Can error propagation explain how event-related potentials in second-language sentence processing depend on cross-language similarity?

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In low-proficiency second-language (L2) learners, syntactic violations give rise to an N400 event-related potential (ERP) effect. With increasing proficiency, this changes into a P600 effect. However, the precise functional interpretation of ERPs remains a matter of debate. One theory proposes that ERPs reflect learning signals that arise from mismatches in predictive processing (Fitz & Chang 2019). These signals are propagated across the language system to improve future predictions. In a model based on the Bilingual Dual-path model (Tsoukala et al. 2021), it was demonstrated that this 'error-propagation'-theory can account for the N400-to-P600 switch in late bilinguals (Verwijmeren et al. 2023).

We investigated if the simulated P600 effect in the model depends on how syntax differs between the L1 and the L2. We simulated results from an ERP study with L1 English learners of L2 Spanish, in which participants were presented with Spanish sentences with or without a syntactic violation (Tokowicz & MacWhinney 2005). The three types of syntactic violations that were investigated in that study differed in how they relate to English: violations in **verb tense** were SIMILAR in Spanish as they are in English (e.g., "Su abuela *cocinando/cocina muy bien"*, His grandmother *cooking/cooks very well*); violations in **determiner gender** are UNIQUE to Spanish since English has no grammatical gender (e.g., "Ellos fueron a *un/una fiesta", *They went to* $*a_{masc}/a_{fem}$ *party*); and violations in **determiner number** are DIFFERENT in Spanish and English since English does encode noun number in the noun but not the determiner (e.g., "*El/Los niños están jugando", $*The_{sing}/the_{plu}$ *boys are playing*). The results revealed P600 effects for verb tense and determiner gender violations but not for determiner number violation (Tokowicz & MacWhinney 2005).

In our simulations, simulated English-Spanish participants showed a P600 in response to constructions that were SIMILAR in cross-language similarity, and showed a reduced P600 in response to constructions that were DIFFERENT in cross-language similarity. These ERPs are in line with what Sabourin and Stowe (2008) found in human ERPs and similar to what Tokowicz and MacWhinney (2005) found. Different from human ERPs, however, simulated participants did not show a P600 in response to violations in syntactic gender that were UNIQUE to the L2. However, exploratory simulations with syntactic gender violations in a monolingual model also didn't result in a P600. Thus, our findings partially support the viability of error propagation as an account of L2 ERP effects, at the same time as bringing a limitation of the model to light.

References

Fitz, H., & Chang, F. (2019). Language ERPs reflect learning through prediction error propagation. *Cognitive Psychology*, *111*, 15–52. https://doi.org/10.1016/j.cogpsych.2019.03.002

Tsoukala, C., Broersma, M., Van den Bosch, A., & Frank, S. L. (2021). Simulating code-switching using a neural network model of bilingual sentence production. *Computational Brain & Behavior*, *4*, 87–100.

Verwijmeren, S., Frank, S.L., Fitz, H. & Khoe, Y.H. (2023). A neural network simulation of event-related potentials in response to syntactic violations in second-language learning, *Proceedings of the 21st International Conference on Cognitive Modelling.*

Tokowicz, N., & MacWhinney, B. (2005). Implicit and explicit measures of sensitivity to violations in second language grammar: An event-related potential investigation. *Studies in Second Language Acquisition*, *27*(2), 173–204.

Sabourin, L. and Stowe, L. A. (2008). Second language processing: When are first and second languages processed similarly? Second Language Research, 24(3):397–430.