Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Memory and Language 54 (2006) 1–19
Journal of Memory and Language
www.elsevier.com/locate/jml

Acquiring an artificial lexicon: Segment type and order information in early lexical entries

Sarah C. Creel *, Richard N. Aslin, Michael K. Tanenhaus

Department of Brain and Cognitive Sciences, Meliora Hall, University of Rochester, Rochester, NY 14627, USA

Received 20 December 2004; revision received 19 September 2005
Available online 28 November 2005

Abstract

The role of segment similarity in early (i.e., partially learned) lexical entries was assessed using artificial lexicons in a referential context. During a learning phase participants heard 40 nonsense words, each accompanied by an unfamiliar picture. In testing, participants heard the direction "Click on the [X]", and chose which of four pictures was the target (X). Target lexical items (e.g., ***pibo***) appeared with foils that were similar: cohort items (***pib**u*), rhymes (*d**ibo***), matched consonants (***p**a**b**u*) or matched vowels (*d**i**k**o***). Two initial experiments demonstrated cohort and rhyme confusions, similar to lexical activation findings. Four further experiments explored the role of segment similarity in word confusions. Consonant-matched CVCV stimuli were more strongly confused with each other than were vowel-matched CVCV stimuli. Placing consonants in syllable-final position (VC[f]VC) weakened consonant effects and strengthened vowel effects. These results suggest that syllable-initial segments play a strong role in word similarity and constrain the organization of new lexical items.

Keywords: Artificial lexicon; Lexical learning; Lexical acquisition; Consonant; Vowel; Word learning; Lexical activation

The research reported here addresses two issues about the representation and processing of spoken words. The first issue is whether vowels and consonants contribute differentially to lexical similarity and if so, whether differences are tied to the potential information provided by each class of segment and/or the position they typically occupy in syllables. In order to address this issue, we examine confusions between newly learned words in an artificial lexicon. Use of an artificial lexicon allows us to manipulate properties that are otherwise confounded in natural language lexicons. For example, most languages have more consonants than vowels and consonants are more common than vowels in word and syllable-initial position.

The second issue is whether there are qualitative differences in the relative importance of consonants and vowels early in learning compared to when a word has been well learned. Partially learned lexical representations, which we will refer to as "early" lexical entries, may show the onset-based processing biases characteristic of words in natural language lexicons (Marslen-Wilson, 1987) and in artificial language lexicons (Magnuson, Tanenhaus, Aslin, & Dahan, 2003) or they may be represented more holistically. If there are qualitative changes in representations as words become better learned, then the relative importance of vowels and consonants might change with the degree of learning.

* Corresponding author. Present address: Psychology Department, University of Pennsylvania, Philadelphia, PA 19104, USA. Fax: +1 215 898 7301.
E-mail address: creel@psych.upenn (S.C. Creel).

0749-596X/$ - see front matter © 2005 Elsevier Inc. All rights reserved.
doi:10.1016/j.jml.2005.09.003

In the remainder of the introduction, we first motivate the rationale for examining differences among consonants and vowels and then introduce the rationale for using the artificial lexicon methodology. We then consider the issue of whether early lexical entries are represented holistically or in the more phonologically elaborated, onset-biased way that characterizes well-learned natural lexical representations.

Research on spoken word recognition has shown that as the acoustic properties of words unfold in time, multiple word candidates are activated in parallel and compete for recognition. Early in processing, the most active candidates have similar onsets (Marslen-Wilson, 1987; Marslen-Wilson & Zwitserlood, 1989; Marslen-Wilson, Moss, & van Halen, 1996), with activation modulated by frequency (Dahan, Magnuson, & Tanenhaus, 2001), among other factors. However, as more input arrives, words that mismatch at onset but are globally similar to the target word also become activated (Allopenna, Magnuson, & Tanenhaus, 1998; Connine, Titone, & Wang, 1993; Goldinger, 1998; Luce & Pisoni, 1998), though these words never compete as strongly as those with similar onsets.

