Toward a Process-Memory Account of Non-native Sentence Processing

Neuronal oscillations at different frequencies subserve parsing needs: gamma band (30+Hz) for neuro-prediction, theta band (4-7Hz) for information unification, and beta band (12-30Hz) for network dynamics (maintaining or changing the current mode of processing; Lewis et al., 2015; Lewis et al., 2016). Such activity is either evoked, likely indicating formation of a neuronal assembly focused on the stimulus, or induced, tracking interactions within and between processing regions (Bastiaansen & Hagoort, 2003). We investigate both types of activity as *wh*-expressions with distinct syntactic and semantic characteristics are predicted in real time processing at an interclausal bridge to belong to a coming embedded clause in stimuli like (1a-c).

24 native speakers (NSs) and 22 advanced L1-English non-native speakers (NNSs) of French completed an RSVP task (300ms/word, 250ms/ISI) involving NP-modifier (Mod; *le concernant* 'regarding him') and N-complement (Comp; *à propos de lui/à son sujet* 'about him') structures. Mod and Comp structures involve distinct anaphora resolution mechanisms—namely: coreference and binding, respectively (Freidin, 1986; Lebeaux, 1988; Chomsky, 1993). A first manipulation (M1) examined the (im)possibility of anaphoric valuation for Mod vs. Comp as a matrix-clause subject matches the pronoun in gender (1a, b) or not (1a′,b′) at the bridge between clauses. A second manipulation (M2) examined anaphora resolution through a semantic distinction in interpreting pronouns as free variables (coreference) with Mod (1a) or as bound variables with Comp in (1b,c) under different syntactic constraints on binding domains imposed by the morphosyntax of *son* 'gen 3p' (1c) and *lui* 'him-masc' (1b).

EEG was recorded on a 64-electrode EGI system. For ERP analysis, average amplitudes with a 50ms baseline for *dit* 'said' and *que* 'that' (Phillips et al., 2005) were compared over four regions (Fiebach et al., 2002; Fig1). For event-related spectral perturbations (ERSP), a baseline [-750, -50]ms before onset of bridge *dit que* 'said that' was averaged across trials. Baseline and bridge were convolved with a Morelet wavelet function with a width of 7 cycles. The same analysis was applied to the ERP data in the same time interval. Subtracting the ERP power from the total power yielded induced power. Cluster-based non-parametric permutation tests were performed in 1Hz steps from 4-40Hz. Contiguous frequencies with significant clusters were combined.

For ERPs, effects were robust in NSs but only marginal in NNS. For ERSPs, there were population wide effects in evoked power in M1: Greater Mod-Comp power differences in mismatch (1a′ vs b′) vs. match (1a vs b) conditions were found at *dit* 'said' in the gamma band (Fig2), suggestive of neuroprediction of an embedded-clause dependency. These differences carried into the theta rhythm as *que* 'that' confirms the prediction (Fig3), indicating unification. Population wide beta band effects obtained in M2: In evoked power, greater differences were found for the binding-domain distinction (1b vs c; Fig4) than for the free vs. bound-variable distinction (1a vs c), whereas in induced power, greater differences were found for the free vs. bound-variable distinction (1a vs c; Fig5) than for the binding-domain distinction (1b vs c). Group differences also emerged, with greater power differences for NNSs in the theta band in M1 and M2. This effect suggests effort dedicated to retaining representations as the embedded clause unfolds in NNSs. In M1, a group difference also appeared in the beta band with greater evoked power differences between Mod and Comp structures (1a+a′ vs b+b′) in NNSs at *dit* 'said' (Fig6) but greater induced power at *que* 'that' in NSs (Fig7). This signals differential management of the processing mode of the language network between NS and NNSs. Finally, M2 also revealed a beta band interaction: Greater binding domain (1b vs c) (syntactic) distinctions were found in evoked power and greater free vs. bound-variable (1a vs c) (semantic) distinctions in induced power in NSs only.

This neurocognitive oscillatory activity supports a process-memory architecture in NSs and NNSs: structures are quickly generated in prediction, retained, and integrated with incoming input while the sentence-meaning representation is determined by harmonizing information across processors. Greater structural vs interpretive distinctions in evoked vs induced power differences link evoked and induced activity to input capture and network synchronization. NNS network management may focus on input structuring at the expense of structure interpretation.

(1.) **a**/*a′*. Quelle décision le concernant est-ce que **Paul**/*Lydie* a dit que **Lydie**/*Paul* avait rejetée sans hésitation?

b/*b′*. Quelle décision à propos de lui est-ce que Paul/Lydie a dit que Lydie/Paul avait rejetée sans hésitation?

c/*c′*. Quelle décision à son sujet est-ce que **Paul**/*Lydie* a dit que **Lydie**/*Paul* avait rejetée sans hésitation?

'Which decision regarding/about him did **Paul**/*Lydie* say that **Lydie**/Paul had rejected without hesitation?'

