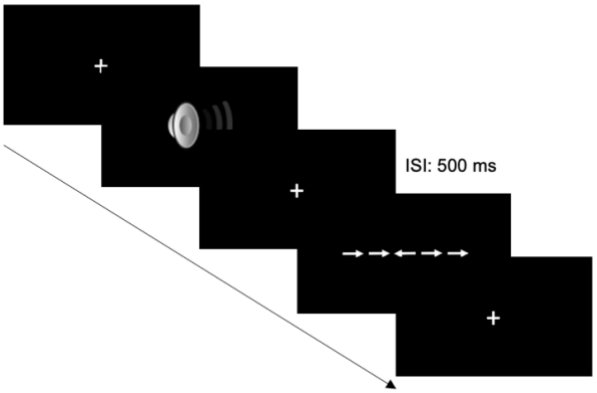
**Title:** Cognitive Control Adaptation in Code-Switching: An ERP Study
**Authors:** Hannah Treadway, Melanie Curado, Alexandra Dabrowski, Claire Kuntz, Samantha Perez, Kirthana Sane, Olivia Shaw, Jorge Valdés Kroff, Souad Kheder, Edith Kaan
**Affiliation:** University of Florida

**Introduction:** The resolution of temporary ambiguity in incremental sentence processing has been tentatively linked to the upregulation of domain general cognitive control.[1] Real-time comprehension of intrasentential code-switching (CS) presents a compelling testbed for cognitive control in language processing as it may require that the bilingual parser engage in cross-linguistic conflict resolution. Previous work finds that CS detection induces an upregulation of cognitive control that spills over to succeeding nonlinguistic tasks (e.g., flanker task): the conflict effect, or the increased effort required to resolve conflicting information in incongruent flanker trials, was reduced after reading sentences with CS relative to unilingual sentences. This result suggests that cross-linguistic conflict resolution elicits cross-task adaptation of cognitive control.[2] However, this adaptation has not been consistently replicated. Some behavioral studies observed either no effect of CS on the conflict effect, or a *larger* conflict effect after CS than after unilingual sentences.[3,4,5] Such results may favor the predictions of the Control Processes Model (CPM), which posits that the open control requisite of some CS makes the computational system vulnerable to interference.[6] This study disentangles upregulation and interference accounts by characterizing the neural signatures underlying CS cross-task paradigms.
**Methods:** Early Spanish-English bilinguals (current $n$=14; goal $n$=40) participated in a cross-task experiment during EEG recording. In critical trials, participants heard a sentence (unilingual Spanish or containing multiple language switches, Table 1) and then responded to a flanker trial (congruent or incongruent; $n$=32 per sentence type) (Figure 1). All experimental items were normed for plausibility by bilingual code-switchers.

If CS processing incurs a boost to cognitive control, N2 (associated with conflict monitoring)[7] and P300 (associated with inhibition)[8,9] amplitude may be attenuated for incongruent flankers following a switch relative to those following a unilingual sentence; however, if CS induces more susceptibility to interference, N2 and P300 amplitudes may be the same or greater for incongruent flanker trials after a switch than after a unilingual sentence.
**Preliminary Results:** A linear mixed effects analysis of frontal electrode sites in the 200-300 ms (N2) time window reveals a main effect of congruency, such that congruent flanker trials have a more negative amplitude than incongruent trials [b=0.42, SE=0.2, p=0.04]; this is the opposite of what is expected if N2 reflects conflict monitoring. An equivalent analysis conducted in the 600-800 ms (later part of P300) time window yields a main effect of congruency, such that incongruent flankers had a more positive amplitude [b=2.1, SE=0.25, p<0.001], and a main effect of sentence type, such that flanker trials following a CS elicited more positive deflections [b=0.5, SE=0.25, p=0.05] (Figure 2). Descriptively, the difference between amplitudes of the positivity attested in this later time window is larger for flankers following a CS than those following unilingual sentences.
**Discussion:** Results for the N2 time window were not anticipated and do not align with either of the tested accounts. The difference in amplitude for a late fronto-central positivity, presently interpreted as a P300 component (an index of cognitive interference), is greatest for flanker trials following CS, with incongruent trials being more positive. This suggests that CS processing for early bilinguals does not bring about boosts in cognitive control that are sustained for following non-linguistic tasks, but rather additionally taxes the cognitive control system. If these results remain consistent, arguments can be made about whether (1) CS constitutes linguistic conflict and (2) some CS classes recruit broader attention (as per the CPM), making nonlinguistic conflict resolution more effortful.

