Language Distance Drives Adaptive Effects in the Anterior Cingulate Cortex in Bilinguals

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Introduction

- The Adaptive Control (AC) hypothesis (Green and Abutalebi, 2013) posits that the neural network of language control, necessary for correct language output in bilinguals, can adapt to specific environmental demands, either via changes in neuronal responsivity, network connectivity and/or structural capacity.
- We suggest that language distance can also place differential demands on such language control processes resulting in adaptive effects in the neural substrates of language control.
- To test this hypothesis, we used an er-fMRI word translation task on ***bilinguals whose language pairs represented distinct levels of linguistic distance***, operationally defined at the word level as the extent of L1-L2 script similarity and phonological overlap: ***Dutch-English*** (DE; low distance: same script/high phonological overlap), ***Hindi-English*** (HE; intermediate distance: different script/some phonological overlap) and ***Cantonese-English*** (CE, high distance: different script/no phonological overlap) (Fig. 1).
- As per the AC model we expected that bilinguals with linguistically close languages should incur greater cross-linguistic conflict and interference than their counterparts whose two languages are linguistically further apart. This in turn should be associated with ***increased anterior cingulate cortex (ACC, linked to conflict monitoring) activity for a low distance group like DE in comparison to groups like HE and CE***.

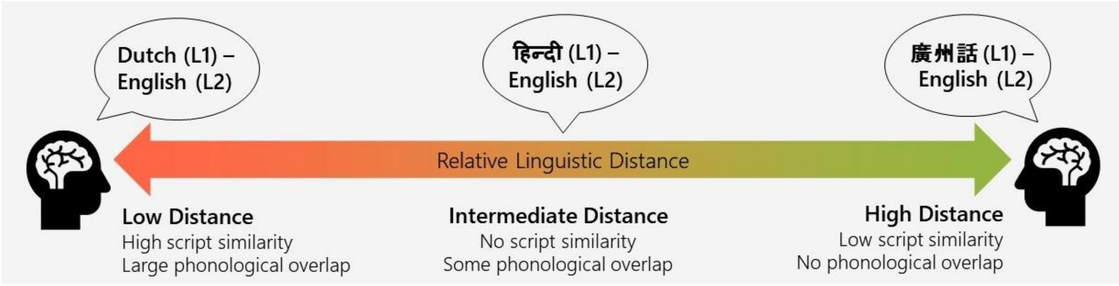

Fig 1. Bilinguals participants of the study with low, intermediate and high distance L1-L2 pairs represented on a relative language distance continuum.

Methods and Materials

Participants

- Right-handed, neurologically normal native Cantonese (n=19, mean age = 21.95±1.78), Hindi (n=19, mean age = 21.37±2.27) and Dutch (n=20, mean age = 21.75±2.07) bilinguals with high proficiency in English (L2) and adequate dual language experience participated. All three groups had comparable years of education and socioeconomic status.

Task

- In the scanner, participants performed mixed language runs of visual word translation (TRAN) and word reading (READ). All stimuli were nouns matched for frequency and cognates/homographs were excluded. L2-English stimuli were identical for all groups (Fig. 2)

Data Analysis

- After standard preprocessing in SPM12, a 3 x 2 x 2 factorial model with factors Group (CE/HE/DE), Task (word reading/translation) and Input Language (L1/English) was estimated at the 2nd level.
- An F-contrast of the main effect of i). Translation, ii). Backward translation condition (English→L1) and iii). Reading were assessed
- Results were thresholded at $p < .001$ (uncorrected) at the voxel level with cluster-level FWE (family-wise error) correction of $p < .05$. Only clusters with atleast 100 contiguous voxels were considered significant.

