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On the time course of lexical stress priming in speech production: Behavioral and ERPs evidence from a free-stress language

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ABSTRACT

The goal of the present research was to study the time course of lexical stress encoding in a free-stress language with unpredictable stress. To this aim we measured event-related brain potentials (ERPs) during lexical priming. Participants named pictures bearing either the dominant or non-dominant stress pattern, and preceded by either a congruent or an incongruent word prime (e.g., CInema-FRAgola'cinema-strawberry' vs. benZIna-FRAgola'petrol-strawberry'). Behavioral results show that participants were slower in naming targets that had the same stress pattern as the prime, and were also faster in producing words with the dominant stress pattern in the language. The electrophysiological results show that both the effects are compatible with the time course of phonological encoding in speech production. Surprisingly, a dominant stress effect occurred in the ERPs elicited by the primes, with a larger positivity for non-dominant stress words in a 150–250 ms time-window. The pattern of results indicates that during speech production: a) the system is sensitive to the stress patterns distribution; b) the automatic pre-activation of a metrical frame may interfere with the phonological encoding of a to-be-uttered word.

1. Introduction

Lexical stress is an abstract phonological property of words that specifies the most prominent syllable in a word. Many languages, such as English, Dutch, or Italian, are defined as free-stress languages, since stress may occupy different positions within a word; in these languages the position of stress may be largely unpredictable or not fully accountable by rules. In order to assign stress to a word, speakers can thus use information derived from different sources, such as sensitivity to distributional properties of language, explicit rules and lexically stored information. Stress may also distinguish word meanings, as there are minimal word pairs segmentally identical differing only for stress (e.g., English: ACcent vs. acCENT; Italian: ANcora'anchor' vs. anCOra'again/yet') (Capital letters indicate the stressed syllable).

Free lexical stress languages pose at least two questions to theories of speech production: (a) How is stress position determined? (b) At what level of the process is lexical stress engaged by the system to prepare the utterance? One of the most prominent theory of speech production (Levelt et al., 1999) answers these questions as follows: (a) Lexical stress (together with the information about the number of syllable) is part of the metrical information of a word and it is assigned either by means of a default rule (in case of regular stress), or through memory retrieval (in case of irregular stress). Stress regularity is defined in distributional terms in Levelt et al.'s model: the default stress is the most frequent pattern in the language (e.g., initial stress in English or Dutch). Note that, in free stress languages, a distributional asymmetry between different stress pattern is very common; however, there is a different degree of markedness among languages (e.g., the words bearing a dominant stress pattern appears are: ~80% in English, >90% in Dutch, ~75% in German, ~70% in Italian); while a strong markedness may become a rule for the system, a weaker markedness might become a simple bias, with a reduced impact on the processing; (b) the speech production system accesses and use the stress during the stage of encoding of the phonological word, i.e. at the stage where the speaker builds the word form by retrieving in parallel and independently segmental information and, in case of irregular (less-dominant) stress words, metrical information. A further assumption of the theory is that metrical and segmental spell-out take approximately the same time. After retrieval, during the segment-to-frame association, segmental and suprasegmental information are combined together through an incremental process that inserts segments into slots made available by the metrical frame. The result is a phonological word, which is then used for the phonetic implementation of the word.

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The experimental evidence on how speakers handle stress information, however, is scanty and inconsistent. For example, the assumption of different mechanisms to assign the regular and the irregular stress pattern – the former assigned by default, the latter retrieved from memory – has been rarely tested and the available data offer inconclusive results, as shown by the two picture-naming studies in Dutch that explicitly investigated the issue. On the one hand, a cross-modal priming study with target pictures and auditory primes showed facilitation for default-regular stress words (i.e., initial stress) compared to irregular stress words (final stress; Schiller et al., 2004); on the other hand, the opposite trend was reported in a picture naming experiment (Schiller et al., 2006).

With regard to the metrical spell-out, the first study investigating the issue was run by Roelofs and Meyer (1998) in Dutch: The authors used the implicit priming paradigm – participants learn cue-target word pairs, and produce the target word upon presentation of a cue word – and found a facilitation when the response words shared the initial segments as well as the metrical structure. No effect was observed when the words shared initial segments but differed in metrical structure, or vice versa (for the absence of pure metrical priming, see also Schiller et al. (2004)). Roelofs and Meyer concluded that the retrieval of metrical information occurs independently of that of segmental information: Metrical and segmental spell-out run in parallel and take the same amount of time. For this reason, speeding up one of the two processes does not speed up the whole process. These conclusions hold for words with irregular stress patterns (either on the second or third syllable in three-syllable Dutch words), which are stored and retrieved from memory; however, in case of words bearing the default stress (i.e., first syllable in Dutch) the phonological word is supposed to be assembled simply from its segmental information, since the metrical pattern is assigned by default.

