The Neural Correlates of Individual Differences In Bilingual Language Control

Brianna L. Yamasaki, Andrea Stocco, and Chantel S. Prat

Department of Psychology, University of Washington, Seattle, USA
Institute for Learning and Brain Sciences, University of Washington, Seattle, USA

Introduction

To successfully manage two languages, bilinguals must recruit additional control mechanisms.

Based on previous research (e.g., Crinion et al., 2006; Friederici, 2006; Hernandez et al., 2015), in a recent review, we proposed that these control mechanisms involved a network of fronto-striatal regions in which the striatal nuclei work as a gating system to route appropriate signals to the prefrontal cortex during language use (Stocco et al., 2012).

In the current investigation, we hypothesized that individual differences in bilingual language control would relate to the functioning of the fronto-striatal network.

Methods

An fMRI investigation of bilingual language control was conducted using a language- and task-switching semantic decision paradigm.

In addition, to quantify individual differences in language and general cognitive abilities, participants completed a standardized reading test in English (L2 = English for 15/18 years) and general cognitive abilities, participants completed a language use questionnaire and psychometric tests (Day 1). The full semantic decision paradigm in the fMRI scanner (Day 2).

Participants completed three sessions over the course of two days:
1. A series of language use questionnaires and psychometric tests (Day 1).
2. A behavioral practice session of the semantic decision paradigm (Day 1).
3. The full semantic decision paradigm in the fMRI scanner (Day 2).

Participants included bilinguals who were highly proficient in two or more languages and had learned both of their languages before adolescence (mean L2 age of acquisition = 4.08 years). A total of 18 bilinguals (9 females, mean age = 20.39 years) completed all 3 sessions and were included in these analyses.

fMRI Procedures

Materials
- 160 concrete, highly imageable nouns
- Divided equally between two languages and two semantic tasks (represented by different colors)

Experimental Design
- Block Design
- Conditions: No Switch (repeat language, repeat task)
- Task Switch (repeat language, switch task)
- Language Switch (switch language, repeat task)
- Double Switch (switch language, switch task)

Imaging Analyses

Images were corrected for slice acquisition timing, motion-corrected, normalized, co-registered, and smoothed to decrease spatial noise and accommodate for individual differences in anatomy. Statistical analyses were performed on individual and group data using the general linear model as implemented in SPM8.

Results

Results revealed:
1. Highly overlapping networks, including the fronto-striatal loop, were recruited during both language switching and task switching conditions (Figure 2).
2. Individual differences in English proficiency were positively correlated with greater recruitment of the putamen (part of the striatal regions) and bilateral prefrontal regions during language switching (Figure 3).
3. Individual differences in English proficiency were also positively correlated with greater recruitment of the striatal and bilateral prefrontal regions during task switching, when language input remained stable.

Importantly, these relations remained significant even when working memory capacity was controlled for using a simultaneous multiple regression.

Conclusions

These results demonstrate that fronto-striatal regions are involved in both language and more general control mechanisms.

Additionally, the results suggest that bilingual individuals with better language proficiency recruit reliably more of this network under conditions that engage control mechanisms.

Taken together, these findings support the hypothesis that the fronto-striatal network is important for bilingual language control.

References