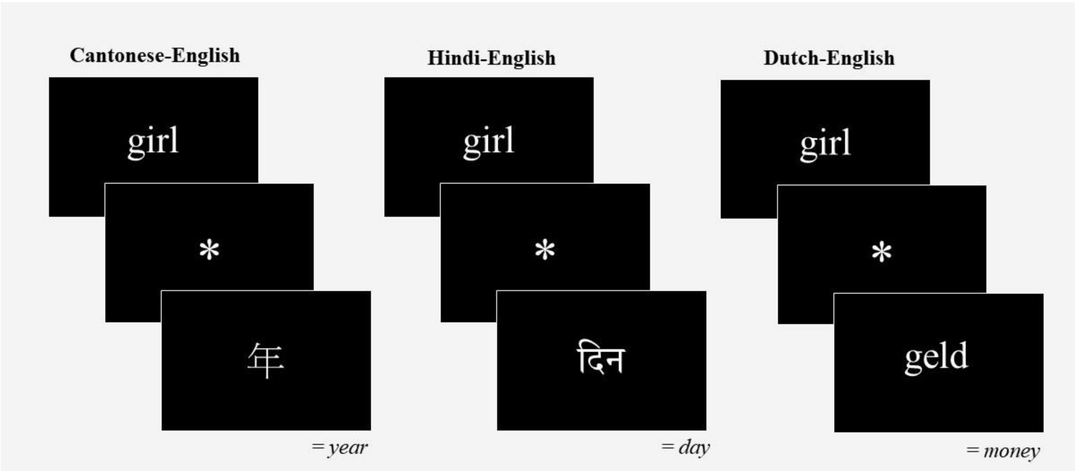

Fig 2. Examples of stimuli presented to CE, HE and DE bilinguals during TRAN/READ

Results

i. The F-contrast testing for differential activity across the groups during TRAN (regardless of input language) revealed ***significant differences in the ACC (x =12, y = 16, z = 40)*** (Fig. 3).
ii. The F-contrast for translating English words into L1 (controlling for input stimuli) revealed a significant differential activity amongst the groups in the same ACC cluster (x =12, y = 17, z = 38) (Fig. 3).
iii. Main effects of Group during READ showed no differential activity in regions associated with cognitive control across the groups.
iv. BOLD estimates from an independently derived ACC ROI (Abutalebi et al, 2012) showed a significantly higher activation for DE than CE ($p < .001$). (Fig. 4)

