Active Antecedent Search in Cataphora Processing: Insights from Neural Oscillations

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The processing of backwards anaphoric (*cataphoric*) dependencies [1] involves an *active search* for an antecedent [2,3]. Encountering the pronoun *he/she* in (1) triggers a search for a potential antecedent, which is found in the main subject *John.* Evidence for active search comes from gender-mismatch effects: the subject NP in (1) is read more slowly when it mismatches the preceding pronoun in gender. Some researchers have argued that active search is sensitive to grammatical constraints [2]: the parser does not consider subsequent NPs as potential antecedents if they are in grammatically illicit positions. For example, the parser should never consider co-reference between *He/She* and *John* in (2), because co-reference is ruled out by Principle C [4].

Initial evidence for a grammatically sensitive active search mechanism came from self-paced reading studies, which showed mismatch effects at NPs in grammatically licit positions, but not at positions ruled out by Principle C [2]. However, recent eye tracking work suggests that structural constraints are only used relatively late during processing to rule out illicit coreference [5]. For sentences like (1) and (2) above the critical interaction (mismatch effect at the potential antecedent *John* in 1 but not 2) appears only in late eye movement measures [5]. This suggests that active search may initially be insensitive to grammatical constraints, indiscriminately positing coreference relations between unbound pronouns and subsequent matching NPs, some of which must later be filtered out based on grammatical constraints. Given that the critical interaction in [5] was only marginal the debate is far from settled.

Our Study used the time-course of neural signatures, which are sensitive to qualitative aspects of processing, to address the interplay between structural (top-down) and lexical (bottom-up) information during cataphora processing. Neural oscillations in the beta frequency range (13-30 Hz) provide a signature of the maintenance (increase) or change (decrease) of the representation of the current sentence-level meaning [5] and are sensitive to grammatical gender violations [6]. Beta oscillations are therefore an excellent candidate to provide a window into the neurophysiological time-course of the kind of active search engaged during cataphora processing.

We used electroencephalography (EEG) to investigate beta oscillations while participants (N = 24) read *Cataphor* sentences like (1), which require an active search for an antecedent and *NonCataphor* sentences like (2), which do not. In addition to varying sentence type, our design also manipulated whether the pronoun (*he/she*) matched or mismatched the grammatical gender of a subsequent subject NP *John* (the target word).

Cluster-based permutation tests on the sensor-level data identified 240-880ms after the onset of the target name as our window of analysis. Time-frequency analysis of power with source reconstructed data (beamformer approach) demonstrated an interaction between sentence type (*Cataphor v. NonCataphor*) and gender match for low beta power (13-19 Hz), [$F(1,23) = 7.65$, $p = 0.011$]. See **Figure 1.** Beta power was lower in the Cataphor-mismatch condition than in the Cataphor-match condition [$t(23) = 3.21$, $p = 0.004$], but no such effect was observed in NonCataphor conditions. The pairwise effect was restricted to left frontal and temporal regions, most notably left inferior frontal gyrus, which is implicated in syntactic prediction [3]. Our results provide support for an early influence of structural constraints on active antecedent search.

(1) After **he/she** met the girl that was wearing orange pants by the store *John* jogged home.
(2) **He/She** met the girl that was wearing orange pants by the store after *John* jogged home.

References: [1] van Gompel et al., 2003; [2] Kazanina et al., 2010; [3] Matchin et al., 2017. [4] Chomsky, 1981; [5] Drummer et al., 2018; [5] Lewis et al., 2015; [6] Lewis et al., 2016

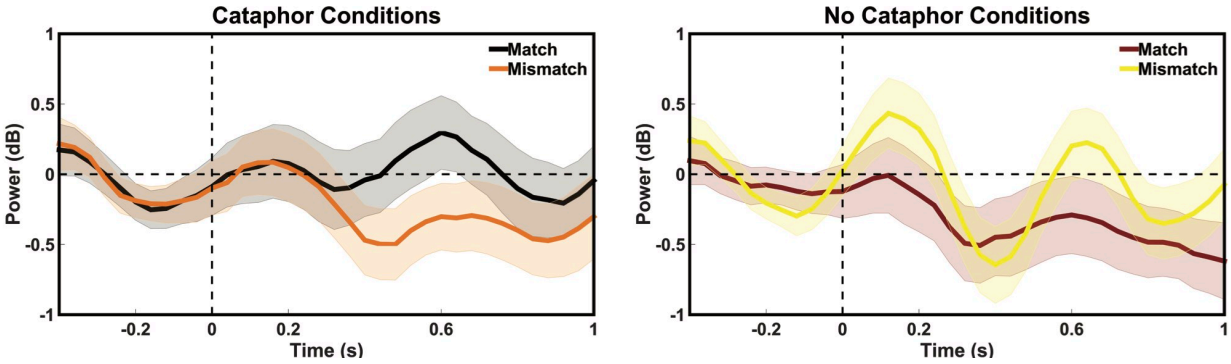

Figure 1. Average low beta power (13-19Hz) following the onset of the target name in Cataphor and NoCataphor conditions.