Syntactic adaptation following short-term experience: Neural correlates and relationship to cognitive control

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How do individuals adapt to linguistic variability? Previous studies have shown improved syntactic processing of infrequent structures following short-term exposure (Fine et al., 2013; Wells et al., 2009). However, the relevant mechanisms and neural substrates are unknown. We hypothesized that if adaptation is driven by detection of a mismatch between the predicted and actual structure, then cognitive control mechanisms for conflict resolution may be involved. If so, (1) adaptation could be sub-served by frontal regions linked to both comprehension and cognitive control—the anterior cingulate cortex (ACC) and the left pars opercularis (ParsOp), and (2) the extent of this adaptation might correlate with individual differences in cognitive control (as indexed by Stroop). This study investigated exposure-based adaptation in garden-path sentence comprehension. Participants (N=28) underwent three runs of functional neuroimaging (fMRI). Neural activation and reading time (RT) for each sentence was recorded. In Run1, participants read equal numbers of unambiguous and ambiguous main verb (MV) and relative clause (RC) sentences (N=120). This served as a pre-training measure of performance. We expected that the parser would predict MV structures, while RC structures would induce garden-pathing. In Run2, participants read 120 RC sentences (half ambiguous) to provide exposure that could lead to adaptation. In Run3, participants again read equal numbers of unambiguous and ambiguous MV and RC sentences (N=120). This phase was used to determine if adaptation was specific to verbs to which participants had been exposed in Run2 or also generalized to unexposed verbs.

Behaviorally, an ambiguity effect was seen in length-adjusted RT for RC [mixed-model $\beta=264.95$, $p<.001$] but not MV [$\beta=-26.12$, $p=0.68$] sentences in Run1, confirming garden-pathing. RC ambiguity effects were observed in the first [$\beta=171.31$, $p<.001$] and second [$\beta=107.28$, $p<.01$] halves of Run2. In Run3, a significant effect was found for RC sentences with untrained verbs [$\beta=175.77$, $p<.001$] and a marginal effect was found for those with trained verbs [$\beta=104.96$, $p=.06$]. No effect was seen for MV sentences [$\beta=22.63$, $p=0.72$; $\beta=-9.34$, $p=0.87$]. Neurally, within individual-level functional regions of interest (ROIs; overlap between All Sentences>Baseline (false-font) and Harvard-Oxford anatomical regions), a structure-and-conflict-specific increase in activation due to ambiguity was seen for RC [$t(27)=2.45$, $p<.05$], but not MV structures in Run1 in ParsOp. No such effects were found in ACC, demonstrating that the pattern was specific to ParsOp and did not apply broadly across the brain. In Run2, there was ambiguity-related activation in Pars Op in the first [$t(27)=4.09$, $p<.001$] but not second half [$t(27)=1.24$, $p>.2$], suggesting sensitivity to syntactic adaptation. In Run3, there was no ambiguity effect for exposed verbs, as expected under adaptation [$p>.1$] but there was a marginal effect for unexposed verbs [$F(1,27)=3.63$, $p=.07$]. ParsOp activation in the second half of Run2, the point at which we detected adaptation, correlated with Stroop [Pearson Skipped $r=0.54$ CI=(0.27 0.76)] but not pre-training ambiguity effects in RT (which could index differences in prior linguistic experience and other variables).

Overall, these results reveal greater sensitivity to adaptation in neural activation than whole sentence RT measures. This is likely due to RT measures capturing other processes not subject to adaptation. Both neural and behavioral effects suggest some verb-specificity in learning, with more persistent ambiguity effects for unexposed than exposed verbs. Secondary analyses (not described) additionally showed quicker adaptation for verbs with higher prior MV bias, consistent with verb-specific prediction-and-error-based learning. Finally, correlation between ParsOp adaptation and Stroop (but not pretraining RT) suggests that adaptation was related specifically to individual differences in cognitive control. Thus, while not all sub-components of comprehension may adapt to short term experience, those related to cognitive control appear to do so using the pars opercularis.

References

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