Paying attention to agreement: rTPJ aids the encoding of agreement in Hindi

D.A. Chacón (NYU Abu Dhabi), S. Shrestha (NYU Abu Dhabi), B. Dillon (University of Massachusetts), R. Bhatt (University of Massachusetts), D. Almeida (NYU Abu Dhabi), A. Marantz (NYU, NYU Abu Dhabi)
dustin.alfonso@nyu.edu

Introduction. Agreement is a focus of study as a core syntactic dependency that facilitates identifying the arguments of a verb. However, theories differ on whether agreement is interpreted by actively encoding information pre-verbally [1], or by retrieving processes post-verbally [2]. Identifying the neural generators of agreement computations has been challenging [3–4], as they are confounded with other syntactic relations, e.g., thematic roles. Here, we exploit the Hindi split-ergative agreement system, in which verbs agree with the highest NP unmarked for case, and in which subject and object case are independently assigned by association with aspect and specificity [5]. Previous results suggest that Hindi speakers identify NPs as potential agreement controllers [6], but neural signatures of pre-verbal agreement encoding processes are unclear in Hindi [7–8]. By examining the neural response to bare objects that control agreement vs. those that do not in MEG, a neuroimaging technique with high spatial and temporal resolution, we show that rTPJ and LATL are both implicated in preverbal agreement processes.

Materials. We prepared 46 sets of 8 items, manipulating SubjCase {Erg/Bare}, ObjCase {Acc/Bare}, and Verb Cloze {High/Low}, **Table 1**. The cloze manipulation was included to identify effects of lexical access at the verb. Sentences consisted of a subject NP, an object NP, and the verbal complex. Genders of the two NPs differed and were counterbalanced.

Procedure. 11 (/ 24 planned) Hindi speakers read sentences while their brain responses were recorded by a 208 axial gradiometer MEG (Kanazawa Institute of Technology). Each phrase was displayed on a screen for 900ms with 100ms ISI. After 25% of the items, there was a picture verification task – participants responded whether a stock image matched the sentence. Stimuli and instructions were in Standard Hindi.

Results. Five lateral ROIs were selected in each hemisphere, plus one bilateral ROI, **Fig 1A**. Test statistics were computed over the average activation level (dSPM) in each time point per ROI, and in each time and source in the whole brain. We then conducted cluster permutation tests over the test statistics to identify significant clusters [9]. Test statistics were *F*-values from ANOVAs (dSPM ~ SubjCase × ObjCase in object NP time window, 0-1000ms; … × Cloze in verb time window, 1000ms–2000ms), or *t*-values resulting from one-tailed *t*-tests over the beta coefficients resulting from regressions at each time point and source per subject (dSPM ~ SubjCase × ObjCase + NP Gender + Verb Gender + List Position + *log*(Lexical Frequency) + Verb Entropy, 0–1000ms; … + Cloze, 1000–2000ms; **Fig 1B**).

ROI analyses revealed significant clusters in right temporo-parietal junction (rTPJ) in object NP time window: ObjCase × SubjCase interaction in ANOVAs (p = 0.01; 360–440ms) and a ObjCase effect in regressions (p = 0.04, 360–430ms), **Fig 2A**. Cloze results were identified in ventro-medial prefrontal cortex (vmPFC) (p = 0.01, 1480–1580ms; p = 0.01, 1630–1690ms) in ANOVAs, and left posterior temporal lobe and occipital lobe (LPTL+LOCC) in regressions (p = 0.04, 1400–1450ms; p = 0.05, 1330–1380ms), **Fig 2B**. There was an effect of Verb Gender in the pre-verbal object NP time window in left anterior temporal lobe (LATL) (p = 0.03, 580ms–630ms), **Fig 2C**. The effect of Verb Gender also localized to LATL in the whole brain regression analysis (p = 0.05; 510–920ms). This shows that rTPJ and LATL are recruited in computing agreement.

Discussion. These preliminary findings suggest that rTPJ is sensitive to case marking around 400ms after onset of the object NP, and LATL is sensitive to which gender feature the verb must carry around 600ms after object NP onset until the verb. rTPJ is implicated in the ventral attentional network and is associated with shifting attention to relevant stimuli [10–11]. We suggest that, upon accessing the lexical content of the object NP, its morphological features are activated. If the case marking requires object agreement, then rTPJ is engaged to shift attention from the features of the subject NP to those of the object NP. These features are then represented in LATL, a "conceptual hub" implicated in linguistic composition [12].

