It takes two ***the*** tango: Predictability and detectability affect processing of phrase structure errors

Anthony Yacovone, Paulina Piwowarczyk, & Jesse Snedeker (Harvard University)
anthony_yacovone@g.harvard.edu

Introduction. If you hear a sentence like "It takes two ***the*** tango," how do you recognize that the speaker misspoke? Prior work with ERPs has found greater neural responses to phrase structure (PS) errors when they occur in sentences that create strong expectations about upcoming words (or syntactic categories).[1] PS errors elicit an early left anterior negativity (ELAN) and a P600—ERP components related to error detection.[2] The ELAN-P600 response, however, is only reported in studies where participants monitor sentences for errors and/or judge their correctness.[2,3] In contrast, studies that de-emphasize errors (e.g. with a visual distractor) often find a sustained negativity.[3] Crucially, many of these studies use stimuli that do not resemble natural speech; thus, their real-world implications are unclear. The present study explores how PS error detection occurs in naturalistic contexts when people listen to a larger discourse without error monitoring. Is predictability still a factor? Which ERP is elicited and when? We answer these questions below.

Method. We used a novel EEG paradigm called the *Storytime task*. In this task, we recorded 30 participants' EEG responses while they listened to a 30-minute story with PS errors. Errors were created by swapping determiners for prepositions (and vice versa) in both predictable and unpredictable contexts (see **Figure 1**). This procedure ensured that each lexical item appeared in both grammatical and ungrammatical conditions. Both errors and controls were spliced into the story. We had 120 target sentences (60 predictable, 60 unpredictable) and participants heard 60 errors in total. Predictability was determined with a cloze probability task (predictable: 81-100%; unpredictable: 0-6.25%). We pre-registered a set of linear mixed models designed to detect an ELAN-P600 response: two models for mean amplitudes from 0-200 and 200-400ms at left anterior electrodes (for ELANs) and another from 500-800ms at Cz and Pz (for P600s).

Results and Conclusions. There were two notable findings: First, ERP waveforms revealed a weak sustained negativity (not an ELAN-P600) for the PS errors overall. However, this effect was driven by the predictable contexts (see **Figure 2**). These findings remain tentative, as our pre-registered models did not find any significant effects. Second, during the debriefing, participants reported hearing only a handful of the 60 errors in our story. Prior work has found that the salience or detectability of the errors influences comprehenders' sensitivity to them.[2,4] Thus, we quantified how detectable each error was by asking a new set of participants on MTurk (N=40) to listen to the story and push a button upon hearing an error. Results confirmed that some errors were very detectable, while others were not (range: 0-86%, median: 33%). The detectability of errors was not strongly confounded with the predictability of the context ($r_s(118) = -.17$, $p = .06$). Given these findings, we returned to our original analyses to see if detectability moderated the effects of predictability. We performed another set of linear mixed models—but this time, we looked at all electrode sites and tested for a 3-way interaction between Error, Predictability, and Detectability (using a median split categorization). This interaction was significant between 200-400ms and 500-800ms. Pairwise comparisons revealed main effects of PS errors only when the context was predictable, *and* the error was detectable (see **Figure 3** for waveforms and model results). These data are consistent with prior work showing that predictability influences comprehenders' sensitivity to PS errors.[1] We also report a novel finding: PS errors in rich discourse contexts do not elicit ELAN-P600 responses but rather sustained negativities akin to the pattern in studies that de-emphasize syntactic errors.[3] The implication of this finding is that listeners may be adopting different processing strategies depending on the task: When simply listening to a story, participants may prioritize understanding the discourse and down-weight speech errors (or at least prolong their resolution). Whereas, in artificial tasks, participants may prioritize resolving errors at the cost of their understanding. These strategies may be able to explain the different ERP effects across studies. However, future work will require replicating and then extending these findings. In particular, we will investigate whether detectability is a bottom-up feature of the stimulus (e.g. the salience of the acoustic difference) or the result of more shallow syntactic processing (e.g. emphasizing content words over function words) in discourse contexts.

	Original sentences	Violations created by swapping words
Predictable	I walked all along ***THE*** row of cages.	I walked all along **OF** row of cages.
	We've been missing a critical piece **OF** evidence.	We've been missing a critical piece ***THE*** evidence.
Unpredictable	She snapped ***THE*** book shut and held it behind her back.	She snapped **FOR** book shut and held it behind her back.
	I am leaving after lunch **FOR** a meeting.	I am leaving after lunch ***THE*** a meeting.

Figure 1: *Examples of stimuli conditions.* Items were paired based on predictability and then the target determiner and the target preposition were swapped to create the PS error conditions.

