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Neural responses to category ambiguous words

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ABSTRACT

Category ambiguous words (like *hug* and *swing*) have the potential to complicate both learning and processing of language. However, uses of such words may be disambiguated by acoustic differences that depend on the category of use. This article uses an event-related potential (ERP) technique to ask whether adult native speakers of English show neural sensitivity to those differences. The results indicate that noun and verb tokens of ambiguous words produce differences in the amplitude of the ERP response over left anterior sites as early as 100 ms following stimulus onset and persisting for over 400 ms. Nonsense words extracted from noun and verb contexts do not show such differences. These findings suggest that the acoustic differences between noun and verb tokens of ambiguous words are perceived and processed by adults and may be part of the lexical representation of the word.

1. Introduction

Like many languages, English contains words that may be used in more than one lexical category (e.g., noun/verb homophones like *run* and *fence*). These words can produce temporary ambiguities when they are used in sentences and could, in principle, cause significant problems for learners who are trying to sort the words they hear into appropriate lexical categories. However, some research suggests that these words, although homophonous at the segmental level, may contain acoustic cues that differentiate their uses (Conwell and Morgan, 2012; Shi and Moisan, 2008; Sorensen et al., 1978) and that infants are sensitive to those cues (Conwell and Morgan, 2012). Whether adults are similarly sensitive, however, is an open question. Infants show greater sensitivity to a wider range of phonetic distinctions than adults do (Werker and Tees, 1999), so although adults produce noun and verb tokens of homophones differently, they may not perceive those differences. This article examines whether adult English speakers show neural discrimination of isolated tokens of noun/verb homophones.

1.1. Nouns, verbs and category ambiguity

Instead of using semantically-driven elementary school definitions such as "a noun is a person, place or thing," linguists categorize words based on their grammatical properties. Nouns are words with noun-like syntax and morphology. They may be the subjects of sentences or the objects of verbs and prepositions. Verbs are words with verb-like syntax and morphology, taking noun phrases and prepositional phrases as arguments. These functional definitions are inherently circular, as "verb-like" syntax requires a definition of "noun" and "noun-like" syntax requires a definition of "verb." Several researchers have proposed methods of "distributional bootstrapping" that children might use to break into this system (Maratsos and Chalkley, 1980; Mintz, 2003; Monaghan et al., 2005). These proposals differ in the details, but in broad terms, they consider whether co-occurrence patterns of nouns and verbs with distinct, highly frequent function words might allow children to create ersatz categories that contain mostly nouns and mostly verbs. Under some implemented models of distributional bootstrapping (e.g., Mintz, 2003), these small categories containing mostly nouns and mostly verbs would be combined on the basis of overlap in items. Noun/verb homophones could confound this process, as a word such as *run* could reasonably appear in both noun and verb contexts. For this reason, these words have been used to argue against the very possibility of distributional bootstrapping (e.g., Pinker, 1987).

Recent developmental research indicates, however, that this problem may not be as significant as it has been made out to be. Parents produce acoustic distinctions between noun and verb uses of both real and novel words when speaking to children (Conwell and Morgan, 2012; Shi and Moisan, 2008) and infants are sensitive to these differences (Conwell and Morgan, 2012). This suggests that distributional bootstrapping need not fall victim to noun/verb homophone confusion because infants may be able to maintain two distinct lexical entries for such words, one that is a noun and one that is a verb. If this were the case, infants would not conflate noun and verb categories because noun tokens of homophones would not be considered "the same" as their verb counterparts.

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Unanswered in this previous work is the question of whether children maintain sensitivity to these distinctions as they age and whether these distinctions might be incorporated into their representations of the words. In other words, if infants are sensitive to acoustic distinctions between noun and verb uses of homophones, do they establish lexical representations that remain distinct as they develop? Perceptual narrowing of phonetic categories is well documented in the literature on speech perception. For example, children show reduced sensitivity to non-native consonant contrasts around 10–12 months of age (Werker and Tees, 1999). However, the children in the Conwell and Morgan (2012) study were 13 months old and still sensitive to prosodic differences in noun/verb homophone pairs, indicating that these differences continue to be perceived even after sensitivity to some non-native phonemic contrasts has weakened. It is possible, therefore, that perceptual sensitivity to these distinctions is preserved across development.

The fact that adults reliably produce these differences may be uninformative regarding their status as part of the lemma or, for that matter, adults' perceptual sensitivity to such information. Adults reliably produce allophonic variations that are conditioned by context, but show reduced sensitivity to the distinctions between those allophones (e.g., aspiration of stop consonants by English speakers). Therefore, there are two possibilities regarding the production of acoustic distinctions in noun/verb homophones by adults. First, these distinctions may arise solely as the result of prosodic processes in production. In that case, adults' representations of noun/verb homophones may consist of only one form and we would not expect adults to be sensitive to this variation. Alternatively, these distinctions, although a by-product of prosody, may be attached to the lemma itself during the learning process, in which case adults should show preserved sensitivity to them.

