

Decoding Language Switching in the Bilingual Brain: evidence from simultaneous speech and sign production

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Abstract:

For a bilingual individual, every utterance requires a choice about which language to use. For people who speak two languages, switching from one language to another inherently means that they concurrently turn one language “off” and the other “on”. This simultaneousness has made it impossible to answer a fundamental question about bilingual language control: are these two actions directed by the same set of control processes or is there a fundamental difference between the “off” and “on” procedures involved in switching? In this experiment we separated these two computations by having American Sign Language (ASL) - English bimodal bilinguals switch between producing ASL, English or both simultaneously (code-blending). Additionally, given recent evidence suggesting that bilinguals use proactive control to prepare for the upcoming language, we targeted whether we could decode language before lexical retrieval started. Our results showed that turning languages on and off relies on two independent processes and that distinct activity can be found for different languages even before lexical access processes are initiated. In all, our results provide crucial evidence to understand the processes involved in bilingual language representation, switching, and control.

Keywords: language switching; bilingual language representation; MEG.

The ability to switch languages is a unique aspect of bilingualism. While this phenomenon has been the object of a significant amount of research (e.g., Blanco-Elorrieta & Pykkänen, 2016; Crinion et al., 2006; Meuter & Allport, 1999), crucial questions regarding language control processes could not be answered because the bilinguals in these studies used two spoken languages (“unimodal” bilinguals). For these bilinguals, language switching involves suppression of the non-target language (turning “off” a language) while simultaneously activating the target language (turning “on” a language). In this experiment we asked: are the switching on and off

processes inherently intertwined such that the same neural mechanisms underlie both?

In order to answer this question we had 21 native ASL – English bilinguals perform a picture naming language-switching task where they switched between producing English, ASL, or both languages simultaneously (code-blending). This design allowed us to tease apart the processes involved in turning a language on (when going from ASL or English into a code-blend (CB)) or turning a language off (when going from a CB to ASL or English).

Methods

MEG data were collected at NYU NYC using a 157 channel axial gradiometer system (Kanazawa Institute of Technology, Kanazawa, Japan). MEG data were recorded at 1000Hz (200Hz low-pass filter) and epoched from 100 ms before the language naming cue to 500 ms after picture onset. Noise was reduced via the continuously Adjusted Least-Squares Method, and artifact rejection was performed as in previous work (Blanco-Elorrieta & Pykkänen, 2016).

For each within-subject analysis, we implemented a five-fold cross-validation procedure. Within the cross-validation, MEG signals were normalized for each classifier separately. Stratified cross-validation balanced the proportion of each switch/language type in each fold. A linear support vector machine (SVM) for each fold and at each time point was then fitted on 4/5 of the trials (i.e., the training set). Each SVM aimed at finding the hyperplane (i.e., the topography) that best discriminated switch/language type at each time sample. This analysis captures evoked activity phase-locked to the beginning of trial. We then computed classification accuracy by testing an independent test set (1/5). The SVM outputted a categorical (i.e., discrete) prediction for each tested language or switch type). Lastly, to equalize the contribution of each of these categories in the definition of the hyperplane, a sample weighting procedure was applied in proportion to the classes. All multivariate analyses were performed with the open-source modules MNE-Python (www.martinos.org/mne/stable/index.htm) and Scikit-Learn (<http://scikit-learn.org>).

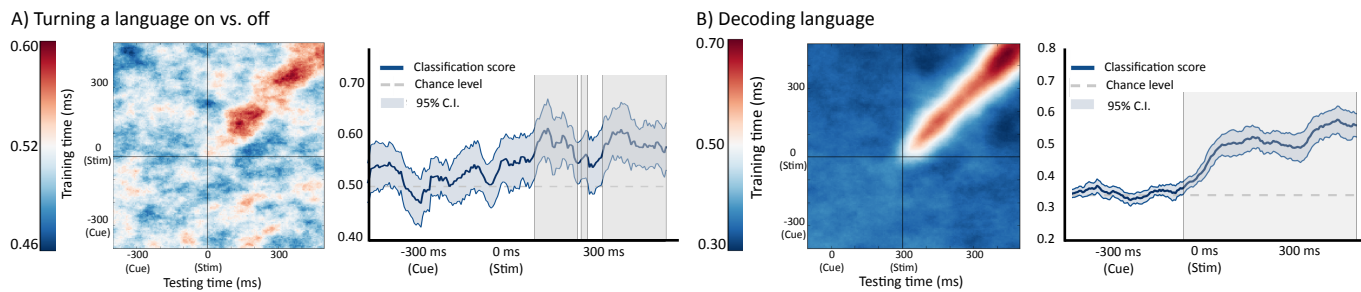


Figure 1. Classification accuracy for A) Predicting whether a language was turned “on” or “off” and B) the language(s) that were produced. In both (A) and (B), the panels on the left show classifier accuracy trained and tested at every time point and the panels on the right show classifier accuracy for the diagonal of the matrix (i.e., when the classifier was trained and tested on the same time point).

Statistical tests to assess the reliability of our classification accuracy were conducted as follows. Mean and standard deviation of the classifier at each time point were estimated over classifier accuracy over participant distribution. Then, we contrasted mean accuracy of the classifier at each time point against classification chance level using a one-sample t-test. Correction for multiple comparisons over time was applied as specified in Benjamini and Hochberg (1995). We report as reliably classified activity the first time-point in a sequence of at least 10 consecutive time-points for which classification accuracy significantly differed from chance level at an alpha of $p < .05$ after correction for multiple comparisons. Confidence intervals (95%) for the sample classification mean accuracy were constructed over subject accuracy distribution.

Results

Figure 1A shows significant decoding of turning a language on vs. off starting at 110 ms after picture presentation and lasting up until 230 ms, then again 245 – 265 ms and 315 to 490 ms. Figure 1B shows significant decoding of the language produced (English, ASL or Code-blends) across trials, starting 360 ms after language cue presentation (40 before picture presentation) and lasting until the end of the trial.

Discussion

Our results show that even though some flavor of language control has to mediate both turning a language “on” and turning a language “off,” the neural underpinnings of these two processes are different, and they start to diverge ~100 ms after a to-be-named picture is presented. This finding has important implications for models of bilingual language control, since it shows that two distinct, parallel, processes take place during language switching. This result challenges basic assumptions of the inhibitory control model as it posits that inhibition of the non-target language may only account for half of the processes involved during language switching. The results from the language decoding analysis show that bilinguals can successfully

utilize proactive control to prepare for the upcoming language before lexical retrieval processes start. However, given that our experiment included a condition in which both languages were simultaneously produced, it is unclear to what extent this proactive control is utilized to apply inhibition to the non-target language (Thierry & Wu, 2017). It is also possible that proactive control is used for (re)activation of the target language or to direct attention to the correct lexicon.

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