The lexical candidates that become most active when a spoken word is processed define the competitor or processing environment for that word. Although effects of acoustic/phonetic similarity are increasingly well-documented, fundamental issues about exactly how to characterize similarity remain unresolved. These issues are intertwined with questions about how acoustic information is represented in the lexicon, e.g., as sequences of phonetic segments, phonemes or syllables. For example, the most detailed model of competitor similarity is the Neighborhood Activation Model developed by Luce and colleagues (for an overview, see Luce & Pisoni, 1998). In this model, each word is stored as a string of phonetic segments. Lexical activation is a function of overall segment similarity with all other words, weighted by the relative frequency of the target word and the frequency-weighted ''neighborhood'' within which the target word resides. Similarity is evaluated using the Neighbor Word Probability rule, which provides graded similarity scaling of words in terms of the relative confusability of segments of one word with the other, such that the neighboring words may not necessarily share segments at all. An alternative ''shortcut'' metric defines as a neighbor any word that can be changed to another by adding, deleting, or changing a single segment (neighbors of *cat* include *cap* [a cohort], *hat* [a rhyme], *cot*, *cast*, *at*, but not *catalyze*). Neighbors are then used to compute the neighborhood similarity function that maps onto the processing notion of activation. Strong support for the concept of lexical neighborhoods comes from evidence that words in sparse neighborhoods are recognized more quickly than words in dense neighborhoods.

Despite the strong evidence that positional overlap influences the degree to which a lexical competitor becomes activated, neither of the similarity metrics used by NAM is explicitly sensitive to order information. For example, according to the shortcut rule, a consonant–vowel–consonant (CVC) target word would be equally confusable with other CVC neighbors, regardless of whether the segment difference resided in the initial consonant, the vowel, or the final consonant. (Note that the more fine-grained confusion-based measure of neighborhoods also collapses confusability estimates over syllable position.)[1]

Another important question is whether vowels and consonants contribute differently to similarity. There are several reasons why segment type may affect competitor similarity. Vowels are louder, longer, and more robust to noise masking (Dorman, Kewley-Port, Brady, & Turvey, 1977; Horii, House, & Hughes, 1970) than consonants. However, they also vary greatly across talker and phonetic context, and are more subject to diachronic changes than consonants (Hillenbrand, Getty, Clark, & Wheeler, 1995; Peterson & Barney, 1952). In contrast, consonants are distributed more tightly along such dimensions as voice onset time (Lisker & Abramson, 1964; Macmillan, Goldberg, & Braida, 1988). Consonants also tend to outnumber vowels cross-linguistically, and constitute the majority of word onsets. Note that these two qualifications are simply informational ones: more alternatives means more information can be conveyed, and elements with temporal primacy can do more informational work that, all other things being equal, could as easily be done by elements later in the word. Thus, it is not clear if the greater robustness of vowels outweighs their greater variability compared to consonants.

Some evidence suggests that consonants are more central to lexical representations than vowels. For instance, Van Ooijen and colleagues (Cutler, Sebastián-Gallés, Soler-Vilageliu, & Van Ooijen, 2000; Marks, Moates, Bond, & Stockmal, 2002; Van Ooijen, 1996) have demonstrated that consonant information may be more integral to word identity than vowel information. In their ''word reconstruction'' task, a nonword is presented which can be turned into a real word by alteration of a single phoneme (e.g., ''teeble'' → *table* or *feeble*). They found that speakers of English (Van Ooijen, 1996), as well as speakers of Spanish and Dutch

[1] It is of interest that the confusion data used in calculating the NWP come from syllables embedded in white noise (Luce, 1986, as cited in Luce & Pisoni, 1998). Knowing that consonants are more strongly masked than vowels, these noise data (and hence the NWP) may underrepresent the discrimination advantage conferred by consonants, classing words with noninitial overlap as more phonologically similar than they actually are, at least in non-noise contexts.