It’s about time!: Relating structure, the brain, and comparative syntax

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ABSTRACT

Studying language in the brain is hard. We’ve identified a left-lateralized ‘language network’ that supports language comprehension across languages, individuals, and ages. However, it's proven difficult to relate the parts of this language network to specific representations or computations. Why is it so hard to get better insight into the functions of the pieces of the language network? One reason is that careful, cross-linguistic comparison across languages is still in its infancy in neurolinguistics. Another reason is that our theories of language comprehension are largely informed by results from serial, slow, word-by-word reading tasks. To understand how the brain processes and represents grammatical knowledge, we need to carefully vary and contrast languages and modalities – our theories of language should not be over-fit to one language or one kind of task. Here, I show how different reading paradigms in Bengali (Bangla), Hindi/Urdu, Nepali, and English can refine our understanding of the brain bases of language.

1 Introduction

The theme of this year’*(f)ASAL* conference is locality. ‘Locality’ in linguistic theory usually refers to the domain of application of grammatical principles, e.g., the relations between an anaphor and its antecedent. One reason why locality is of interest is that languages differ in how locality operates – English anaphors cannot be bound in possessor positions (**Ram read himself’s book*), whereas the Hindi/Urdu[1] anaphor *apnā* can, for instance (Cohen 1973). Factoring out the universals and perspicuously describing the remaining variation is a key goal of linguistic theory. In psycholinguistic research, more attention has been paid to the how long the cognitive processes needed to comprehend and produce language take, and how the grammatical principles identified in linguistic research might (or might not) be implemented (e.g., Apurva & Husain 2021 on Hindi verb prediction; Chacón et al. 2016 on Bangla scrambling). Because of this, studies on locality and variation are also important for characterizing the relationship of grammatical structure and the mind and brain.

Of course, ‘locality’ most literally refers to the position in space. From the perspective of where in the brain language-related computations and representations reside, what can we learn by comparing and contrasting different languages? At larger grain-sizes, activity in the ‘language network’ – a set of regions in the left temporal and frontal lobes – appear to be uniform across individuals and language groups, even across typologically and historically unrelated languages (Lipkin et al. 2022; Malik-Moraleda et al. 2022). But, what can we say about the differences between languages? Does the uniform language network

[1] I follow standard practice in using ‘Hindi/Urdu’ when making generalizations that apply to both standardized languages, and ‘Hindi’ and ‘Urdu’ in the context of specific experiments where one orthography/standard must be adhered to.

‘do’ things differently in the brains of users of different languages? At some level of abstraction, the answer to this question must be ‘yes’, but how? To date, explicit cross-linguistic comparisons have contributed prominently to understanding the neural responses to unexpected vs. expected words in sentence processing (Bornkessel-Schlesewsky et al. 2011, 2019; see also Gulati et al. 2024). Despite this, we are still in the early days of parceling which aspects of brain activity correspond to shared universal features and which correspond to the kinds of variation observed in language descriptions.

This lag can be attributed to a few reasons. The first reason is methodological. It is difficult to know in advance which languages or phenomena to investigate without careful language descriptions. We need linguists and psycholinguists to tell us what languages look like and how they are processed before we can ask about their neural bases. The second reason is practical. The equipment needed for experimental research historically has been expensive and difficult to use and maintain, and therefore not always accessible to scientists or participant populations who speak these languages. The relative time and money to establish a data point in the cognitive neuroscience of language is much greater than traditional methods used in theoretical linguistics and language description, which further contributes to the lag between theoretical and experimental work in syntax. This also results in biases towards languages that are spoken in wealthy and industrialized countries (Anand et al. 2011; Collart 2024), which affects both the data that we can collect and the questions that are considered important. The third reason is conceptual. What is the relationship between the results of cognitive neuroscience experiments and our theoretical primitives? Cognitive neuroscience experiments usually require participants to perform a language processing task, and the results are typically a difference in recorded brain activity in time and space. By contrast, the constructs of our representational theories (Agree, *v*P, [CORONAL]) are amodal, time-independent, abstract. Cognitive neuroscience experiments usually require some kind of language processing task, and so recorded brain responses index the cognitive processes deployed moment-by-moment (prediction, cue-based retrieval, reanalysis), indirectly reflecting the representations that linguists traditionally are interested in. More generally, the expectations that we have for an explanatory theory in cognitive neuroscience are evolving (Poeppel 2012, Embick & Poeppel 2015), especially as our techniques and understanding of the brain become more sophisticated over time.

