Not moving, fast: An HD-EEG parallel reading study on Urdu and Mandarin Chinese *wh-in-situ*

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Introduction. A major question in the cognitive neuroscience of language is where and how the brain represents syntactic structure [1]. Linguistic theory posits that *wh-in-situ* constructions and *wh*-movement constructions share many abstract properties, despite their superficial differences [2–3], and both may engage similar working memory retrieval mechanisms [4–6]. Here, we present preliminary EEG data collected in two *wh-in-situ* languages, Urdu and Mandarin Chinese (MC). In contrast to previous studies, short sentences were presented in parallel, centered in the fovea and read in one fixation, which partially mitigates the working memory demands of word-by-word processing. Some grammatical features are distinguished by EEG/MEG responses in this parallel presentation style, usually ~300ms [7–10]. Our preliminary results show that brain activity distinguishes *wh*- vs. NP-object constructions ~300ms in MC and ~500ms in Urdu. This shows that processing *wh*-in-situ phenomena engages different operations and representations than their NP controls in the first ~500ms of processing parallel sentences, even without overt displacement. Furthermore, exploratory source reconstruction suggests that *wh-in-situ* phenomena may localize to left inferior frontal cortex (LIFC) in Urdu. This supports the hypothesis that LIFC represents *wh*-constructions, abstracting away from the memory operations needed to process them word-by-word with overt displacement [11].

Methods. Participants (*N* = 24 Mandarin; *N* = 8 Urdu – 35 of each planned by conference) were given a sentence-matching task, where they saw a quickly presented target sentence followed by a test sentence [8–10]. They determined if the sentences matched via a key press, **Fig 1A**. Target sentences were shown for 200ms followed by 600ms of blank screen; presentation rate was continuously adjusted based on performance. On 50% of trials, the sentences matched. Feedback was provided for incorrect responses. Stimuli were 64 sets of questions, manipulating Subject Type (Wh, NP) and Object Type (Wh, NP), **Fig 1B**. Stimuli were presented in pseudorandom order, within-subjects. Brain activity was continuously recorded with a 64-channel EEG.

Results. [Behavioral]**.** No significant effects for accuracy by condition were observed in either Urdu or MC. Accuracy in Urdu was reduced for mismatch trials for verbs compared to objects, mirroring previous word position effects observed in English [8, 9] (**Fig1E**).

[EEG Sensor Data]. Analyses were conducted independently for Urdu and MC. Spatio-temporal cluster-based permutation tests [12] were conducted with ANOVA Subject Type × Object Type, from 200–800ms post-sentence onset, with $p < 0.1$, 10ms and 5 sensor minimum clustering parameters. In both languages, a cluster of Object Type was identified, showing more positive EEG activity for Wh Objects compared to NP Objects (Urdu: left parietal sensors, from 359–693ms, $p = 0.043$; MC: central parietal sensors, from 181-301ms, $p = 0.0097$), **Fig 1C**. No other clusters were found.

[Source Estimates]. EEG data was coregistered with fsaverage template brain, warped to fit participants' head shapes. Ico-4 source spaces were built and normalized to fsaverage. Forward solution and inverse solution computed with sLORETA to estimate source activity [13]. Responses were averaged left inferior frontal cortex (LIFC) (Brodmann's Area 44, 45, 46, 47). No significant clusters were identified in ROI; however, we observe a sustained response for NP Subject, Wh Object conditions in Urdu, but not MC **Fig1D**.

Conclusion. The neural bases of *wh*-constructions have been sought after as a link between linguistic theory and brain structure. The cognitive mechanisms used to compute *wh*-constructions unfolding in time confound attempts at identifying the brain's amodal representations. In rapid parallel visual presentation, left prefrontal cortices may aid in representing *wh*-constructions, abstracting away from working memory demands present in word-by-word language processing.