1.2. Use of prosodic information in development

The distinctions that have been observed between noun and verb uses of homophones may arise because of an interaction between sentence-level prosody and the usual distributions of nouns and verbs in sentences. Specifically, noun tokens tend to be longer than verb tokens of the same word (Conwell and Barta, In preparation; Conwell and Morgan, 2012; Sorensen, et al., 1978) and nouns are more likely than verbs to appear in phrase-final position in sentences. English has robust phrase-final lengthening (Shattuck–Hufnagel and Turk, 1996), which would explain why words that are more likely to be at the ends of phrases are also more likely to be longer in duration.

Prosodic cues are used to facilitate sentence processing across the lifespan. Infants use phrase-final and sentence-final prosody to bundle words, preferring to listen to phrases that were prosodically coherent during a familiarization period (Nazzi et al., 2000; Soderstrom et al., 2003). Adults can use prosodic information to resolve syntactic ambiguities (Kjelgaard and Speer, 1999) and word-level prosody, such as syllabic stress, distinguishes meanings of some words in English (e.g., inCENSE and INcense; Sereno and Jongman, 1995). Preschool-aged children also use prosody to disambiguate sentence structure, although these effects are slower in children than in adults (Snedeker and Yuan, 2008) and there is some evidence that children fail to use focal stress in an adult-like way when processing sentences (Cutler and Swinney, 1987). Most studies, however, do not ask whether prosody affects the processing of individual monosyllabic words, as the research on homophone perception by infants suggests.

There are two ways that prosody could affect interpretation of words. The first is that prosodic regularities (e.g., noun uses tend to be longer than verb uses) are encoded in the lemma itself. That is to say, homophones are homophonous at the segmental level, but meanings are linked to word forms that are suprasegmentally distinct. Prior evidence indicates that less frequent meanings of homophones are longer in duration than tokens that capture more frequent meanings (e.g., *thyme* is longer in duration than *time*; Gahl, 2008). Adults also use emotional prosody to disambiguate senses of homophones with distinct emotional valence (e.g., *bridal* and *bridle*; Nygaard et al., 2002). Likewise, meanings that are distinct in their syntactic properties (i.e., noun/verb homophones) could be suprasegmentally distinct, not just in production, but in their representation. Alternatively, the distinct meanings of homophones could be linked to a single phonological form, but prosody could function like referential context to disambiguate the meanings. Under this account, prosodic cues to the lexical category of an ambiguous word arise as by-products of syntax and are not inherent in the representation of that word.

The research on infants' ability to distinguish between noun and verb uses of homophones does not differentiate these accounts (Conwell and Morgan, 2012). That study showed only that infants can *perceive* the distinction, not that it is incorporated into their representations of the words. If the prosodic distinctions are part of the representation itself, then adults should show effects associated with the particular lexical category of use. In other words, verb uses of noun/verb homophones should elicit different responses from adults than noun uses do. Translating infant methods for use with adult participants is challenging for a range of reasons, but neural methods allow for implicit responses to stimuli in a way that many behavioral methods typically used with adults do not.

1.3. ERP responses to nouns and verbs

Research using event related potentials (ERPs) measured with electroencephalography (EEG) provides a means of measuring neural response to stimuli. In the domain of language research, ERPs have been used to examine lexical access using both visual and auditory stimuli. Brown et al. (1973), (1976), (1979) exposed participants to noun/verb homophones in sentence contexts while recording from 4 electrodes on the scalp. In one of these studies, participants heard identical auditory tokens of these words spliced into carrier phrases that produced either a noun or verb interpretation (Brown et al., 1973). Brown et al. report a differential response to noun and verb uses in an early negative-going component for the left anterior, but not the right anterior, electrode. In later research, Brown et al. (1976), (1979) presented the tokens in ambiguous phrases and instructed participants to interpret those phrases with either a noun or a verb reading at the beginning of each epoch. In this case, participants again showed discrimination at the left anterior recording site both at 150 ms after stimulus onset and in a later period between 390 and 500 ms. These findings suggest that neural responses to noun/verb homophones differ depending on the interpretation of those words by the participant.

Work examining the processing of unambiguous nouns and verbs shows that frontal sites produce differences in the amplitude of a negative-going component beginning around 250 ms following stimulus onset and continuing for another 250 ms (Molfese et al., 1996). Specifically, nouns produced greater amplitude than verbs did. Research with preschool-aged children likewise finds amplitude differences in a negative component in the same time frame, although in this case, verbs produced greater amplitude than nouns did (Tan and Molfese, 2009). These studies use auditory presentation of words with matching or mismatching videos. Using visual presentation of text similarly produces differences in response to unambiguous nouns and verbs around 230 ms following stimulus onset, with verbs eliciting greater negativity than nouns (Pulvermüller et al., 1999). Because the stimuli used in these studies were all unambiguous nouns and verbs, it is unclear whether