The influence of top-down grammatical knowledge on the rapid visual perception of full sentences: MEG evidence

Although natural reading typically involves eye movements, skilled readers are also able to understand multi-word messages that are flashed quickly in parallel, such as notifications on a phone or messages on the road. A growing psycholinguistic literature has provided evidence of rapid sentence composition in such circumstances with a technique called rapid parallel visual presentation (RPVP; Snell and Grainger, 2017; Massol et al., 2021). However, the neural mechanisms of such rapid combinatory computations are not yet understood. The behavioral RPVP evidence shows that subjects perform better when all words in a stimulus form a grammatical sentence as opposed to an ungrammatical string, a so-called Sentence Superiority Effect (SSE, Snell and Grainger, 2017). Additionally, subjects often miss errors when presented with sentences that contain an inner transposition such as *you that read wrong* (Mirault et al., 2018).

In our MEG experiment, we sought to characterize the earliest neural correlates of the sentence superiority effect. Our main goal was to assess whether at that stage, neural signals would also "miss" an inner transposition, meaning that such errors would pattern with grammatical sentences due to top-down impact of grammatical knowledge, or whether inner transpositions would diverge from grammatical sentences, indicating a more detailed, bottom-up analysis.

Using RPVP with a 300ms presentation of a full sentence, we presented 25 native English-speaking participants with four-word English sentences that were either normal sentences (*all cats are nice*), strings with an inner transposition between the second and third words (*all are cats nice*), or reversed sentences (*nice are cats all*), as shown in Fig 1. Our behavioral task, requiring subjects to indicate whether an immediately following stimulus was the same or different as the task stimulus, showed a robust SSE. A spatiotemporal clustering ANOVA was performed over the entire left and right hemispheres to identify the neural correlates of sentence superiority and sensitivity to the transpositions.

The clustering analysis revealed two significant activity clusters in the left hemisphere, and none in the right hemisphere, suggesting strict left laterality (Fig 2.). The first cluster was broadly distributed across the left-lateralized language cortex in anterior and inferior temporal regions at 210 - 460ms after stimulus onset. This cluster showed a three-way distinction between the three conditions: grammatical sentences elicited the highest activation and reversed ones the lowest, with inner transpositions patterning in the middle. All pair-wise comparisons were significant. Since inner transposition diverged from grammatical sentences, this effect conforms to the hypothesis where top-down effects of syntactic predictions do not yet guide the interpretation of the bottom-up recognition of the stimulus. Its localization was consistent with prior findings on rapid bottom-up composition that shows sensitivity to the form typicality of the stimulus (Flick and Pylkkänen, 2021; Matar et al., 2021).

The second cluster was significant later, at 450 - 720ms in the left inferior frontal gyrus (LIFG) and anterior temporal pole, with greater activity for the grammatical and inner transposition conditions as compared to the reversed sentences. Grammatical sentences and inner transpositions patterned together and thus the effect conforms to the top-down hypothesis, where top-down syntactic predictions fix any inner-transpositions in the stimulus.

In sum, we discovered that the early stage of comprehending a rapidly flashed full sentence contains both a bottom-up and a top-down mechanism, with the bottom-up mechanism emerging first in the left lateralized language cortex and the top-down mechanism immediately following in the LIFG and anterior temporal pole.

Figure 1.

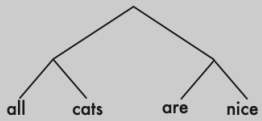
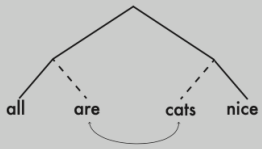
Transposition	Quantifier	Example	Structure
Grammatical	all	all cats are nice	
	some	some cats are nice	
	no	no cats are nice	
	the	the cats are nice	
Inner Transpose	all	all are cats nice	
	some	some are cats nice	
	no	no are cats nice	
	the	the are cats nice	
Reversed	all	nice are cats all	
	some	nice are cats some	
	no	nice are cats no	
	the	nice are cats the	

Figure 2.