Agreement is more than the sum of its parts: 'At-a-glance' reading in Urdu with EEG

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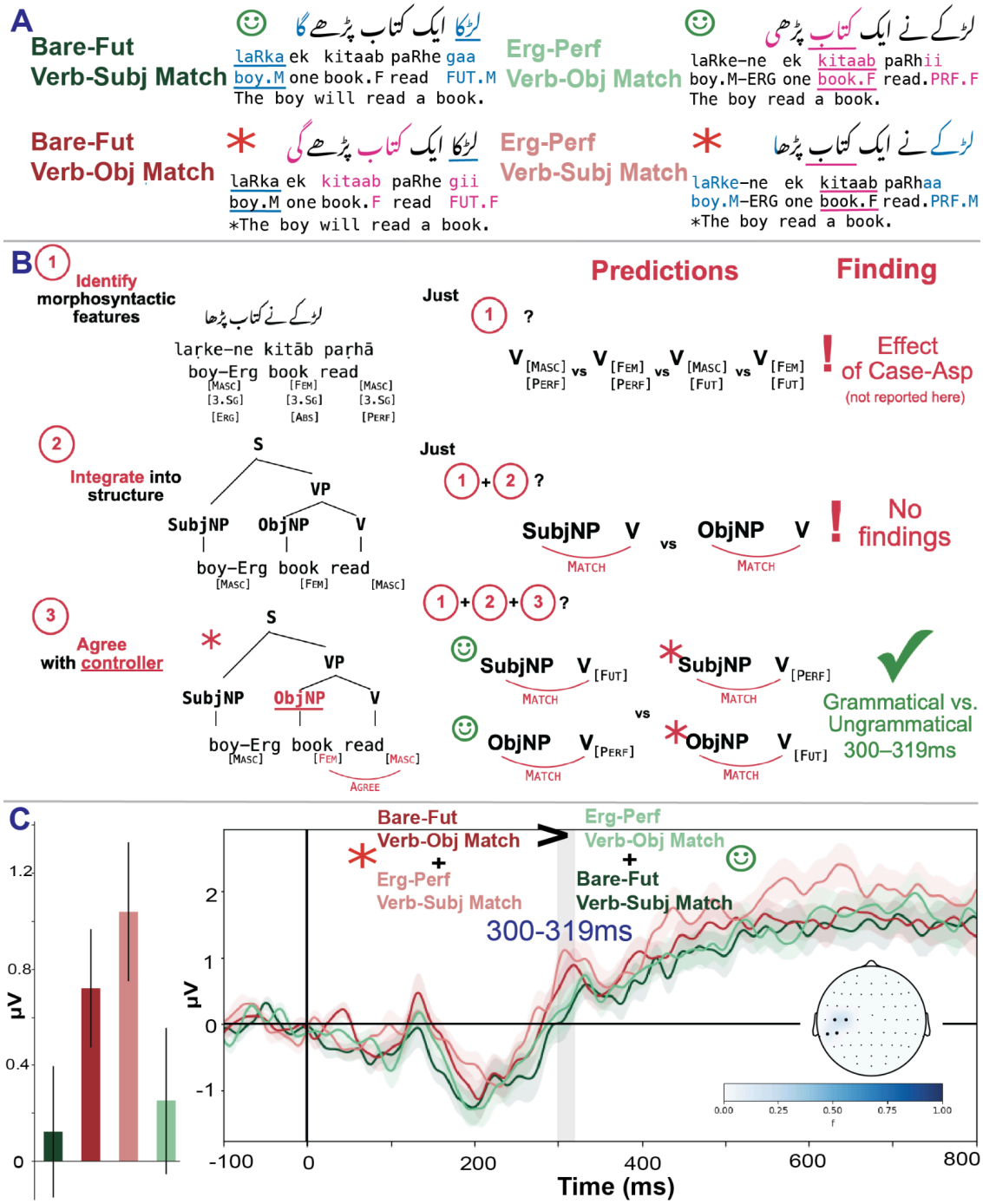
[INTRO] Significant progress has been made in understanding language comprehension 'word-by-word', but what happens when quickly glancing at a text message or scrolling through social media? Behavioral [1] and neural [2–5] measures demonstrate that short sentences can be processed within 200-300ms presentation time. However, in English, agreement errors appear to be undetected in neural measures [3,5]. This suggests that 'at-a-glance' reading may yield less detailed analyses than observed in word-by-word comprehension. However, English subject-verb agreement is not visually salient (*–s* vs. -Ø), and is generally 'fallible' [6]. Here, we present a rapid parallel visual presentation study using electroencephalography (EEG) in Urdu. In Urdu(/Hindi), verbs can agree with the subject NP, object NP, or neither. The verb must agree with the argument NP unmarked for case ('bare') that is structurally highest. Subject NPs are assigned ergative case inflection with perfective aspect verbs, but bare in other tense/aspects; object NPs are assigned accusative case or bare depending on specificity. Therefore, across sentence types, argument-verb agreement is orthogonal to the morphosyntactic features of any specific argument. Processing argument-verb agreement in Urdu requires (1) identifying morphosyntactic properties of each argument NP and verb, (2) integrating them into a syntactic parse, and (3) identifying which NP is the agreement controller and evaluating the verb's inflectional features against it [7-9], ***Fig B***. Our research question is: **do Urdu readers detect argument-verb agreement violations in sentences presented in parallel for ~200ms?** We find that EEG responses for grammatical vs. ungrammatical agreement structures diverge ~300ms post-sentence onset. This demonstrates that 'at-a-glance' readers can detect and evaluate a detailed parse of a sentence ~300ms.

