# Early cortical sensitivity to ambiguous morpheme boundaries in speech: MEG evidence from Arabic

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In speech processing, the brain must segment a continuous input stream into meaningful units. Most work on the neural basis of speech processing has focused on the phoneme level or the orthographically-defined word level. But does the brain place within-word boundaries between meaningful segments (i.e. morphemes)? If so, what is the nature of this process?

We contrast three possible models: (i) the morphologically-naïve brain, insensitive to morphemic information/boundaries; (ii) the 'patient' brain, which places morpheme boundaries only once it uniquely identifies a morpheme (i.e., at its uniqueness point), and (ii) the 'eager' brain, which places boundaries as soon as it identifies a *potential* morpheme, even if it's not unique.

We used a single-word auditory presentation paradigm in Standard Arabic, where words consisted of a verbal stem and a direct object pronoun. We had two conditions:

(a) Morphologically unambiguous: 30 verbal stems followed the exact same pattern: '$\boldsymbol{C_1}a\boldsymbol{C_2}\boldsymbol{C_2}a\boldsymbol{C_3}a$' (e.g., '**q**a**yy**a**m**a-ni', meaning 'He evaluated me.'). Each stem had a different set {$\boldsymbol{C_1}$,$\boldsymbol{C_2}$,$\boldsymbol{C_3}$}, which are Arabic root-consonants. The stems' uniqueness points are at $\boldsymbol{C_3}$, and no initial substring of any stem forms a morpheme on its own.

(b) Temporarily morphologically ambiguous: here, half the verbal stems (30) followed the previous pattern (e.g., '**j**a**rr**a**b**a-ni', meaning 'He tested me.'). For each stem, we also used a corresponding stem consisting of a substring of the longer stem ('$\boldsymbol{C_1}a\boldsymbol{C_2}\boldsymbol{C_2}a$'; e.g., '**j**a**rr**a-ni', meaning 'He dragged me.'). As the stems unfolds, there is temporary ambiguity: is the stem long or short? A 'patient' brain waits for the $\boldsymbol{C_3}$ uniqueness point to place a boundary; an eager 'brain' starts setting a boundary early, at $\boldsymbol{C_2}$, since a potential stem's been identified.

27 participants listened to our words while we recorded their brain activation using magnetoencephalography (MEG). After 25% of trials, they had a comprehension task targeting either stems or pronouns. Using source-localization, we estimated cortical activation in auditory and morphology-sensitive regions (bilateral inferior frontal, and superior/middle temporal lobes).

When locking the long-stemmed stimuli to uniqueness point onset (t=0 at $\boldsymbol{C_3}$ onset), we find two evoked effects in the bilateral superior temporal cortex (Fig. 1a): (i) an early effect shows more negative activity for ambiguous vs. unambiguous words, roughly 200–50ms before the uniqueness point $\boldsymbol{C_3}$. We interpret this effect as early ('eager') sensitivity to the potential morpheme boundary in the ambiguous condition; (ii) a later effect, 50–125ms after $\boldsymbol{C_3}$, shows the opposite pattern, which could reflect a revised boundary setting in the ambiguous condition.

We also find a left inferior frontal effect, with a cluster stretching between -35–25ms relative to $\boldsymbol{C_3}$ (Fig. 1b). This effect, in a non-sensory area, follows the early temporal effect; it could index higher-up processing of eager boundary setting and/or morpheme identification.

In sum, our results provide more evidence for morphological segmentation during speech processing, and support a model in which the brain actively tries to segment available content into meaningful units, rather than passively wait for uniqueness points to fully identify morphemes. Next, we will use a temporal response function (TRF) regression framework, to compare the 3 models and determine which has the best fit to the neural data.

