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The neuroprotective effects of bilingualism upon the inferior parietal lobule: A Structural Neuroimaging Study in Aging Chinese Bilinguals

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A B S T R A C T

It is a timely issue to understand the impact of bilingualism upon brain structure in healthy aging and upon cognitive decline given evidence of its neuroprotective effects. Plastic changes induced by bilingualism were reported in young adults in the left inferior parietal lobule (LIPL) and its right counterpart (RIPL) (Mechelli et al., 2004). Moreover, both age of second language (L2) acquisition and L2 proficiency correlated with increased grey matter (GM) in the LIPL/RIPL. However it is unknown whether such findings replicate in older bilinguals. We examined this question in an aging bilingual population from Hong Kong. Results from our Voxel Based Morphometry study show that elderly bilinguals relative to a matched monolingual control group also have increased GM volumes in the inferior parietal lobules underlining the neuroprotective effect of bilingualism. However, unlike younger adults, age of L2 acquisition did not predict GM volumes. Instead, LIPL and RIPL appear differentially sensitive to the effects of L2 proficiency and L2 exposure with LIPL more sensitive to the former and RIPL more sensitive to the latter. Our data also intimate that such

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differences may be more prominent for speakers of languages that are linguistically closer such as in Cantonese-Mandarin bilinguals as compared to Cantonese-English bilinguals.

1. Introduction

How does using more than one language affect the human brain? Evidence of the protective effects of bilingualism in delaying the onset of symptoms of Alzheimer's disease (e.g., Alladi et al., 2013; Craik, Bialystok, & Freedman, 2010) and mild cognitive impairment (Bialystok, Craik, Binns, Ossher & Freedman, 2014) make understanding the impact of bilingualism of great neuroscientific and public interest. One of the brain areas prone to neuroplastic changes induced by bilingualism, and key to our investigation, is the left inferior parietal lobule and its right counterpart (Mechelli et al., 2004).

In humans the inferior parietal lobule (IPL) contributes to linguistic, attentional and action-related functions (Caspers et al., 2011; Iacoboni, 2005). Its functional diversity is reflected in its structural segregation with distinct connectivity patterns. At a macroanatomical level, IPL may be divided into the supramarginal gyrus (i.e., the antero-superior part of the IPL) and the angular gyrus (i.e. the more postero-inferior portion of the IPL). In the left hemisphere, the more caudal portion of the LIPL (left inferior parietal lobule) is active during language-related tasks with a focus on semantic and phonological issues (Price, 2012; Vigneau et al., 2006). LIPL is also engaged during verbal short-term memory tasks (Wise et al., 1991; Zatorre, Evans, Meyer, & Gjedde, 1992) and in attentional tasks when revaluating conflicting choice options (Rushworth, Paus, & Sipila, 2001), and more generally in task related attention processing (Muller et al., 2003; Todd & Marois, 2004).

Earlier research based on clinical observations in bilingual aphasia implicated the left parietal lobe as critical to bilingual language processing. Indeed, in the 1920s the German neurologist Pötzl (1925) postulated that area PGa in the LIPL, i.e., the anterior angular gyrus, hosts a switch mechanism allowing voluntary transition between the bilingual's languages. Indeed Kauders (1929) labeled the resulting clinical outcome following damage to this area as a ‘polyglot reaction’ and Leischner (1948) labeled this area as a multilingual talent area. More recent theoretical work (Abutalebi & Green, 2007; Green & Abutalebi, 2013) supports the relevance of left parietal regions in the maintenance and implementation of task representations during bilingual language production. Such task representations have to be held on-line for the control process in order to achieve correct language output in the target language. Consistent with these notions, Della Rosa et al. (2013), in a longitudinal study of very young trilingual speakers, showed that grey matter density in the angular gyrus, correlated with language competence and skill in resolving non-verbal conflict. Here we are specifically interested in following up earlier work indicating the relevance of this region to lexical processing in bilingual speakers.

In a study of young bilingual and monolingual adults, Mechelli et al. (2004) were the first to show that language proficiency correlated positively with GM density in a left posterior supramarginal gyrus region (left pSMG) of the LIPL with a weaker effect in the homologous right hemisphere region. Within bilingual speakers, they also found that the age of second language (L2) acquisition correlated inversely with GM density in this region. Later work showed that the very same region was in fact specifically sensitive to vocabulary knowledge in monolingual adolescents (Lee et al., 2007) but not in monolingual adults (Richardson, Thomas, Filippi, Harth, & Price, 2010). In a study of young bilingual and multilingual adults, complementing that of Mechelli et al., 2004, and supporting the relevance of vocabulary knowledge as the critical factor, Grogan et al. (2012) using pSMG as a region of interest (ROI), found GM density to be greater in multilingual compared to bilingual speakers though significantly so only for the right pSMG. Noteworthy this effect obtained regardless of whether a speaker's native language was a European or an Asian language. However, in contrast to Mechelli et al. (2004), Grogan et al. (2012) report no effects of age of L2 acquisition in this right hemispheric ROI for bilingual speakers though,