel items (2).

1.1.2. Procedure

In a continuous one-hour session, each participant first read a short booklet introducing three novel (e.g. paca, noni) and three familiar (e.g. badger, apple; mean $SUBTLEX_{UK}$ Zipf: 3.91; van Heuven, Mandera, Keuleers, & Brysbaert, 2013) disyllabic real-word exemplars of six semantic categories (e.g. mammals, fruits). They then completed two card-sorting training tasks, rated their prior familiarity with each exemplar, and finally completed the timed picture naming testing task. Pseudorandom trial orders for picture naming allowed estimating semantic interference from novel and familiar category coordinates, plus generalized slowing, as minimally collinear within-items/subjects effects. To assess consolidation-dependent changes, the protocol was repeated 1–7 days later (M = 46.0 h, SD = 36.6).

Introduction booklet (training). Each page introduced one novel or familiar exemplar, including three color photographs (selected from the internet) to establish view-invariant visuospatial representations and three one-sentence facts (e.g. "Pacas dig burrows for shelter and protection,"). Participants studied this 36-item booklet for ten minutes.

Cardsorting (training). The same 36 × 3 photographs then served as the bases for two rounds of word-to-picture and picture-to-word speeded cardsorting. Each card showed a photograph on one side and its name on the other. In the word-to-picture task, participants sorted 108 randomized word-side-up flashcards onto a grid of pictures, naming each in the process; time-pressure encouraged memorization. An analogous picture-to-word task matched picture-side-up cards to the word grid. Within the picture or word grid, each (unlabeled) column contained randomly arranged exemplars of a single category, providing shared affordances analogous to real-world category use. Five minutes were allowed for Round 1, four minutes for Round 2; anyone exceeding the four-minute deadline repeated the tasks as Round 3.

Novelty ratings. In this 36-trial E-Prime-based task, participants saw one photograph of each item, with its name below, rating it on a seven-point scale from "I use this word at least once a week" to "I had never encountered this word before this experiment."

Timed picture naming (testing). The same 36 photographs now served as stimuli for a pseudorandomly ordered 36 × 6 = 216-trial E-Prime-based timed picture naming task. Participants were instructed to quickly and accurately name each picture, avoiding omissions. Each trial presented a 500 ms blank screen, 500 ms fixation, 500 ms blank screen, and then a centered color photograph for 2500 ms or until the 50 ms-delayed-threshold voicekey (Tyler, Tyler, & Burnham, 2005) triggered; the desired name then appeared below for 700 ms as feedback. Vocalizations were digitally recorded via a headmounted microphone, and transcribed offline.

1.1.3. Design

Eighteen counterbalanced lists optimized the timed picture naming orders for subsequent analyses. In each list, 6 × 36-trial 'Cycles' each included one photograph of each exemplar (Fig. 1); each exemplar appeared once in each within-category ordinal position (e.g. as the fifth mammal). In each Cycle, 6 × 6-trial 'Subcycles' contained one exemplar from each semantic category (three novel, three familiar), interleaving all exemplars, categories, and novelty levels. Across lists, exemplars appeared equally in each 'Ordinal Position within Novelty level', and with constant proportions in each 'Ordinal Position between Novelty levels', allowing separate estimation of interference from novel and familiar exemplars. Each item also appeared equally in each 'Trial in Subcycle' position, allowing estimation of decay or non-semantic interference.

1.1.4. Analyses

To ensure the novelty of novel exemplars, data from any that a participant failed to rate as completely novel (Appendix A) was discarded, unless its Session 1 accuracy was at or below their confirmed-novel items',[1] thus excluding approximately two exemplars per

[1] Several participants voiced concern over miskeying subsets of their novelty ratings.