Here, I hope to make a humble contribution. I will not draw any strong conclusions about any particular brain area or function in this paper, targeted towards an audience with specialization in South Asian languages and theoretical linguistics. Instead, I hope to show that cross-language comparisons *per se*, drawing specifically from South Asian languages, are valuable for understanding the brain bases of language. This point is probably uncontroversial, but in practice it is not obvious how to (systematically) compare and contrast languages. I also hope to demonstrate that rethinking standard methodological assumptions in language processing research – that sentences are necessarily comprehended ‘word-by-word’ (Snell & Grainger 2017; Wen et al. 2019; Flower & Pylkkänen 2024) – can introduce a new perspective on connecting the brain and language description by manipulating the relation between abstract grammatical structure and temporally-bound psycholinguistic processes. Overall, my argument is that our theories of language in the brain should not be over-fit to any particular language, modality, or task and that a theory of *language* in the brain must allow for a theory of *languages* in the brain.

2 Morphosyntactic Processing in Bengali in the Temporal and Orbitofrontal Lobes

Before jumping into more complex syntactic phenomena, let us start with something (deceptively) simpler – words. Here, I hope to demonstrate that careful cross-language comparisons of a well-understood brain response can clarify which aspects are universal and which aspects may reflect specific properties of individual languages. In short, recent work on the processing of morphologically complex words in Bengali (Bangla) demonstrates a right-lateralized brain response that largely mirrors a left-lateralized response that otherwise appeared universal (Moitra et al. 2024). This demonstrates that some aspects of the cortical organization and time course of these processes are largely uniform, but which hemisphere supports these computations can vary.

Early brain responses to words show distinct patterns of activation near the relevant sensory cortex, i.e., auditory word recognition shows early patterns of activity near auditory cortex and visual word recognition shows early patterns of activation near visual cortex (Marinkovic et al. 2003). These earlier brain responses to visual stimuli have been of great interest for understanding 'morphological decomposition', or identifying the constituent morphemes of a word, e.g., *kicked* consists of the stem *kick* and the suffix *-ed*. In reading, morphemes are identified on their orthographic form (Taft & Forster 1975; Rastle & Davis 2008 for review). In magnetoencephalography (MEG) recordings, morphologically complex words (*refill*) exhibit different activity than orthographically-similar, monomorphemic controls (*reckon*) ~170ms post-word onset (the M170). This M170 response localizes to the left fusiform gyrus, known as the 'visual word form area' (VWFA), an area showing specialization to written words (Cohen et al. 2000; Tarkiainen et al. 1999; Gwilliams et al. 2016). The amplitude of the M170 response correlates with stem-to-whole word transition probability, i.e., the ratio of the frequency of the whole word (*refill*) and the frequency of the stem in all its uses (*fill*), further demonstrating early morphological decomposition on the basis of the word form (Solomyak & Marantz 2010; Lewis et al. 2011; Wray et al. 2022).

Subsequent to morphological decomposition, there are (at least) three separate identifiable brain responses (Schreuder & Baayen 1995). The first stage is lexeme look-up, in which the properties of the constituent morphemes are accessed (what lexical item does <*fill*> correspond to?). MEG evidence from Greek (Neophytou et al. 2018) and English (Stockall et al. 2019) show that stem frequency correlates with activity in left temporal lobe in grammatical words ~200–300ms post-word onset, consistent with this stage[2]. The two other stages are category licensing, in which the syntactic category of the morphemes are identified (e.g., *fill* is a verb), and composition, in which the interpretation of the entire structure (*refill* means 'to fill something up a second time'). These stages can be identified by exploiting grammatical affixes with category and semantic selectional restrictions to generate non-words, and comparing which neural response shows sensitivity to which selectional violation. For instance, *re-* requires a verb stem (category restriction) that has a

[2] This neural response likely correlates with the N400/M350 (see Lau et al. 2008).

patient/internal argument (semantic restriction). Thus, **rehat* and **relaugh* are category and semantic violations respectively. MEG evidence shows greater activity for word-internal category violations (**rehat*) ~200–300ms post-word onset in left posterior temporal lobe, a candidate brain area for syntactic information (Matar & Marantz 2021; Matchin & Hickok 2022). This is then followed by greater activity ~300–400ms post word-onset for word-internal semantic violations (**relaugh*) in orbitofrontal cortex, an area often implicated in semantic violations (Brenan & Pylkkänen 2008; Pylkkänen et al. 2009a, Pylkkänen et al. 2009b). These results provide strong empirical support for psycholinguistic models that involve these distinct computations following morphological decomposition (Schreuder & Baayen 1995, Gwilliams & Stockall 2022), and align with the posterior-to-anterior flow of information from occipito-temporal to anterior brain areas (Marinkovic et al. 2003). This is summarized in Figure 1.