	Subject	Object	{High Cl. V / Low Cl. V}
Bare, Bare	लड़का *boy*	एक किताब *a book*	{पढ़ता था *read* / फाड़ता था *tore*}
Erg, Bare	लड़के ने *boy-Erg*	एक किताब *a book*	{पढ़ी थी *read* / फाड़ी थी *tore*}
Bare, Acc	लड़का *boy*	एक किताब को *a book-Acc*	{पढ़ता था *read* / फाड़ता था *tore*}
Erg, Acc	लड़के ने *boy-Erg*	एक किताब को *a book-Acc*	{पढ़ा था *read* / फाड़ा था *tore*}

Table 1. *Sample stimuli. Agreeing NP highlighted*

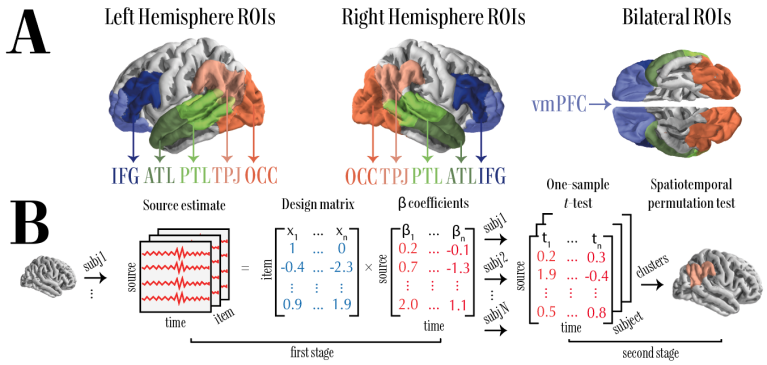

Fig 1. *(A) ROIs of interest. (B) Workflow for single-trial regression analysis.*

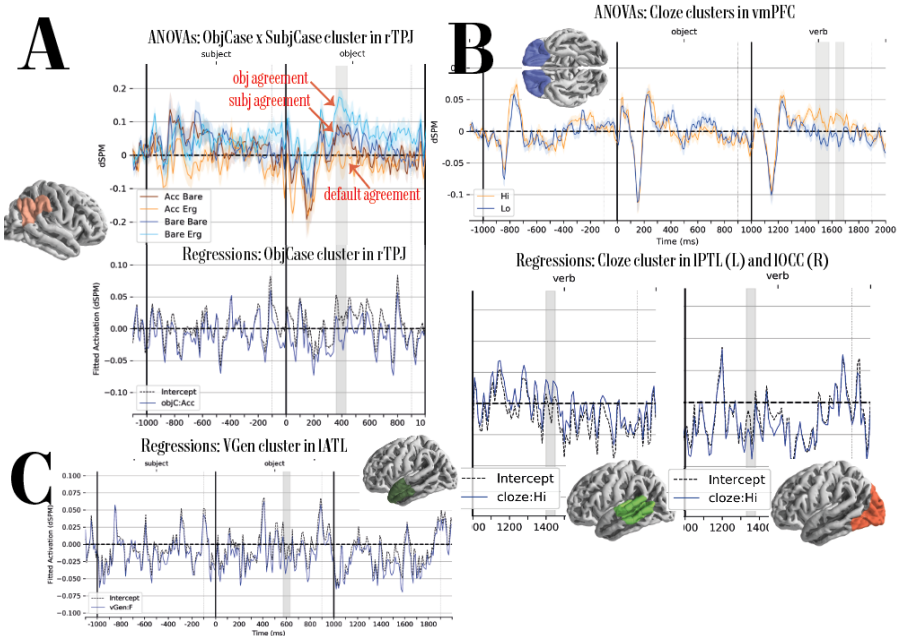

Fig 2. *Results for ROI analyses.*

Refs. [1] Eberhard, K., Cutting, J.C., Bock, K. (2005). *Psych Rev* 112(3) [2] Wagers, MW., Lau, E., Phillips, C. (2009). *JML* 61(2) [3] Carreiras, M., Carr, L., Barber, H.A., Hernández, A.E. (2009). *NeuroImage* 49(2) [4] Carreiras, M., Quiñones, I., Mancini, S., Hernández-Cabrera, J.A., Barber, H. (2015). *NeuroImage* 120. [5] Bhatt, R. (2005). *NLLT* 23. [6] Bhatia, S. (2019). Ph.D. Thesis. [7] Choudhary, K.K. (2011). Ph.D. Thesis. [8] Choudhary, K.K., Schlesewsky, M., Roehm, D., Bornkessel-Schlesewsky, I. (2009). *Neuropsychologia* 47(13). [9] Maris, E., Oostenveld, R. (2007). *J Neurosci Methods* 164(1). [10] Corbetta, M., Shulman, G.L. (2002). *Nat. Rev. Neurosci* 3. [11] Corbetta, M., Patel, G., Schulman, G.L. (2008). *Neuron* 58. [12] Pylkkänen, L. 2019. *Science*