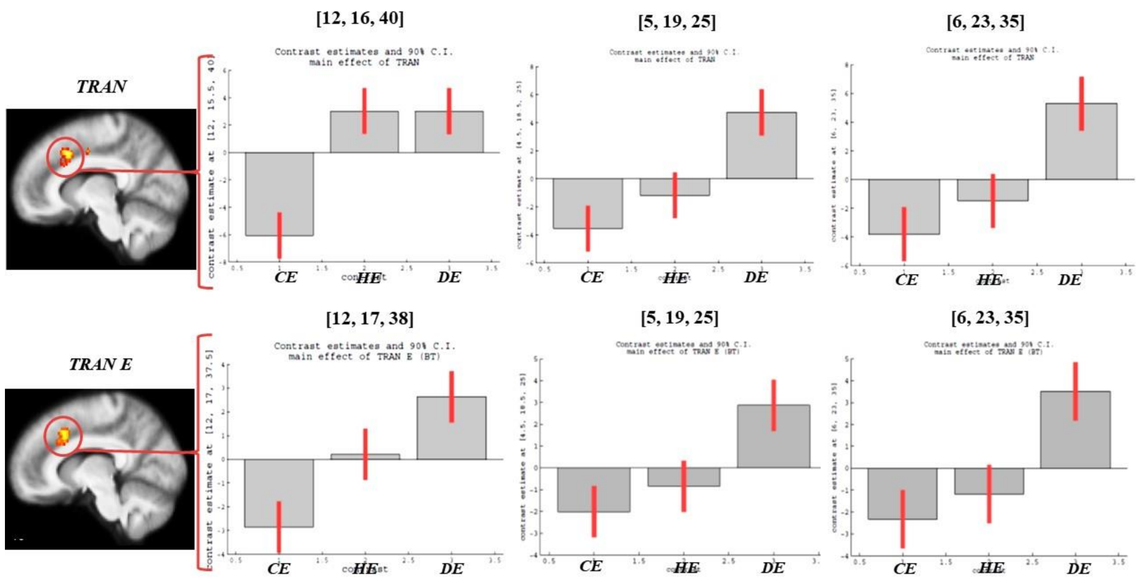

Fig 3. Contrast estimates plotted at voxels of the ACC cluster (BA 32/24) that showed significant differential activity during TRAN (top panel) and during TRAN E (bottom panel) across the three groups. Differential activity in ACC cluster during TRAN (top left) and TRAN-E (bottom left) has been overlaid on 3-group averaged structural image.

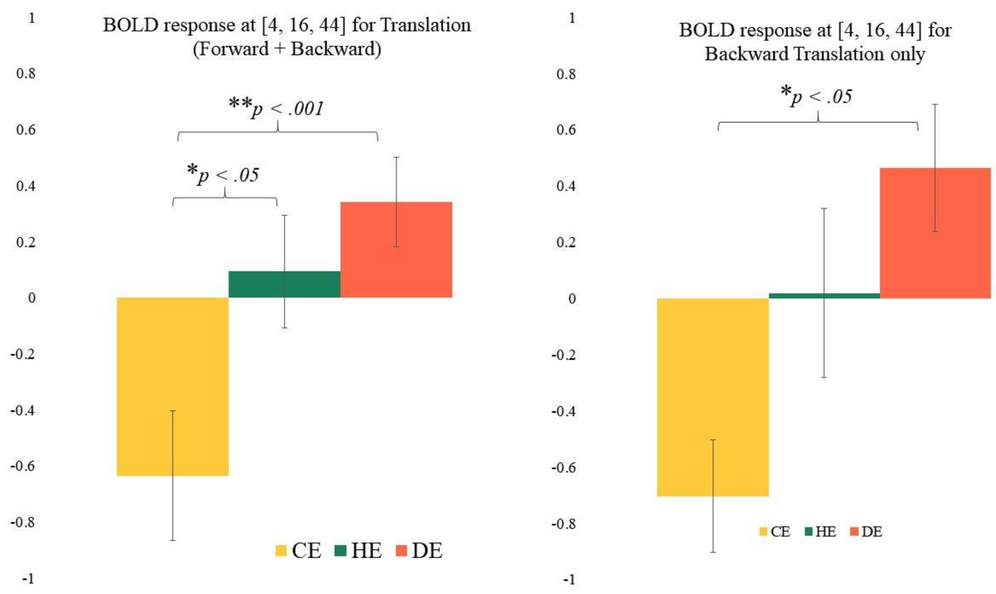

Fig 4. Effect sizes with for BOLD response at 8mm ACC ROI centred at x = 4, y = 16, z = 44. Error bars represent SE.

Discussion

- As predicted, ACC activity, during word translation increases with decreasing L1-L2 language distance. ACC activity is significantly higher for the low distance DE bilinguals compared to the high distance CE.
- The increased conflict that only low-distance DE bilinguals seem to face during word translation was reflected as greater involvement of the ACC in order to successfully perform the same task compared to the intermediate distance HE and high distance CE groups.
- For the HE and CE groups, given that their languages are linguistically further apart and have comparatively greater distinguishing features, there is lesser cross-linguistic co-activation and conflict to manage.
- Consequently, bilinguals with more distant languages elicited lesser engagement of the conflict management region for the same linguistic task.

Conclusion

- Taken together, these results suggest that language distance can influence conflict monitoring/ACC activity in bilinguals. The ACC adapts to the conflict control demands generated by language distance during tasks requiring language control.
- The results of this study may be taken as emerging evidence of ***language distance being a potential modulating factor*** (like relative proficiency, AoA etc.) that can influence language control demands and indirectly induce adaptive neural changes in bilinguals.

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Key References

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