This model depends on fast mapping between visual orthographic features and abstract morphological structure. But, orthography and morphology vary dramatically across languages. Does this model hold up when investigating languages that use abugidas or abjads instead of alphabets, or morphological operations like infixation (as seen in Tagalog) or root-and-pattern morphology (as seen in Arabic)? Linnaea Stockall's group has sought to 'stress test' this model of (ortho)morphographic processing by contrasting Bengali, Arabic, Tagalog, Serbian, and Slovenian (Stockall 2021; see Wray et al. 2022; Cayado et al. 2024; Moitra et al. 2024a for Tagalog and Bengali findings).

For Bengali, the study needed to have a different design. Unlike English and Greek, Northern Indo-Aryan languages do not feature productive derivational verbal morphology like *re-* with clearly identifiable syntactic/semantic selectional criteria. Instead, Moitra et al. (2024b) extended the basic design to noun morphology. In a corpus study, we observed that the nominal prefixes *prôti-* and *duḥ-* overwhelmingly attach to independent nominal stems (category restriction) that describe processes, events, or otherwise abstract or non-concrete referents (semantic restriction). The prefix *prôti-* typically describes a reversal or mutual action (*hiṃsa* 'violence', *prôti-hiṃsa* 'revenge'; compare English ***counter**-argument*), and *duḥ-* imparts negative affect towards its stem's referent (*ghôṭôna* 'event', *dur-ghôṭôna* 'accident'; compare English ***mis**-fortune*). Thus, we constructed non-words by attaching these prefixes to adjectival stems to generate category violations (**prôti-lômba* PRÔTI-long; **dus-kalo* DUḤ-black), and to concrete noun stems to generate semantic violations (**prôti-rôktô* PRÔTI-blood; **dus-nak* DUḤ-nose).

The Bengali MEG data revealed a familiar pattern as to prior studies. We found the expected M170 response, ~170ms post-word onset, followed by greater activity for the category violations ~200–300ms and greater activity for semantic violations ~300–400ms, corresponding to category licensing and composition respectively. However, the M170 response localized to the right fusiform gyrus instead of the left fusiform gyrus, and the greater activity for category violations localized to posterior portions of the right middle temporal lobe instead of the left posterior temporal lobe. Thus, the pattern observed in the left hemisphere in English and Greek resurfaced in the right hemisphere in Bengali. Finally, in a *post-hoc* exploratory analysis, we found that the greater activity elicited by semantic violations in orbitofrontal cortex likely began earlier than we expected, also in the ~200–300ms time window. These results are summarized in Figure 1.