[METHODS] Urdu (N = 28) speakers performed a sentence matching task, where a target sentence was quickly flashed on the screen, followed by a test sentence. Responses were recorded via key press. Target sentences were presented for ~200ms (800ms ISI). Stimuli were 48 sets of 4-word subject-object-verb (SOV) sentences. We manipulated **SUBJ(ECT) CASE-ASPECT** (BARE-FUT(URE); ERG-PERF(ECTIVE)) and whether the verb matched inflectional features with the subject or object NP (**VERB-MATCH**: VERB-SUBJ(ECT); VERB-OBJ(ECT)). The future requires a bare subject, and the perfective requires an ergative subject. Thus, BARE-FUT/VERB-SUBJ and ERG-PERF; VERB-OBJ are grammatical configurations, ***Fig A***. Stimuli were presented pseudorandomly within-subjects while a 64-channel EEG recorded brain activity.

[RESULTS] **Behavioral:** Mixed effects models did not identify significant differences in reaction time or accuracy (ps > 0.10). **EEG**: Data were analyzed with spatio-temporal cluster based permutation tests [10] with 2 × 2 ANOVAs **SUBJCASE-ASP** × **VERB-MATCH**, 150-500ms post-sentence. An interaction cluster was observed, showing greater negative amplitude for the two grammatical conditions vs. the two ungrammatical conditions (300-319ms; p=0.04), ***Fig C***. A cluster of **SUBJCASE-ASP** was also observed (301–362ms; $p < 0.01$), not shown here.

[CONCLUSION] Urdu readers ***are*** sensitive to argument-verb gender agreement violations in 'at-a-glance' reading in EEG measures. Thus, the parser is capable of quickly identifying morphosyntactic properties of arguments and verbs, integrating them into a hierarchical parse, and evaluating their grammaticality with ~200ms of exposure. Failure to identify subject-verb number agreement in neural measures in English may be due to the relative difference in visual

saliency of the orthographic representation of agreement morphology (*-s*/*-Ø* vs. Nasta`līq *-ī*/*-ā*), or different statuses of number and gender agreement in the brain's language system [11].



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