Language dominance and code-switching cost: fMRI data from Chinese EFL speakers

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Background: Switching between languages during word production provides a window into how bilinguals regulate lexical access. In inhibitory-control accounts (e.g., the Inhibitory Control Model [1]) and the Neurocognitive Language Control Model [2, 3], switching from a dominant L1 into a weaker L2 should be more demanding than the reverse direction, because in the former scenario the cognitive system must both select L2 and actively suppress L1, leading to an asymmetry in switch costs. Behavioural evidence for this asymmetry is mixed [4–6], especially in relatively skilled L2 learners. Here we test whether the asymmetry is more robustly expressed as a neural cost during picture naming, and whether this cost scales continuously with individual language dominance. Using a relatively large fMRI sample of English as a foreign language (EFL) learners (L1 Chinese), we ask (i) whether L1⟶L2 switching elicits stronger activation than L2⟶L1 switching in the bilingual control network, and (ii) how the magnitude of this neural cost is predicted by dominance variables (age of acquisition, perceived dominance, and test-based proficiency).

Method: We analysed a subset of a publicly available fMRI dataset [7] of college-level Chinese EFL learners (original N = 77; five excluded due to corrupted images), yielding 72 participants, all right-handed with normal/corrected vision and no reported neurological/psychiatric history. Participants completed a cued bilingual picture-naming task (using black-and-white drawings). Each trial presented a fixation cross (0.3 s), a black screen (0.2 s), then a picture framed by a coloured square (red/blue) that cued response language (Chinese vs English; cue–language mapping counterbalanced). The picture remained for 1 s, followed by a white screen (1–4 s).

Behavioural measures were naming RTs and error rates for switch and non-switch trials in each language. fMRI analyses were conducted in SPM12 (MATLAB), with standard first-level modelling of condition onsets and a second-level whole-brain contrast of L1⟶L2 (forward) > L2⟶L1 (backward) switching. Clusters were reported using a conventional threshold ($p < .001$, FWE-corrected; minimum 10 voxels). To examine individual differences, we extracted BOLD activation from six key regions central to language control and speech production (ACC, left inferior frontal cortex, left caudate, left supramarginal gyrus, left insula, left precentral gyrus). Dominance variables included CET-4 English test scores, age of acquisition for English (AoA), and a perceived dominance index based on rating scores in each language (the ratio between English and Chinese).

Results and discussion: Behaviourally, both languages showed reliable switch costs (switch > non-switch), but forward versus backward switch costs did not differ robustly, and error rates were low and comparable across switch directions. In contrast, fMRI revealed a clear asymmetry in neural effort: forward switching (L1⟶L2) elicited stronger activation than backward switching (L2⟶L1) across a distributed control-and-production network, including ACC/pre-SMA (conflict monitoring), left inferior frontal cortex and left precentral/premotor regions (selection and speech planning), and a large subcortical cluster spanning caudate/putamen/thalamus/insula. Critically, the magnitude of this neural switch cost showed a dominance-linked gradient: later AoA and stronger L1 dominance were associated with larger activation differences, whereas objective proficiency explained comparatively little variance. Together, these results suggest that bilingual word production can recruit additional control resources to maintain behavioural performance, and that language dominance here is best conceptualised as multidimensional: age-based and self-perceived dominance variables track neural control demands more sensitively than a test-based proficiency score.

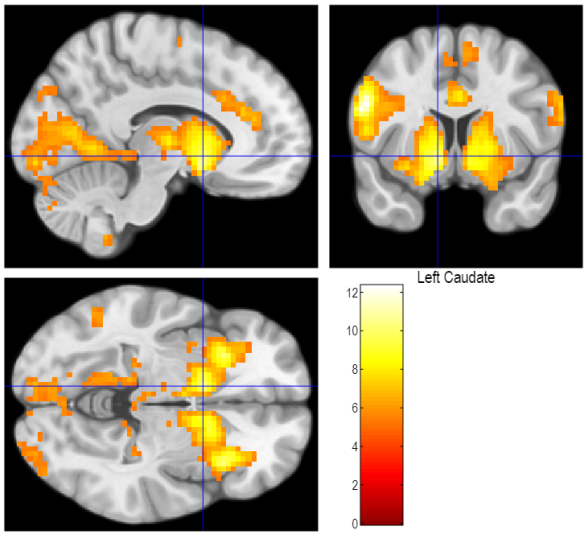

Figure 1: Neural activation as shown in the second level (group) analysis. Forward switching (naming in one's L2 when the previous trial was in their L1) led to higher neural activation than the opposite direction.

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