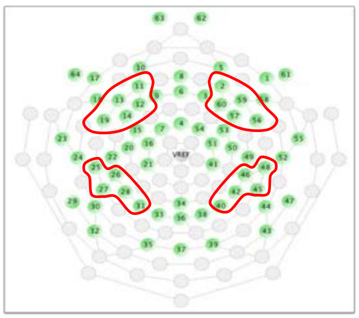

Fig1. ERP Regions of interest.

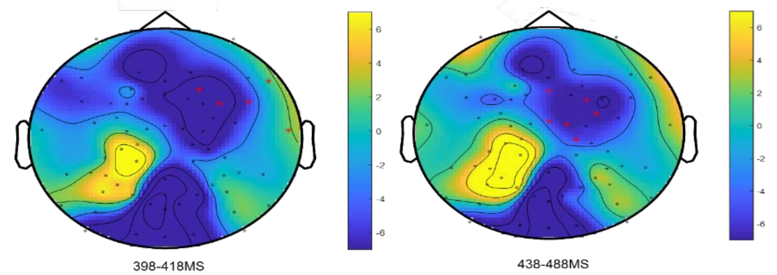

Fig2. M1: Evoked power: [1a-1b < 1a′-1b′] at *dit* 'said' at 34-40Hz, clusterstat = -525.13, *p* = .007

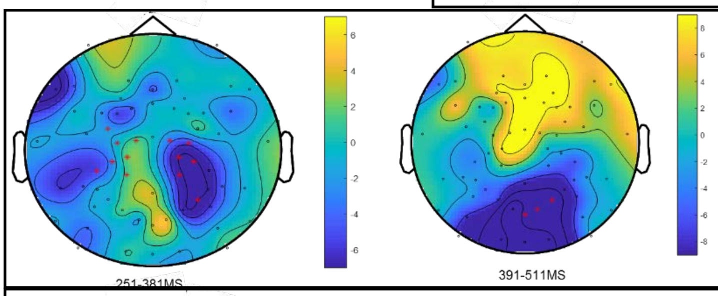

Fig3 (Left). M1: Evoked power: [1a-1b < 1a′-1b′] at *que* 'that' at 6Hz, clusterstat = -2117.2, *p* = .004

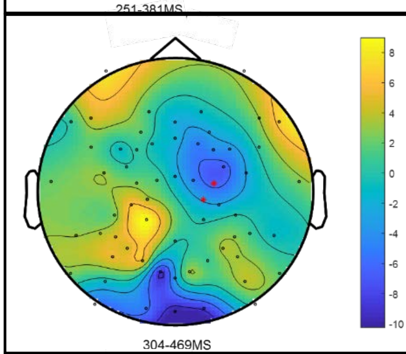

Fig4 (Left). M2: Evoked power: Binding domain effect [1b – 1c > 1a – c] at *dit* 'said' at 19-21Hz, clusterstat = -520.962, *p* = .02

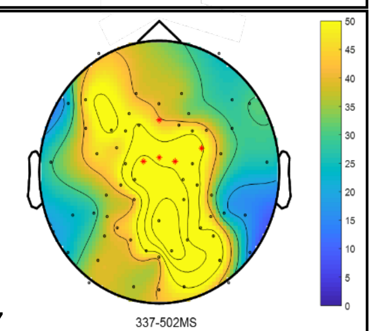

Fig5 (Right). M2: Induced power: Free vs. bound variable effect [1a – 1c > 1b – 1c] at *que* 'that' at 15-16 Hz, clusterstat = .001, *p* =.007

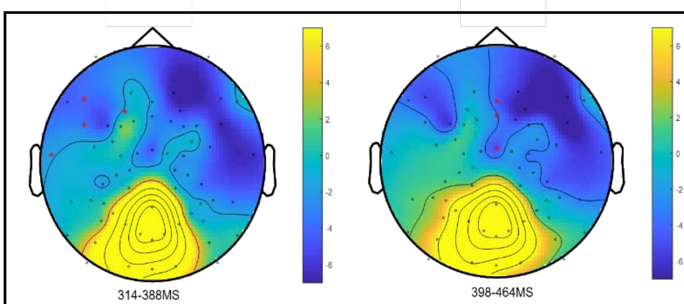

Fig6 (Above). M1: Evoked power: Group effect [NNS > NS] at *dit* 'said' at 18-20Hz, clusterstat = -916.11, *p* = .008

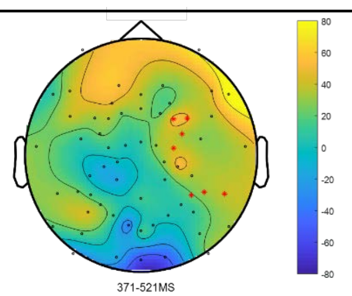

Fig7 (Above). M1: Induced power: Group effect [NS > NNS] at *que* 'that' at 15-21Hz, clusterstat = 1932.1, *p* = .002