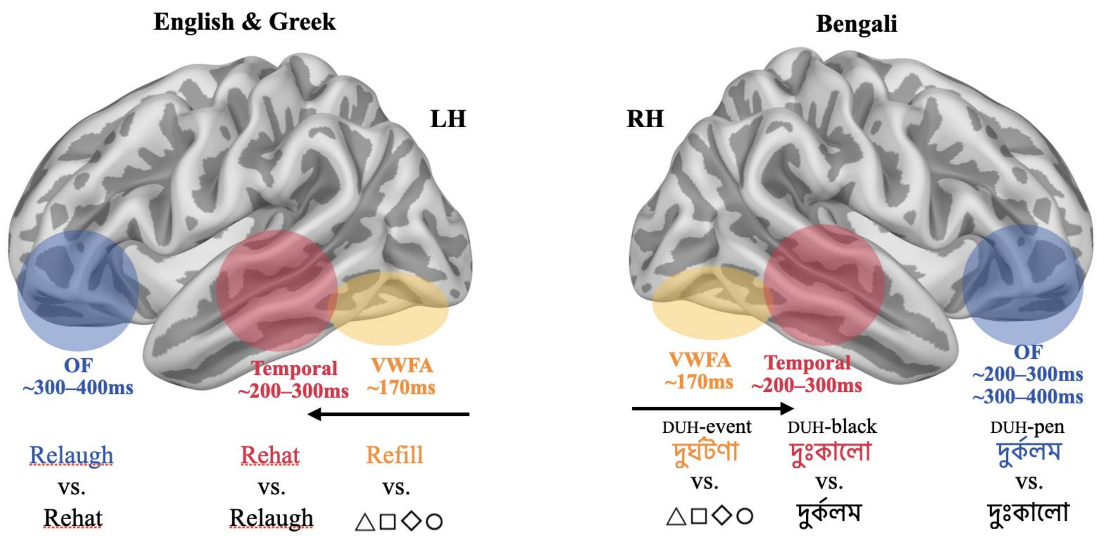

Figure 1. (Left) Schematic of English and Greek results (Neophytou et al. 2018; Stockall et al. 2019). (Right) Schematic of Bengali results (Moitra et al. 2024). Identification of word form begins at 170ms in visual word form area (VWFA), followed by greater activity for category violations in temporal lobe (200–300ms) and semantic violations in orbitofrontal cortex (OF). English and Greek results are plotted on the left hemisphere; Bengali results on the right. Bengali OF activity surfaces at 200–300ms and 300–400ms.

What conclusions can we draw from this? We did not conduct this study testing the hypothesis that these processes would localize in the right hemisphere in Bengali. Although the left hemisphere has largely been the focus of language research, activation in the right temporal lobe is language processing tasks is not unusual (e.g., Kircher et al. 2001, Stowe et al. 2005), including some studies on morphosyntax (Zweig & Pylkkänen 2009). But, this finding raises the question of why previous studies on morphological processing found left temporal activity, whereas ours found right temporal activity. Is this a feature of the denominal morphemes selected in our study, the writing system, or something else that we didn't anticipate? In Moitra et al. (2024a), we found that word length effects in Bengali modulated activity ~130ms in the VWFA in the left hemisphere, so it seems unlikely that Bengali readers' visual word recognition processes are wholly right lateralized. Secondly, our exploratory results suggest a concurrent activation of the category licensing stage with the semantic composition stage, given the patterns of activity identified in right temporal cortex and orbitofrontal cortex ~200–300ms – another surprise. If this coincident right temporal and orbitofrontal cortex activity replicates in other cases, then this places constraints on the architecture of the theory. It cannot be the case that category licensing necessarily *precedes* semantic composition. We now need to explain why some semantic violation responses occur around the same time as category violation responses, and others are delayed[3]. At this point, no strong inferences can be made about the nature of the hemisphere localization in Bengali vs. English and Greek, nor the different time-courses. However, we can now formulate newer hypotheses that can further refine our understanding of earlier stages of lexical access in the brain.

3 Case/Agreement Hindi/Urdu and Nepali in Left Temporoparietal Juncture

The Bengali morphosyntactic processing data demonstrated the necessity of testing (putatively) universal models in new languages. Similarly, investigations into new languages may reveal questions that are otherwise unaskable in more well-studied languages like English. Moreover, comparisons between similar languages can suggest new hypotheses for the functions of brain regions that may not be obvious otherwise (Chacón et al. 2024a; Khokhar et al. 2024). In this section, I review three experiments on the interaction of split-ergativity and agreement in Hindi/Urdu and Nepali. In two MEG studies contrasting Hindi/Urdu and Nepali, I show that the left temporoparietal junction (LTPJ)[4] may support the processes deployed in processing argument-verb agreement in Hindi/Urdu. More tendentiously, I suggest that this brain area may be activated in these studies because it plays a key role in the (amodal) *representation* of aspect or agreement, not because of the temporal dynamics and memory operations of language processing. This is because we see a similar response in the LTPJ in word-by-word reading tasks, in which participants must process the sentence slowly and incrementally, and in parallel reading tasks, in which participants see the sentence 'at-a-glance', which may favor parallel reading vs. serial word-by-word reading (see Wen et al. 2019, Dunagan et al. 2024; Flower & Pylkkänen 2024).

The necessity of examining familiar processing questions in new languages was recently demonstrated by Bhatia & Dillon (2022) in their investigations into the processing of argument-verb agreement in Hindi. The processing of argument-verb agreement has been a useful window into the kinds of processes that support language comprehension generally. This is usually done by examining cases like (1), which exhibit the 'agreement attraction' phenomenon. Comprehenders rarely notice the ungrammatical plural verb *are*, which should agree with the singular verb *key*, due to interference of the plural NP *cabinets*. This faultiness of agreement has been leveraged as a window into how long-distance dependencies are formed and represented in the mind generally (Eberhard et al. 2005; Wagers et al. 2009; Chacón 2022).

