

Dynamics of cortical activity during interactive language use

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During conversation, humans avoid overlap and minimize silent gaps between speakers, commonly known as turn-taking. Such interactive language use requires a complex interplay of simultaneous speech perception and planning as well as precisely timed speech production to achieve this degree of temporal coordination. For example, inter-turn gap duration is typically ~200 ms, which is considerably shorter than reaction times observed in simple production tasks (e.g. picture naming)¹. While the psycholinguistic mechanisms of turn-taking have been studied previously, the neural circuitry underlying the process – especially the planning subcomponent – is largely unknown. To address this gap in understanding, we used intracranial electrocorticography to record neural activity from the brains (left dominant hemisphere) of neurosurgical patients (n=7) as they engage in unconstrained conversation as well as tasks replicating the interactive nature of turn-taking.

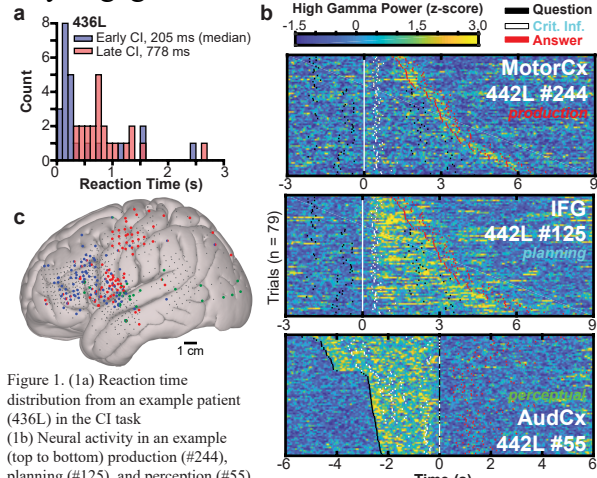


Figure 1. (1a) Reaction time distribution from an example patient (436L) in the CI task (top to bottom) production (#244), planning (#125), and perception (#55) related site during all CI task trials from one patient (442L); offset and onsets of questions, CI, and patient responses are indicated with black, white, and red ticks (1c) Canonical brain with all significant production (red), planning (blue), and perception (green) sites indicated (GLM with Bonferroni correction); mixed sites are indicated with multiple colors

lateral temporal cortex, consistent with previous studies^{4,5}. Planning sites were largely restricted to inferior frontal gyrus (IFG), middle frontal gyrus, and premotor cortex.

We next investigated whether planning sites are selectively active during language planning by instructing patients to execute motor behaviors varying in linguistic complexity. We observed that planning sites displayed little or no activity while non-speech hand and orofacial movements were prepared (Fig. 2a). Likewise, when patients were instructed to repeat words or pseudowords, only a minority of planning sites were active during the preparatory period (Fig. 2a,b). However, in trials where patients formed irregular or regular plural nouns, most planning sites displayed increased neural activity during speech preparation (Fig. 2a,c). Therefore, these results demonstrate that planning sites are selectively active for higher-level speech planning (e.g., lexical access) rather than general motor programming. We next examined the behavior of planning sites

during natural turn-taking in unconstrained conversation and found that many sites were active while patients listen to their partner's turns (Fig. 3a,b) or prior to patient turn initiation (Fig. 3c). Therefore, planning sites identified with the CI task are also active in natural conversation in a manner consistent with speech planning.