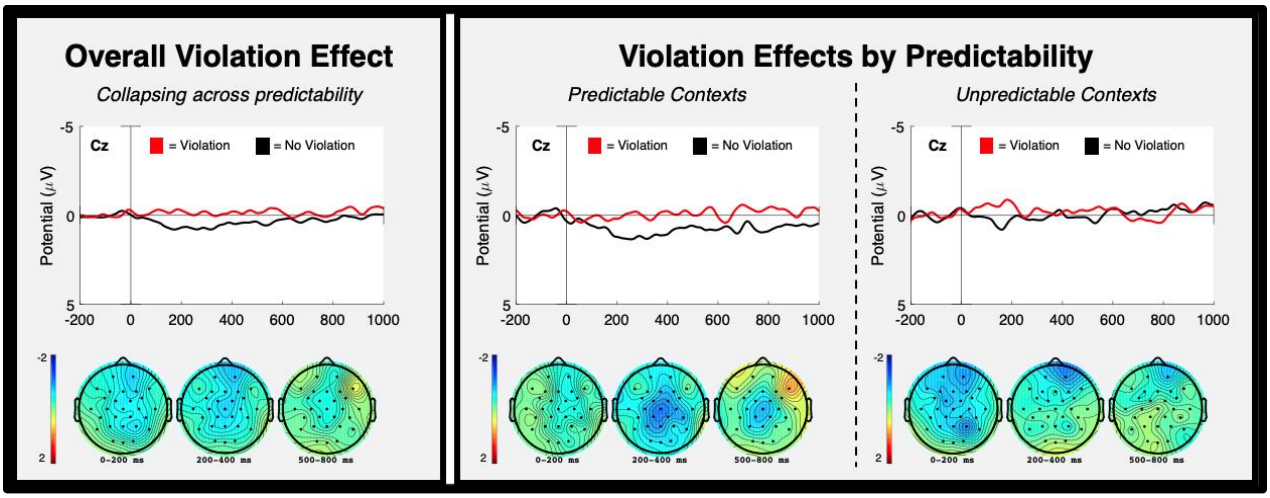

Figure 2: *Results from pre-registered analyses.* ERP waveforms revealed a weak sustained negativity for PS errors. The effect is primarily found in the predictable contexts. Scalp maps reveal that the effect is centrally located on the scalp in predictable contexts, and critically the negativity is long-lasting, and it is not left-lateralized (no ELAN).

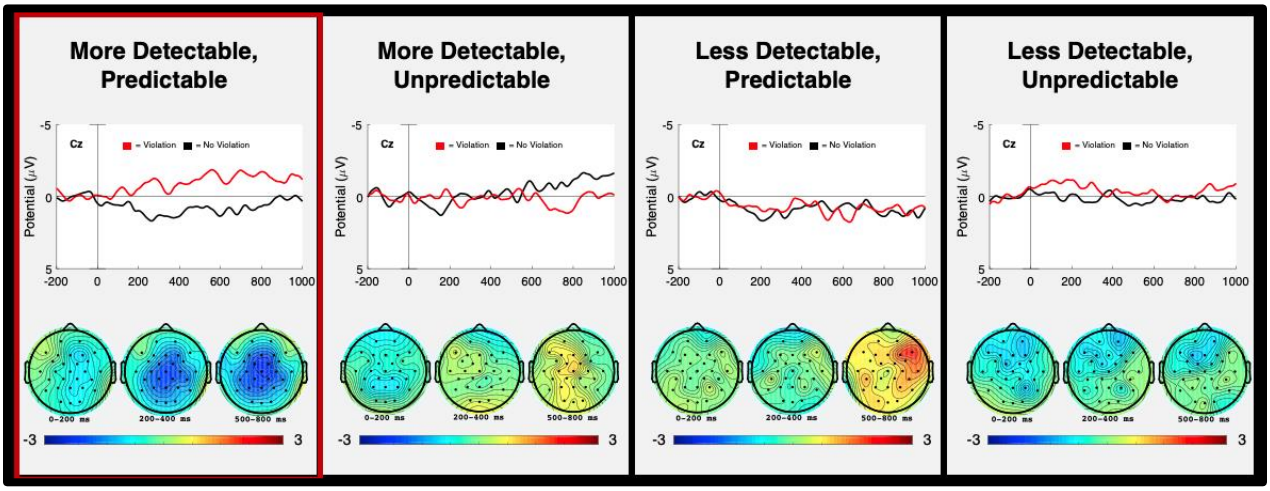

Figure 3: *Results from exploratory analyses*. When categorizing the effects by detectability, there were significant 3-way interactions between 200-400ms ($\hat{\beta}$ = 1.87, SE = 0.86, t = 2.19, $p < 0.05$) and 500-800ms ($\hat{\beta}$ = 3.22, SE = 1.05, t = 3.06, $p < 0.01$). Pairwise comparisons revealed main effects of the PS errors only when the context was predictable *and* the error was detectable ($\hat{\beta}$ = 1.35, SE = 0.51, t = 2.65, $p < 0.01$).

References: [1]Lau, Stroud, Plesch, & Phillips, 2006; [2]Steinhauer & Drury, 2012; [3]Hasting & Kotz, 2008; [4]Gunter, Friederici, & Hahne, 1999.