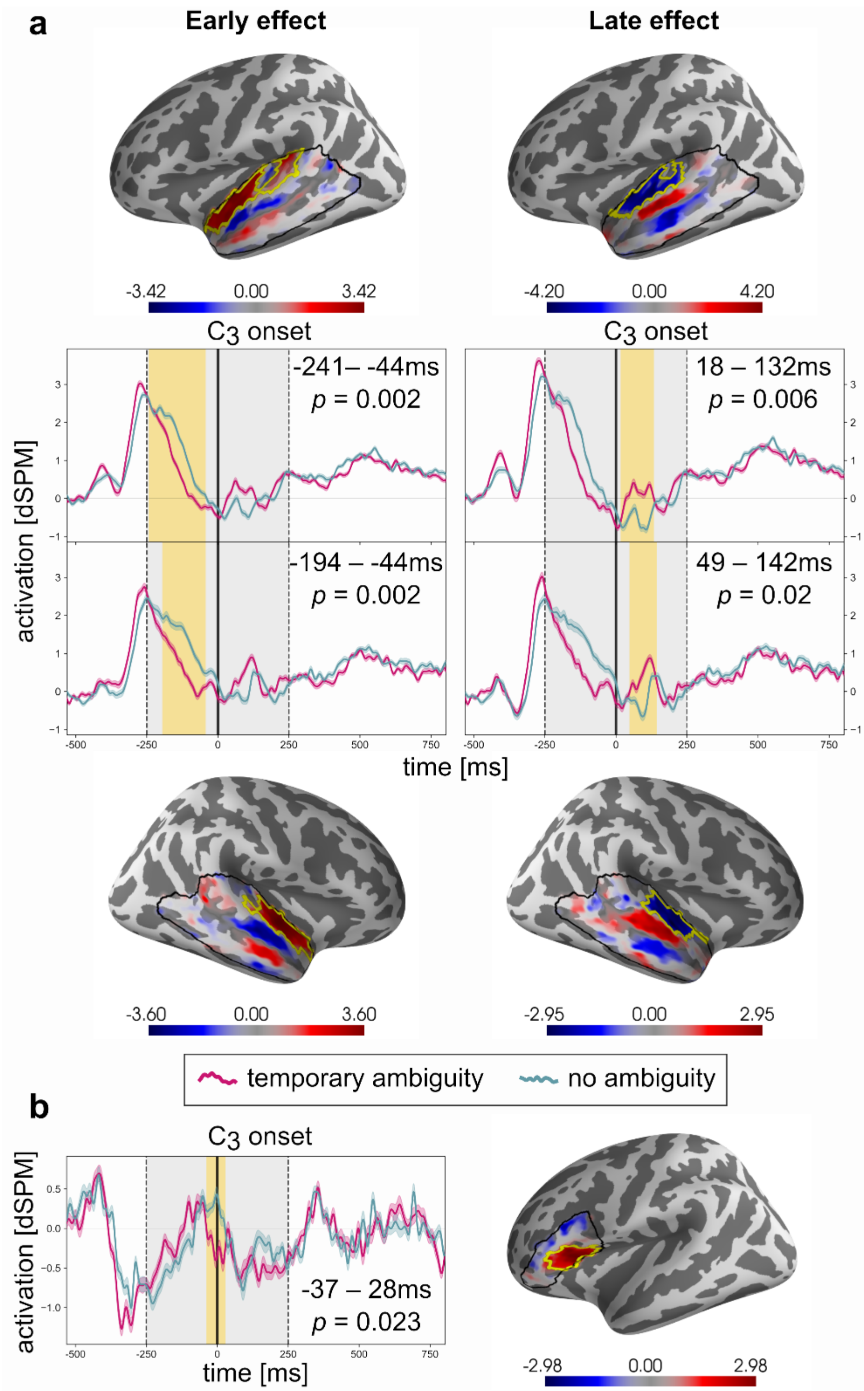


**Fig. 1**. a) Early (left) and late (right) morphological effects in bilateral temporal cortex. Top: results from left superior temporal cortex. Bottom: right superior temporal cortex.
b) Morphological effect in left inferior frontal cortex. Timecourses: evoked responses in significantly big clusters. t=0 is onset of stem uniqueness point ($C_3$). Shaded gray area

represents test window. Shaded yellow area shows temporal extent of cluster. Brains: black border delineates spatial test windows. Yellow border delineates spatial extent of cluster. Colormap shows average t-values in clusters. All p-values corrected for multiple comparisons.