(1) [$_{\text{NP}}$ The key$_{\text{[SG]}}$ [$_{\text{PP}}$ to the cabinets$_{\text{[PL]}}$]] { is$_{\text{[SG]}}$ / *are$_{\text{[PL]}}$ } on the table

Bhatia & Dillon (2022) explore agreement attraction phenomena in Hindi/Urdu, a language

[3] One possibility may be that concrete vs. abstract concepts in general are distinguished earlier in lexical access, potentially during the lexeme lookup stage. Abstract vs. concrete nouns elicit different N400 effects (Kounios & Holcomb 1994), the EEG correlate of the M350. Thus, the concrete / abstract distinction might 'come on-line' earlier than the kind of semantic features in previous studies on verb morphology.
[4] I use the left temporo-parietal junction to refer to the angular gyrus (Brodmann Area 39) and supramarginal gyrus (Brodmann Area 40) and posterior portions of the superior temporal lobe. This overlaps with the traditional 'Wernicke's Area' and the inferior parietal lobule.

in which the verb does not necessarily agree with the subject NP. In Hindi/Urdu, the verb agrees with the highest NP in the structure that does not bear a case suffix, a 'bare' NP (Pandharipande & Kachru 1977). This may be the subject NP, the object NP, or neither. The subject NP may be bare or ergative, because Hindi/Urdu uses an aspect-based split-ergative system. If the verb is perfective, then the subject NP is marked with the ergative suffix *-ne*, and cannot control agreement. The object NP may be bare or not because Hindi/Urdu uses differential object marking. Animate object NPs must always be marked with the dative/accusative suffix *-ko*, and therefore can never control agreement. Inanimate object NPs may surface as bare, or they may take the *-ko* case ending to mark a definite interpretation. If the subject NP is bare (2, 4), then the verb agrees with the subject NP in person, number, and gender, since it is the highest bare argument NP. If the subject NP is ergative and the object NP is bare (3), then the verb agrees with the object NP in person, number, and gender, since the object NP is the highest bare argument. Finally, if both subject and object NP are marked with an overt case suffix, (5), then a default 3rd person singular masculine form surfaces on the verb.

(2)	**laṛkā**$_{[3,\ \text{M},\ \text{SG}]}$	ek	kitāb$_{[3,\ \text{F},\ \text{SG}]}$	paṛhtā$_{[3,\ \text{M},\ \text{SG}]}$	hai
	boy	a	book	read	AUX
	'A boy reads a book' – subject NP agreement				
(3)	laṛke-ne$_{[3,\ \text{M},\ \text{SG}]}$	**ek**	**kitāb**$_{[3,\ \text{F},\ \text{SG}]}$	paṛhī$_{[3,\ \text{F},\ \text{SG}]}$	hai
	boy-ERG	a	book	read	AUX
	'A boy read a book' – object NP agreement				
(4)	**laṛkā**$_{[3,\ \text{M},\ \text{SG}]}$	ek	kitāb-ko$_{[3,\ \text{F},\ \text{SG}]}$	paṛhtā$_{[3,\ \text{M},\ \text{SG}]}$	hai
	boy	a	book-DAT	read	AUX
	'A boy read a book' – subject NP agreement				
(5)	laṛke-ne$_{[3,\ \text{M},\ \text{SG}]}$	ek	kitāb-ko$_{[3,\ \text{F},\ \text{SG}]}$	paṛhā$_{[3,\ \text{M},\ \text{SG}]}$	hai
	boy-ERG	a	book	read	AUX
	'A boy read a book' – default agreement				

In a series of behavioral studies, Bhatia & Dillon (2022) found that Hindi readers are susceptible to agreement attraction. But, across their studies, they find that only NPs that control agreement of one verb serve as attractors for other verbs. There is no evidence that Hindi readers attempt to retrieve an argument NP by its grammatical function or its morphosyntax. In other words, Hindi users do not systematically seek to relate verbs to subject NPs, object NPs, or even morphologically bare NPs necessarily. Rather, Hindi readers attempt to retrieve an 'agreer' NP, i.e., only the bolded NPs in (2–5) could tamper with the processing of other agreement relations in multiclausal structures, but not the unbolded NPs. This suggests that the grammatical details of the language guides comprehenders to represent a particular NP as relevant for agreement processes, which then guides processing of agreement.