**References:** [1] Ness, T., Langlois, V., Kim, A., & Novick, J. (2023). The state of cognitive control in language processing. *Perspectives on Psychological Science*, 1–22; [2] Adler, R. M., Valdés Kroff, J.R., & Novick, J. (2020). Does integrating a code-switch during comprehension engage cognitive control? *Journal on Experimental Psychology: Learning, Memory, and Cognition*, *46*(4), 741–759; [3] Hofweber, J., Marinis, T., & Treffers-Daller, J. (2020). Experimentally induced language modes and regular code-switching habits boost bilinguals' executive performance: Evidence from a within-subject paradigm. *Frontiers in Psychology*, *11*; [4] Han, X., Li, W., & Filippi, R. (2022). The effects of habitual code-switching in bilingual production on cognitive control. *Bilingualism: Language and Cognition*, *25*(5), 869–889; [5] Kheder, S., Medina, R. M., Valdés Kroff, J., & Kaan, E. (2024). Investigating the Effects of Code-Switch Types on Cognitive Control [Preprint]. https://doi.org/10.31219/osf.io/q9kzn; [6] Green, D. W. (2018). Language control and code-switching. *Languages*, *3*(2), 8; [7] Acheson, D. J., & Hagoort, P. (2014). Twisting tongues to test for conflict-monitoring in speech production. *Frontiers in Human Neuroscience*, *8*, 1–16; [8] Bosma, E., & Pablos, L. (2020). Switching direction modulates the engagement of cognitive control in bilingual reading comprehension: An ERP study. *Journal of Neurolinguistics*, *55*; [9] Wu, Y. J., & Thierry, G. (2013). Fast modulation of executive function by language context in bilinguals. *Journal of Neuroscience*,*33*(33), 13533–13537a.



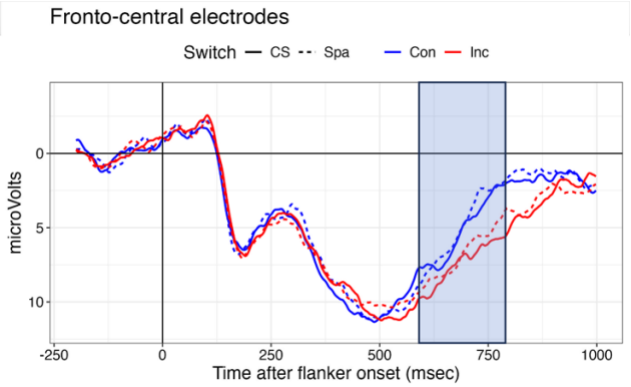




**Figure 1 (left). Critical trial structure for main experimental task.**

**Figure 2 (right). Grand average ERP signatures time-locked to post-sentence flanker trials for fronto-central electrode sites.** Negative is plotted up. The 600-800ms time window is highlighted. Waveforms for flanker trials following unilingual Spanish sentences are plotted with dashed lines, while those following CS sentences are plotted with solid lines. Incongruent flanker trials are plotted in red and congruent flanker trials are plotted in blue.

**Table 1.** ***Critical sentences by sentence type.***

| Sentence Type | Example | Translation |
|---|---|---|
| **Unilingual Spanish** | *En la fiesta, la joven pidió una copa de vino de la anfitriona*. | "At the party, the young woman asked for a glass of wine from the hostess." |
| **CS** | *Un* recent study *reveló que* the popular diet *realmente perjudica la salud*. | "A recent study revealed that the popular diet actually harms health." |