Spatiotemporal signature of morphosyntactic planning in English sentence production

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Fluent sentence production relies on the precise and timely coordination of content and structure building prior to motor execution, with morphosyntactic planning playing a critical role in this process. While previous research has explored the neural mechanisms underlying morphosyntactic planning using various neuroimaging methods (e.g., fMRI, EEG/ECoG, MEG), identifying key brain regions (e.g., Broca's area, posterior temporal lobe)[12] and the neural timing before word production[3], the spatiotemporal dynamics of morphosyntactic planning within sentence production remain underexplored. This study addresses this gap by examining the locations and times of brain activity using MEG during language production, with a focus on delineating the subcomponents of sentence planning, namely lexical access, inflectional processes (which are different for nouns and verbs), and constituent assembly[4] that lead to successful utterance production.

In a novel overt picture naming paradigm, participants saw object or action pictures along with an icon (Figure 1) that was designed to elicit one of the subcomponent sentence processes: lexical access, inflectional marking (plurals for objects, tense for actions), and constituent assembly (adjective + object or pronoun + action) or an articulation control ("blah blah"). This approach allows us to decompose the different elements of sentence planning. In each trial, participants first viewed a fixation cross for 1000 ms, followed by an object or action picture for 400 ms, and then another fixation cross for 400 ms. Next, an icon was presented for 400 ms, immediately followed by an image serving as a speaking prompt, which cued participants to produce the utterance (Figure 2).

Based on data from twenty native English-speaking right-handed neurotypical adults, our results (generated from volume source space vector-valued dipole currents using Hotelling's T-Square statistics and threshold-free cluster enhancement correction for multiple comparisons)[5] revealed the following:

1) **Lexical access activates additional brain activity compared to picture viewing paired with articulation:** Compared to the control condition (producing "blah blah" regardless of the picture's content), _noun naming_ showed increased activity in the right parietal region starting from 150 ms following icon presentation, extending into bilateral activation of the inferior parietal, inferior frontal, and anterior temporal regions starting from 250 ms after the icon. _Verb naming_ showed a similar activation pattern to noun naming, however approximately 150 ms later (i.e., 300 ms after the icon), which agrees with behavioral results from noun vs verb picture naming reaction time studies[6].

2) **The neural correlates differ between lexical access and constituent assembly, as well as between verb and noun conditions.** Compared to the noun naming condition ("tree"), _noun constituent assembly_ ("a blue tree") showed increased right lateralized activation in parietal and temporal regions at 150ms, then a bilateral activation of the middle frontal region, followed by left inferior frontal and superior temporal regions at 600ms after the icon was presented. Compared to the noun naming condition ("tree"), _noun inflection_ ("trees") showed increased activity in the right inferior parietal, inferior frontal, and anterior temporal regions at 250ms, which then shifted to a left lateralized activation in inferior and middle frontal regions at 450ms after the icon was presented. Compared to the verb naming condition ("pour"), _verb tense inflection/constituent assembly_ ("he poured") showed increased left lateralized activity in the inferior parietal, middle frontal, and anterior temporal regions at 250ms, followed by similar

bilateral activation to the noun inflection condition at 450ms, however with a more prolonged response time after the icon was presented.

In sum, we observed distinct spatiotemporal signatures associated with different subcomponents of sentence production, characterized by 1) faster activation onset time in the noun naming than verb naming conditions, 2) stronger initial left lateralized activation, and prolonged activation time for the regular verb past tense condition than the noun plural condition.
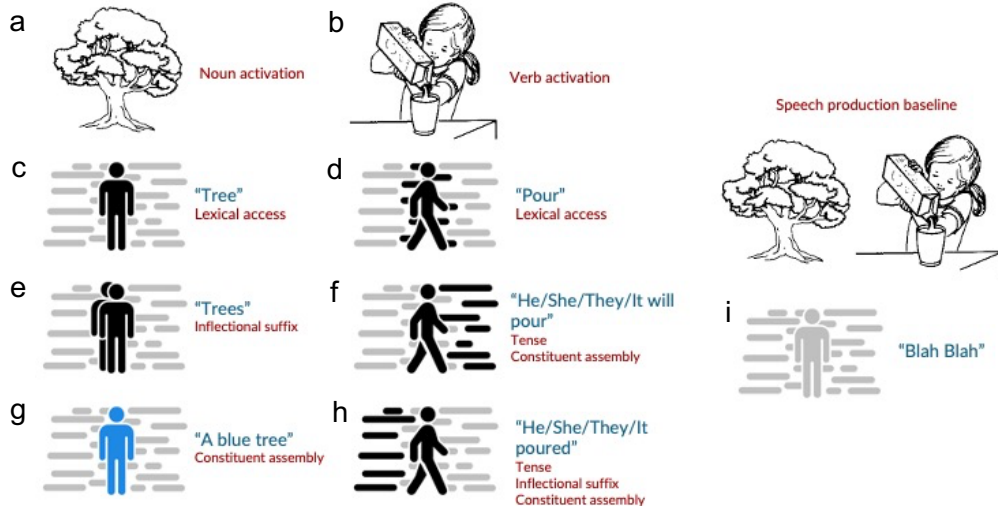

Figure 1: The different experimental conditions used in the study. a-b: example object and action pictures. c-i: icons that were designed to elicit one of the subcomponent sentence processes with the object/action pictures. Expected verbal responses are indicated in quotes and the component sentence planning process is indicated in red.
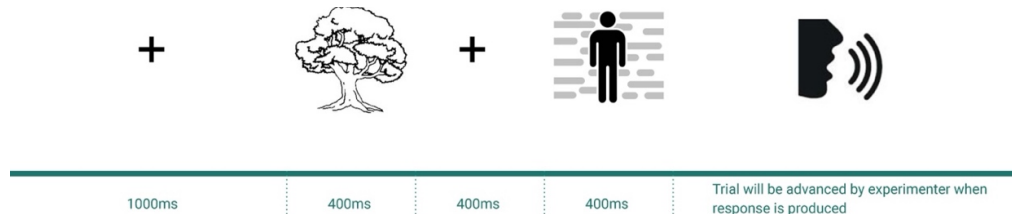

Figure 2: The timeline of an example trial.

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