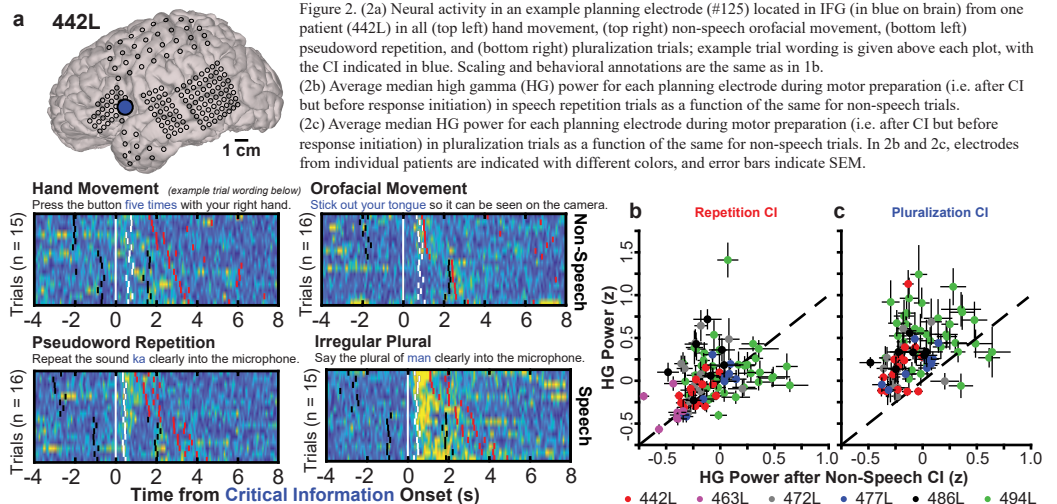


Figure 2. (2a) Neural activity in an example planning electrode (#125) located in IFG (in blue on brain) from one patient (442L) in all (top left) hand movement, (top right) non-speech orofacial movement, (bottom left) pseudoword repetition, and (bottom right) pluralization trials; example trial wording is given above each plot, with the CI indicated in blue. Scaling and behavioral annotations are the same as in 1b. (2b) Average median high gamma (HG) power for each planning electrode during motor preparation (i.e. after CI but before response initiation) in speech repetition trials as a function of the same for non-speech trials. (2c) Average median HG power for each planning electrode during motor preparation (i.e. after CI but before response initiation) in pluralization trials as a function of the same for non-speech trials. In 2b and 2c, electrodes from individual patients are indicated with different colors, and error bars indicate SEM.

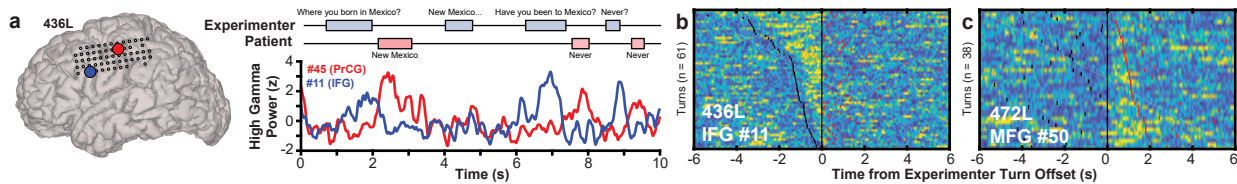


Figure 3. (3a) Neural activity in an example planning electrode (#11) located in IFG (in blue on brain) and production electrode (#45) in precentral gyrus (in red on brain) from one patient (436L) during 10 seconds of unconstrained conversation; transcription of speech is presented above neural activity traces. (3b) Neural activity from one example IFG planning electrode (#11 in patient 436L) in all turn-taking interactions during natural conversation; onset and offset of experimenter turns are indicated in black, and patient turns with red; scaling is the same as in 1b. (3c) Neural activity from one example MFG planning electrode (#50 in patient 472L) in all turn-taking interactions during natural conversation.

Lastly, to begin to causally implicate the observed putative planning site in rapid conversational turn-taking, we applied direct current stimulation (15V, 50Hz, 0.2ms duration biphasic pulses) to a single IFG planning site while a patient performed the previously described interactive tasks. We observed that disruption of neural activity at this site did not cause speech arrest or articulatory errors but resulted in significantly slower RT (418 vs 635 ms [median], $p < 0.005$, rank-sum test) and increased lexical errors (2.1% vs 19.2%). Therefore, this preliminary dataset further suggests that neural activity at planning sites is required for rapid turn-taking and proper lexical planning.

References

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