This raises a new question – what does the brain do when it encounters an agreement-controlling NP, like *ek kitāb* 'a book' in (3), and how does this brain response compare to the same NP that does not control agreement, as in (2)? Chacón et al. (2024a) sought to answer this question using a phrase-by-phrase reading paradigm using MEG[5]. In this study, we used simple, subject-object-verb (SOV) grammatical sentences, like those in (2)–(5). During the processing of the object NPs, we found a pattern of activity in the LTPJ which showed different patterns depending on the case of the subject NP. Specifically, we saw that there was greater activity during the object in the object NP-agreement NP-ERG–NP sequences, (3), vs. the subject NP-agreement NP–NP sequences, (4). This is sketched in Figure 2. We also found spatially and temporally distinct responses to the NP's case assignments, which had main effects in left inferior frontal cortex ('Broca's area') and left anterior temporal lobe. We interpreted this LTPJ response as reflecting an attention control process necessary for identifying the object NP as the agreement controller. In SOV structures, readers must shift from attending to the subject NP and its morphosyntactic features to those of the object NP's. In a language like Hindi with object-agreement structures, this may also require suppressing the number, gender and person features of the subject NP in favor of those of the object NP's. Thus, we interpreted the LTPJ finding as reflecting a necessary shift in which NP's features must be in the focus of attention for the purposes of processing argument-verb relations. This is consistent with other findings which suggest a role of LTPJ in reorienting attention (e.g., Doricchi et al. 2010; Silvetti et al. 2015).

Is this convincing? In the critical comparison, the object NPs are the same words with the same morphology, and they bind the same thematic role. Thus, these features could not be driving the difference in the MEG response. On the other hand, the object NP occurred immediately after an ergative subject NP in one condition, and after a bare subject NP in the other. There could be variables that we failed to control for, such as the frequencies of the noun-case-noun trigrams. Thus, we conducted a (near-)identical study in Nepali, a language with a largely similar aspect-based split-ergative case alignment (Li 2007) and differential object-marking system, but with no object agreement. Unlike Hindi/Urdu, Nepali exhibits subject agreement with person, number and gender regardless of whether the subject NP is bare or marked with the ergative suffix *-le*, (6–7).

(6) **keṭā**$_{[3,\ \text{M},\ \text{SG}]}$ euṭā kitāb$_{[3,\ \text{SG}]}$ paṛhcha$_{[3,\ \text{M},\ \text{SG}]}$
boy a book read.PROG
'A boy reads a book' – subject NP agreement

(7) **keṭā-le**$_{[3,\ \text{M},\ \text{SG}]}$ euṭā kitāb$_{[3,\ \text{SG}]}$ paṛhyo$_{[3,\ \text{M},\ \text{SG}]}$
boy-ERG a book read. PERF
'A boy read a book' – subject NP agreement

In the Nepali MEG study, we replicated the main effects of NP case in left inferior frontal cortex and left anterior temporal lobe, demonstrating processing the (correlates of) case morphology. But, we failed to identify any distinct patterns of case interactions in the LTPJ. Instead, the patterns of activation in the LTPJ during the processing of object NPs were

[5] We were not the first to investigate the brain bases of agreement in split-ergative Indo-Aryan languages. Previous results found P600 responses for unlicensed agreement (Nevins et al. 2007), and distinct N400/P600 complexes for agreement violations versus subject case marking-verb aspect mismatches (Choudhary et al. 2009). See also Sauppe *et al.* (2021) for neural bases of speech planning of split-ergative structures in Hindi.

similar, regardless of whether the previous subject was bare or ergative. Thus, Hindi users' brains respond to NP-ERG–NP sequences differently than NP–NP sequences, even with the same thematic relations and lexical material, whereas Nepali users' brains do not differentiate these sequences in the same way. I take this as more compelling evidence that this response reflects a unique processing adaptation that Hindi comprehenders' brains deploy in mapping agreement relations to argument NP case morphology. The results of the Hindi MEG results could only be suggestive without the contrast with Nepali, and leveraging the similarities (case assignment) and differences (argument-verb agreement).