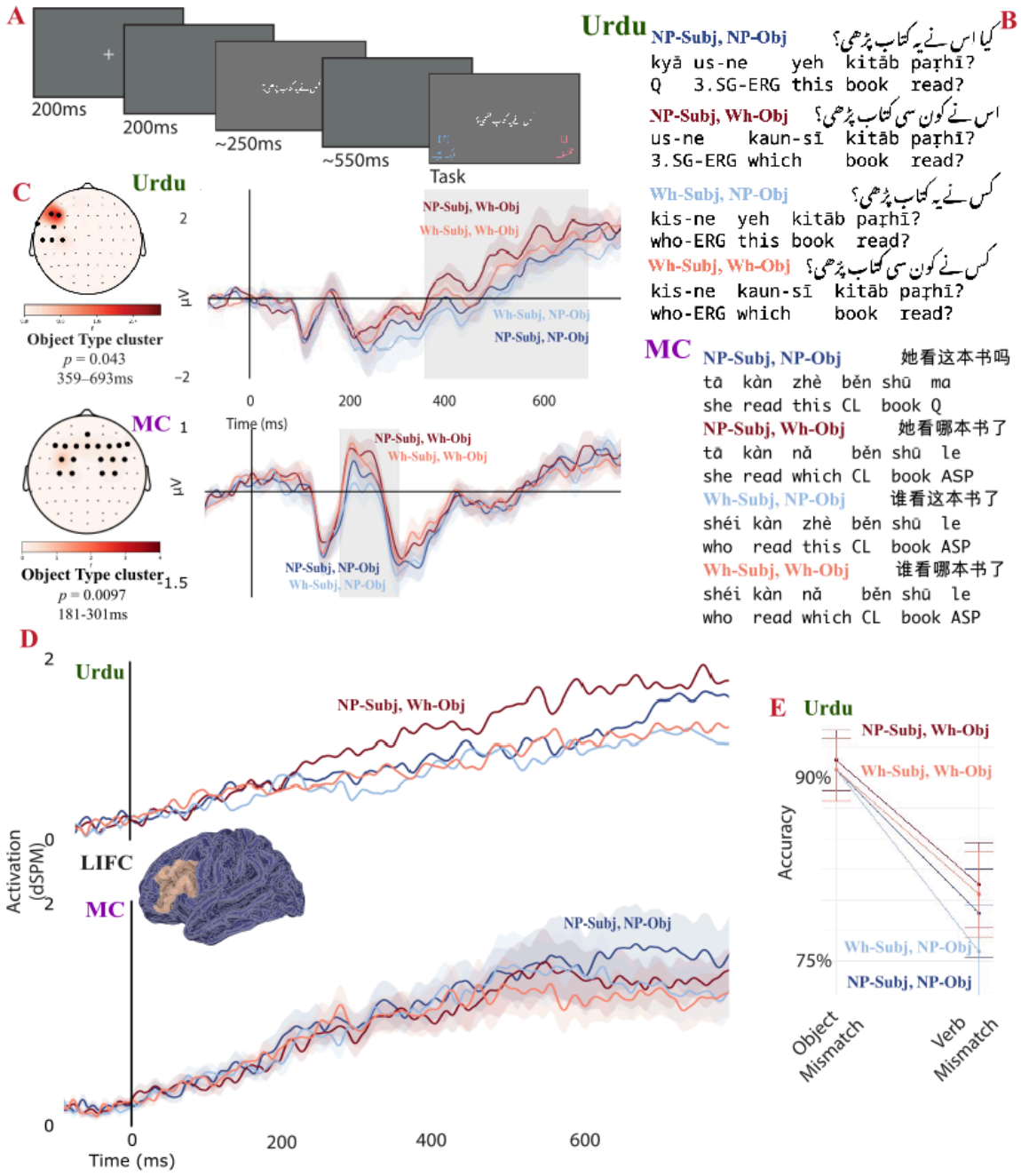

Fig 1. A) Trial structure in Urdu (MC not shown) B) Sample stimuli C) Sensor space results D) Source space results E) Urdu behavioral results

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