Recently, some Italian studies have shown that the metrical structure of a word may be primed independently from its segmental content, that is when prime and target share the metrical frame but not the segmental content (e.g., TESsera-BUfala'card-buffalo' vs. maTIta-BUfala'pencil-buffalo'). Two studies (Colombo and Zevin, 2009; Sulpizio et al., 2012) investigated reading aloud while one (Mulatti et al., 2013) investigated picture naming. In all cases word primes were used. Interestingly, while in reading aloud prime-target pairs consistent for stress were faster than inconsistent pairs, for picture naming the opposite pattern was found. While the asymmetry between the two tasks is interesting by itself, and akin to processing and/or representational differences between them, the findings clearly indicate that metrical information can be retrieved independently from segmental information, and that, at least in Italian, pure metrical priming can occur.

Lexical stress has also been investigated through event-related potential (ERP), as it allows assessing the time course of information processing during language production. In an ERPs experiment in Dutch conducted by Schiller (2006), participants were presented pictures and were asked to perform a go/no-go decision about the stress location of the picture bisyllabic names. Schiller found that the N200 (an ERPs component evident in go/no-go paradigms; see, e.g., Kutas and Schmitt (2003)) peaked earlier when the go/no-go decision was contingent on initial- than final-stress information. The pattern was taken as evidence that participants could access to stress information earlier when the stimuli had initial stress, and this because of the hypothesized metrical encoding occurring in a rightward incremental way. Moreover, the time dynamic of the effect was compatible with the time course of phonological encoding, which has been estimated to start approximately 250 ms after the presentation of a picture evoking a spoken response (i.e., the picture name; see Indefrey and Levelt (2004) and Indefrey (2011)). Note, however, that initial stress is also the default pattern in Dutch and, thus, a possible effect of stress regularity, instead of – or in addition to – stress position, cannot be ruled out. Another alternative account is that the ERPs effects do not directly mirror the timing of access during production, given that a metalinguistic task was used: if the go/no-go choice is made on the basis of a self monitoring routine rather than directly on the abstract metrical pattern representation then a difference can not be unambiguously attributed to the production process.

Evidence for the occurrence of phonological effects in the time window identified by Indefrey and Levelt (2004) comes also from production studies manipulating the segmental information. In a Picture-Word-Inferfence experiment, Dell'Acqua et al. (2010) found that the effect of picture-word phonological overlap occurs ~300 ms after stimulus presentation, with a wide distribution on the scalp (see also Qu et al. (2012)). Moreover, in picture naming experiment with anomic patients affected by lexical-phonological impairment, Laganaro et al. (2009) shown that the electrophysiological response of such patients diverged from that of control participants from 340 ms to about 430 ms after picture presentation, with the differences limited to the electrodes from the left central region. A topographically asymmetrical effect of phonological activation was also reported by Jouravlev et al. (2014), who reported larger negativity for phonological-incongruent than phonological-congruent prime-target pairs at the left-anterior sites of the scalp.

In the present study we address two issues pertaining to lexical stress in speech production. The first issue deals with how stress position is determined: Although the Levelt et al.'s model postulates that, in free-stress languages as English, Dutch or Italian, only irregular stress is retrieved from memory, the regular one being assigned according to a default rule, the available evidence on this issue is inconclusive. Moreover, while some studies failed to report a pure metrical prime, recent evidence suggests that the metrical frame of a word can be primed also in absence of shared segmental content.

The second issue pertains to the time course of lexical stress assignment during speech production. The study is done in Italian, a language in which metrical-only priming is attested in the literature (Colombo and Zevin, 2009; Sulpizio et al., 2012; Sulpizio and Job, 2015). Italian is a polysyllabic language with an interesting stress system, in which there is no rule-based algorithm for stress assignment (Kramer, 2009)[1]. This implies that the stress pattern of a word can only be reliably established through lexical retrieval. However, the different stress patterns have an asymmetric distribution in the Italian lexicon: While ~75% of words bears penultimate stress, ~20% of words bears antepenultimate stress (Kramer, 2009)[2]. Thus, according to the Levelt et al.'s (1999) theory of speech production, which identifies as the default the most frequent stress pattern in the lexicon, penultimate stress might be considered as the default in Italian.

We implemented a picture naming experiment with an unmasked priming procedure and manipulated the stress of the target pictures as well as the prime-target stress congruency: Pictures had either penultimate or antepenultimate stress and were preceded by briefly presented words that did or did not share the stress pattern with the target (e.g., CInema-FRAgola'cinema-strawberry' vs. benZIna-FRAgola'petrol-strawberry'). A third non-linguistic prime condition (####) was also added as a

[1] The unique Italian rule for stress assignment requires to assign penultimate stress to those words that have a heavy penultimate syllable (e.g., bi. SO**N**.te'bison'). The rule shows also some exceptions (e.g., MAN.do**r.**la 'almond', LE.pa**n.**to).

[2] The estimate is based on polysyllabic words with three or more syllables. The remaining words bear stress on the final syllable (e.g., co.li. BRÌ, 'hummingbird').

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