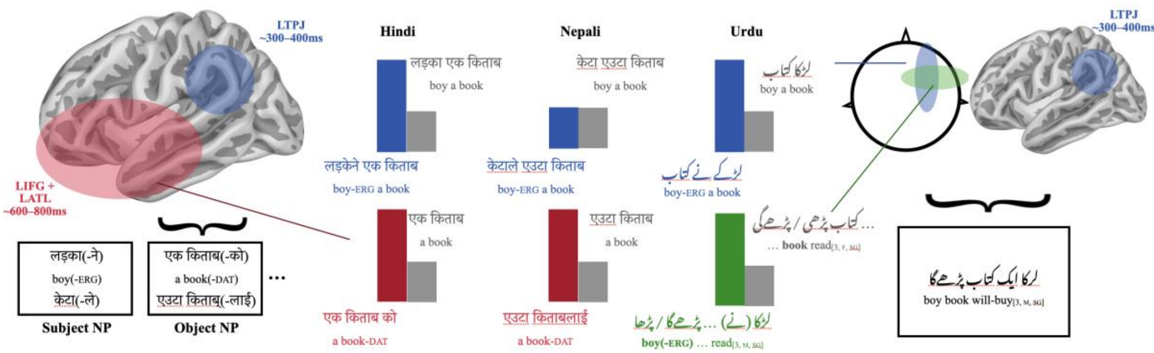

Figure 2. Summarized results from split-ergative agreement studies in Hindi, Nepali and Urdu. (Left) In a word-by-word reading task, responses in the LTPJ show greater activation in Hindi readers for NP-ERG–NP sequences compared to NP–NP sequences, but not in Nepali readers, whereas left inferior frontal gyrus and left anterior temporal lobe (LIFG+LATL) activity showed similar increased activity for case marking across structure types and languages. (Right) In a parallel reading task, Urdu readers showed greater activation in the right midline+anterior sensors and in the LTPJ for ergative subject NPs/perfective verbs compared to bare subject NP/imperfective verb sentences, and different activation for right parietal/lateral sensors for subject NP-verb agreement sentences compared to object NP-verb agreement sentences.

I could conclude the story here: The Hindi-Nepali comparison demonstrates the utility of comparing and contrasting languages to fine-tune the understanding of neural responses to case and agreement in the LTPJ, the left inferior frontal cortex, and the left anterior temporal lobe. But, are there any compelling alternatives? In these studies, we followed standard methodological practice with reading studies in sentence processing research. The interpretation we assigned to these results crucially depended on the attention and memory processes that Hindi and Nepali readers must undertake for the task, in which each phrase appears independently and sequentially. Our methods and theory both favor a view in which there are discrete processing stages at each word/phrase, i.e., something 'happens' at the subject NP, then at the object NP. But, this is not standard practice in morphological processing experiments. Participants are not asked to read morphemes one-by-one. Instead, experimenters allow participants' minds (and brains) to process structurally complex words 'all at once' by revealing the entire word, and permitting participants to process the stimuli on their own accord. What could be learned by adopting this methodology and conducting studies in which participants read entire (short) sentences, displayed all-at-once?

With Liina Pylkkänen's lab, we have started systematically exploring what computations and representations are involved in this kind of reading (Pylkkänen & Chacón 2024; Fallon & Pylkkänen 2024). Previous results show distinct neural responses in both EEG and MEG recordings for grammatical sentences (*the man can run*) vs. scrambled non-sentences (*can man run the*), displayed at-once for 200ms (Wen et al. 2019; Flower & Pylkkänen 2024; Dufau et al. 2024). These findings may demonstrate some degree of rapid and parallel processing of grammatical information, and a useful new tool for investigating the brain's language network divorced from the methodological assumptions of careful word-by-word reading. In both EEG and MEG recordings in English, we replicated the distinction between sentences and scrambled non-sentences. However, in two independent EEG and MEG studies, we failed to find sensitivity to argument-verb agreement (*the man runs* vs. *the man run*) (Fallon & Pylkkänen 2024; Dunagan et al. 2024).

Do these findings reveal something crucial about the processing of sentences read 'at-a-glance'? Or, do they just show that an English -*s*, placed on a subject NP or a verb, can be easily missed in complex stimuli displayed for 200ms? Follow-up research in Urdu suggests the former (Khokhar et al. 2024). In a 'high-density' (HD-) EEG study, we contrasted grammatical subject NP-agreement and object NP-agreement sentences like (2) and (3) with ungrammatical counterparts, in which the verb was marked with the grammatically-unlicensed gender marking, (8–9). Urdu readers' neural responses diverged for bare subject/imperfective sentence structures (2, 8) and ergative subject/perfective sentence structures (3, 9) around 300ms, in right parietal/lateral sensors. Urdu readers' neural responses also diverged for sentence structures in which the verb agreed with the subject NP (2, 9) and for structures in which the verb agreed with the object NP (3, 8), also around 300ms, in midline/right anterior sensors. Crucially, this demonstrates that Urdu readers' brain responses are sensitive to the two 'ingredients' of agreement in Urdu – which argument NP the verb shares features with, and which aspect the verb carries (and subject NP case assignment). However, we failed to find evidence that Urdu readers distinguish whether the possible combinations of case morphology, verb aspect, and verb feature specifications are *grammatical* given the context of the entire sentence. In other words, Urdu readers 'noticed' the relevant morphosyntactic properties implicated in argument-verb relations, but these neural responses did not 'notice' whether the agreement relation is licensed by the grammar.

