

## Selective effects of cognitive control on the P600: Evidence from a large-scale individual differences study

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**Introduction:** Comprehenders are able to use certain cues, such as the selection restrictions of verbs, to constrain their mental models to particular sets of events (event structures). When new inputs have semantic or syntactic properties that violate these event structures, a posteriorly distributed late positivity effect, otherwise known as the P600 effect, is often elicited. It has been theorized that the P600 reflects the *detection of conflict* between the comprehender's prior mental model and the discourse representation dictated by the new input, as well as prolonged attempts to re-establish coherence through reanalysis and/or a re-evaluation of the prior mental model (e.g. Kuperberg, 2007; van de Meerendonk, et al., 2009). While there is some prior experimental evidence suggesting that the P600 is related to working memory capacity (Nakano & Swaab, 2010; Kim & Mikayke, 2018), it remains unclear whether the P600 is specifically linked to domain-general *cognitive control* -- the ability to detect, resolve and monitor conflict between competing representations. To address this question we conducted a large-scale individual differences study (N=77) in which participants carried out both an ERP experiment designed to evoke both N400 and P600 effects, as well as an extensive neuropsychological battery assessing: (1) *Cognitive Control* (Stroop and the "AX" continuous performance task), (2) *Working Memory* (verbal and non-verbal complex span tasks), and (3) *Language Experience* (vocabulary and reading comprehension).

**Methods:** In the ERP experiment, participants read three-sentence discourses for comprehension while performing delayed plausibility judgements. In the third sentence, they saw a critical noun that was either plausible or semantically anomalous in context (see examples below). Anomalous nouns always violated animacy-based selectional restrictions of the prior verb, and critical words were counterbalanced across items to generate plausible and anomalous continuations (lexical probabilities <1%). Consistent with previous research, anomalous continuations generated both a clear N400 effect (300-500ms:  $t(76) = 3.96$ ,  $p < .001$ ), as well as a semantic P600 effect (600-1000ms:  $t(76) = 5.94$ ,  $p < .001$ ). Both effects were operationalized as average voltage differences within *a priori* time-windows and spatial regions. **Results:** As predicted, an exploratory Factor analysis demonstrated a clear distinction between our three cognitive constructs of interest. Behavioral accuracy showed significant zero-order correlations with all three latent factor scores ( $r$ s: 0.3 - 0.36,  $p$ s < .01). However, the only *unique* predictor in a multiple regression analysis was *Cognitive Control* ( $t = 2.2$ ,  $p = .03$ ). This suggests that multiple cognitive abilities are associated with the behavioral detection of semantic anomalies, but that *Cognitive Control* is the most central factor in accounting for differences in classification accuracy (Low Control:  $d' = 2.2$ , Moderate Control:  $d' = 2.8$ , High Control:  $d' = 2.7$ ). In terms of online neural responses, we observed *no* significant effects of *Language Experience* or *Working Memory* on the P600, but a robust U-shaped relationship between *Cognitive Control* ability and the amplitude of the P600 ( $t = 3.32$ ,  $p = .001$ ). This U-shaped function was driven by a larger semantic P600 effect in individuals with intermediate levels of cognitive control, relative to individuals with either low or high cognitive control abilities (see Figure 1). An inverse U-shaped relationship was found on the N400 ( $t = 3.97$ ,  $p < 0.001$ ), suggesting a possible trade-off between these two ERP responses (Kim & Osterhout, 2005). **Discussion:** These results provide evidence for a selective influence of cognitive control on the P600. They also suggest that both the *effectiveness* and *efficiency* of domain-general conflict monitoring mechanisms can influence the amplitude of this component. Individuals with *poor cognitive control* showed small P600 effects and poor offline behavioral accuracy, consistent with previous work showing that the P600 is only produced when comprehenders successfully detect conflict (Sanford et al., 2011). Individuals with *strong cognitive control* abilities showed good behavioral accuracy but also small P600 effects, suggesting that they engaged fewer neural resources to efficiently detect and categorize the anomalous sentences. The largest P600 was observed in individuals with intermediate levels of cognitive control. Behaviorally, these participants successfully detected anomalies, but may have engaged more neural resources in prolonged attempts to resolve conflicting representations during reanalysis.

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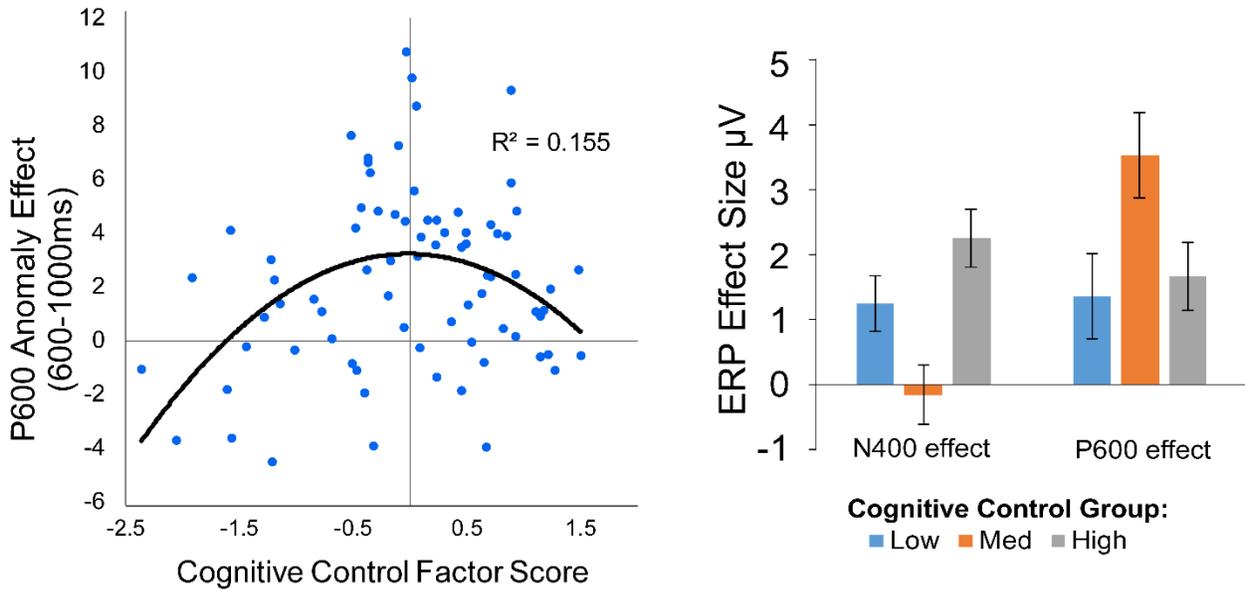


Figure 1: The scatter-plot to the left demonstrates the U-shaped relationship between the amplitude of the P600 effect to semantic anomalies and individual differences in cognitive control ability (N = 77). The bar graph to the right illustrates differences in ERP effect sizes on the N400 and P600 component for groups differing in cognitive control abilities. Error bars represent  $\pm 1$  SEM.

**Example discourses with plausible/anomalous critical words in bold:**

*The lifeguards received a report of sharks right near the beach.  
 Their immediate concern was to prevent any incidents in the sea.  
 Hence they cautioned the **trainees/drawer** to be wary.*

*Edgar spent all day ignoring the problem with the door  
 It squeaked whenever he opened it.  
 Finally, he greased the **tracks/community** with the oil.*

*Amanda had just prepared a pasta dish.  
 She was ready to eat, but she wanted to give it more flavor.  
 Before she continued, she ground some **seasoning/artists** over the food.*

