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Journal

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Publication Date

2022

Peer reviewed

Bilingual Sentence Processing: when Models Meet Experiments

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Keywords: language; bilingualism; sentence comprehension and production; computational models; psycholinguistic experiments

Although sentence comprehension and production are increasingly often studied by combining computational modeling and human experiments, this approach remains mostly restricted to studies of monolingual or first-language (L1) processing. There are currently only very few sentence-level computational models of second-language (L2) or bilingual processing (Frank, 2021). This lack of computational specifications can hamper further progress in bilingualism research. Moreover, better understanding of bilingual processing will give more insights into more general mechanisms such as cognitive control processes involved while switching languages (Luk et al., 2012). Our symposium aims to bring together researchers from different labs and with different research traditions, working on the intersection of models and experiments in bilingual sentence processing.

The symposium has four talks, by Edith Kaan (associate professor, specializing in psycholinguistics of bilingualism), Yung Han Khoe (PhD student, working on models of bilingual sentence production), Lin Chen (research associate with an expertise in reading processes), and a joint talk by Irene Winther (PhD student working on bilingual sentence processing) and Yevgen Matusevych (research associate in computational cognitive science of language). Finally, we will have a panel discussion to suggest how models could be challenged by experimental data, and provide new explanatory mechanisms. This discussion will be moderated by Xavier Hinaut (research scientist in computational neuroscience) and Stefan Frank (associate professor in computational psycholinguistics).

Edith Kaan: The value and challenges of modelling bilingual sentence processing

Experimental research on sentence processing in L2 learners and other bilinguals has yielded interesting insights in language activation and language control. I will illustrate this with examples from code-switching and predictive processing. To account for differences between and within individuals in sentence processing a myriad of factors has been proposed that are tuned to the individual's knowledge and skills, past experience, and the current context and goals. This abundance of factors makes it hard to make new predictions that can be empirically tested. There is therefore a clear need for computational models in order to test proposals as to how these factors interact. I will discuss existing computational models on code-switching and predictive processing, where they succeed and where they fail, and conclude by listing the challenges such models face.

Yung Han Khoe: Modeling cross-language structural priming

Speakers' tendency to reuse syntactic structures that they have recently encountered (structural priming) is a phenomenon that occurs not only within a language, but also between different languages. This has been demonstrated in behavioral experiments (e.g., Hartsuiker et al., 2004) as well as corpus studies (for a review, see Gries & Kootstra, 2017). We have previously shown that cross-language priming can be explained as the result of error-driven implicit learning (Khoe et al., in press). We are now investigating which factors affect the strength of priming, focusing on factors that result from differences in the language environment that shape a bilingual's language system. We start with simulated experiments to determine if proficiency or exposure modulate cross-structural priming in the model. We further investigate whether modulating effects such as these are the same in simultaneous and sequential bilingual models. These types of population differences might shed light on conflicting behavioral results on the modulating effect of proficiency, which is found in some studies (Favier et al., 2019) but not others (Kutasi et al., 2018).

Lin Chen: What can we learn from probabilistic language models about L1 and L2 reading?

This study tested the continuous word-by-word incremental reading processes during L1 and L2 reading, and how L1 background affects L2 reading. Native English speakers, Spanish-English speakers, and Chinese-English speakers (all enrolled in college) were tested for reading texts from the New York Times in a self-paced reading paradigm. Multiple lexical-level and syntactic-level factors (word frequency, lexical predictability, word position, syntactic complexity, and syntactic predictability) and individual differences (language proficiency) were included to assess their effects and interactions in incremental reading.

Probabilistic context-free grammars and n-gram models, trained on a Wikipedia corpus, provided measures of lexical and syntactic predictabilities. We found that: 1) both L1 and L2 reading were sensitive to both lexical- and syntactic-level factors; 2) L1 readers showed a more robust effect of lexical predictabilities than L2 readers; 3) Spanish-English speakers showed patterns more similar to those of native speakers (e.g., sensitivity to word position within a sentence) than did Chinese-English speakers.

The results suggest that the incremental reading processes in L1 and L2 are generally influenced by the same lexical and syntactic factors. Differences were more quantitative than qualitative, reflected in the weights of these factors, which are mediated by language proficiency. We suggest that high-quality lexical and syntactic representations, which are more characteristic of L1 than L2 reading, enable rapid word-to-text integration, taking advantage of predictive opportunities measured by probabilistic language models.

Irene Winther and Yevgen Matusevych: Frequency effects in bilingual language models

To better understand various effects in bilingual language learning, several studies have used language models trained on two languages (e.g., Winther et al., 2021). However, there is mixed evidence on whether such "bilingual" language models are, in fact, good cognitive models of bilingualism. Here, we first test whether bilingual (L1 Dutch and L2 English) LSTM models predict bilingual speakers' reading times better than monolingual English models. We then evaluate our models against empirical findings with bilingual speakers related to the frequency effect (i.e., faster processing of more frequent words).

We use mono- and bilingual LSTM models which correctly predicted cognate facilitation (Winther et al., 2021) and have them compute surprisal values for each word from a bilingual eye-tracking corpus (Cop et al., 2017). First, the correlation between bilingual speakers' L2 reading times and our bilingual models' surprisal is at least as high as with our monolingual models' surprisal. Second, all models exhibit a frequency effect in L1 and L2: lower surprisal is associated with higher word frequency. In our bilingual model, the size of the frequency effect for L2 test data is larger than for L1 test data, matching the results with bilingual speakers from Cop et al. (2015). However, when we compare the mono- and bilingual models' predictions on their respective L1s, we observe a larger frequency effect in the monolingual compared to bilingual model. This result diverges from Cop et al. (2015), who found no difference in the frequency effect size between mono- and bilingual speakers in L1.

Taken together, our findings suggest that whilst LSTM models trained on two languages can predict some effects in bilingual language processing, they do not always predict the data better than their "monolingual" counterparts. Therefore, such models may not fully capture the specifics of human bilingualism, and care should be taken when deriving conclusions about bilingual learning and processing from such models.

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