(8)	***laṛkā**$_{[3,\,M,\,SG]}$	ek	kitāb$_{[3,\,F,\,SG]}$	paṛhtī$_{[3,\,F,\,SG]}$	hai
	boy	a	book	read	AUX
	'A boy reads a book' – subject NP agreement				
(9)	*laṛke-ne$_{[3,\,M,\,SG]}$	**ek**	**kitāb**$_{[3,\,F,\,SG]}$	paṛhā$_{[3,\,M,\,SG]}$	hai
	boy-ERG	a	book	read	AUX
	'A boy read a book' – object NP agreement				

How does this relate to our previous MEG findings in Hindi and Nepali? In an exploratory source reconstruction analysis with the Urdu study[6], we found that the neural response to verb aspect/subject NP case localized to the LTPJ. In other words, the same brain region showing distinct patterns of activity for subject- and object-agreement in our previous Hindi MEG study was also sensitive to subject NP case/verb aspect alignment in our Urdu EEG study. This provides more support for the view that the LTPJ is relevant for these processes. However, our Urdu readers did not seem to care about the well-formedness of the agreement relation, just as we found in English. Furthermore, the proposed explanation that we provided for the Hindi vs. Nepali contrast may not apply in the Urdu study. In Chacón et al. (2024a), our explanation assumed distinct stages of processing at the subject NP and the object NP necessitated the serial presentation paradigm. But, it is not clear that our Urdu participants needed to attend to the subject NP *and then* the to object NP in the parallel presentation study.

So, what function could the LTPJ serve in the brains of our Hindi and Urdu participants? In Khokhar et al. (2024), we suggested that LTPJ may instead serve a key *representational* function that is a precursor to evaluating agreement in Hindi/Urdu split-ergative structures, not necessarily a *processing* function as we suggested in Chacón et al. (2024a). The LTPJ supports processing and representing events and relations, although its precise function is still controversial (Bedny et al. 2013, Meltzer-Asscher et al. 2013; Williams et al. 2017; Matchin et al. 2019). Connecting this to the Hindi/Urdu and Nepali findings across the three experiments is similarly still murky. It may be tempting to suggest that the LTPJ activity we reported in Hindi and Urdu readers reflected construction of perfective vs. imperfective event representations, with no necessary connection to agreement processing. However, this approach is unlikely to succeed as well, given the insensitivity of LTPJ in otherwise identical structures in Nepali readers' brains. How to best theorize the role of the LTPJ and its relation to attention, event/argument structure interpretation, and argument-verb agreement is still ongoing. However, these three findings can place strong constraints on what kinds of theories are viable, and may also suggest that the LTPJ serves a function linking between grammatical structure and interpretation (e.g., Meltzer-Asscher et al. 2013).

4 Conclusion

It is a encouraging that we've identified a uniform left-lateralized language network that supports language. This also aligns with the theoretical linguistic goal of identifying universal linguistic representations and computations, and building explanatory models of language in the mind and brain. But, we must also characterize how differences in grammatical structure across languages mold moment-by-moment processing dynamics, and how these differences correspond to and are reflected in the language network. This is hard both for theoretical and logistical reasons, but I believe it's a necessary step and offers

[6] EEG data affords less spatial resolution than MEG data, and for this reason EEG data are usually only presented in 'sensor-space'. However, higher sensor density and more sophisticated analysis pipelines can provide source localization results similar to MEG; although this is still not standard practice, and there are still limitations of source localization with EEG (see Asadzadeh et al. 2020 for overview)

many exciting opportunities for collaborations between theoretical linguistics and psycho/neurolinguists. Here, I showed two cases in which careful comparison between languages, informed by linguistic theory, language descriptions, and sophisticated psycholinguistic models, can guide and refine our understanding of the neural bases of language.

In this paper, I focused on South Asian languages, for the obvious reason that it is the theme of this conference and my personal interest. However, much of the theoretical and descriptive work in South Asian languages has emphasized comparison. The findings I sketch here raise many challenging questions about other kinds of morphological and syntactic phenomena that are similar to, but not identical to, the Bengali, Hindi/Urdu, and Nepali ones described here. For instance, many questions remain about how the mind and brain processes and represents split-ergative agreement patterns in Gujarati, Punjabi, or Kashmiri, all of which have comparable patterns to Hindi/Urdu and Nepali, but with notable variations that challenge the basic models we proposed here.

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