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Cortical thickness increases after simultaneous interpretation training

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ABSTRACT

Simultaneous interpretation is a complex cognitive task that not only demands multilingual language processing, but also requires application of extreme levels of domain-general cognitive control. We used MRI to longitudinally measure cortical thickness in simultaneous interpretation trainees before and after a Master's program in conference interpreting. We compared them to multilingual control participants scanned at the same interval of time. Increases in cortical thickness were specific to trainee interpreters. Increases were observed in regions involved in lower-level, phonetic processing (left posterior superior temporal gyrus, anterior supramarginal gyrus and planum temporale), in the higher-level formulation of propositional speech (right angular gyrus) and in the conversion of items from working memory into a sequence (right dorsal premotor cortex), and finally, in domain-general executive control and attention (right parietal lobule). Findings are consistent with the linguistic requirements of simultaneous interpretation and also with the more general cognitive demands on attentional control for expert performance in simultaneous interpreting. Our findings may also reflect beneficial, potentially protective effects of simultaneous interpretation training, which has previously been shown to confer enhanced skills in certain executive and attentional domains over and above those conferred by bilingualism.

1. Introduction

There is growing interest in understanding the brain's structural changes, or plasticity, arising from bilingualism (García-Pentón et al., 2014; Klein et al., 2014; Li et al., 2014; Mechelli et al., 2004; Ressel et al., 2012; Stein et al., 2012) and from training in language-specific domains, such as phonetics (Golestani et al., 2011; Vandermosten et al., 2015) and simultaneous interpreting (Elmer et al., 2014; Elmer et al., 2011). A growing number of cross-sectional (Klein et al., 2014; Li et al., 2014; Mechelli et al., 2004; Olulade et al., 2015; Ressel et al., 2012) as well as some longitudinal (Schlegel et al., 2012; Stein et al., 2012) studies on bilingualism have reported structural findings in regions including the left inferior parietal cortex, the auditory cortex, the inferior frontal gyri bilaterally and in regions involved in polyglot language control (Abutalebi and Green, 2007, 2008; Hervais-Adelman et al., 2011). However, the results are relatively heterogeneous and diverse (Golestani, 2014), perhaps due to differences in populations, brain imaging sequences and brain imaging analysis approaches across studies (García-Pentón et al., 2015; Higby et al., 2013).

Beyond work on language acquisition and bilingualism, previous work on language expertise has shown grey (Golestani et al., 2011) and white matter (Vandermosten et al., 2015) differences between phonetics experts and controls in the auditory cortices bilaterally and in the left pars opercularis. These regions belong to the dorsal, audio-motor stream that subserves audio-motor mapping of sounds onto articulatory-based representations, rather than to the ventral meaning integration interface (Golestani, 2015; Golestani and Pallier, 2007; Hickok and Poeppel, 2004, 2007; Rodriguez-Fornells et al., 2009; Saur et al., 2008). Moreover, among the phoneticians there was a correlation between years of phonetics transcription training and grey and white matter properties of these regions, suggesting experience-dependent plasticity in relation to this relatively low-level form of linguistic expertise (Golestani et al., 2011; Vandermosten et al., 2015).

Simultaneous interpreting (SI), by contrast, is a linguistic task that involves higher-level (i.e. phonetic but also semantic, syntactic and prosodic) linguistic processing and extensively taps cognitive control

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Table 1
Characteristic information and comparison of control group and trainee interpreters. P-values reported for the between-groups comparisons are derived from chi-square or *t*-tests, as appropriate for ratios or continuous measures.

	N	F:M	LH:RH	Site1:Site2	Interscan interval in years (stdev)	Age at baseline in years (stdev)	NLang (stdev)	LEXP (stdev)	Prof score (stdev)	AoA score (stdev)	L2 Acq S:E:L
Controls	33	19:14	04:29	13:20	1.11 (.11)	25.7 (5.27)	4.09 (1.35)	32.94 (8.86)	13.63 (3.48)	19.30 (5.82)	7:10:16
SI Trainees	34	19:15	03:30	12:22	1.13 (.06)	26.03 (4.39)	4.62 (1.13)	37.18 (8.37)	14.88 (3.52)	22.35 (5.15)	12:7:15
Between-groups difference (p)	–	.796	.545	.607	.252	.78	.088	.048*	.15	.027*	.349

Abbreviations: N=number, F=female, M=male, LH=left-handed, RH=right-handed, NLang=number of languages reported, LEXP=language experience and proficiency score, AoA =age of acquisition, Prof=proficiency, L2 Acq=age of acquisition of the first second language, S=simultaneous (in the first year after birth), E=early (up to six years old), L=Late (after six years old)

* Denotes a significant difference between the groups.

mechanisms that are not specifically linguistic in nature. Listening to continuous prose in one language while simultaneously converting and producing the narrative in another language requires real-time processing of a source input, whilst simultaneously transposing the content of that input to a target language, monitoring production of that output, whilst maintaining access to and control over the relevant phonetic, semantic, syntactic and prosodic rules of both source and target languages. Interpreters listen to source language input while producing target language output for an average of 65% of their time on task. In order to monitor their output in the target language interpreters need to listen to it, while simultaneously listening to newly arriving input in the source language. Thus, success at simultaneous interpretation depends not only on outstanding processing speed and excellent verbal working memory skills, but also on the ability to simultaneously comprehend and produce speech in two oftentimes structurally very dissimilar languages, while also monitoring one's output and continuously translating it in real-time (Moser-Mercer et al., 1997). Consistent with this, a recent functional magnetic resonance imaging (fMRI) study has shown that simultaneous interpretation recruits brain networks associated with speech comprehension and production such as the left inferior frontal gyrus, auditory and posterior temporal and temporo-parietal regions, alongside regions involved in more domain-general functions such as task-switching, conflict resolution, and inhibition; functions that have previously been implicated in language control. These latter regions included the anterior cingulate cortex and a thalamo-striatal-cerebellar network (Hervais-Adelman et al., 2015b).

Two recent structural brain imaging studies have investigated grey (Elmer et al., 2014) and white matter (Elmer et al., 2011) in professional simultaneous interpreters. Unlike the trainee interpreters studied by Hervais-Adelman et al. (2015a, 2015b) described above, these two studies featured highly experienced professionals. Elmer and colleagues (Elmer et al., 2014) revealed lower grey matter volumes in the interpreters compared to control participants in the left pars opercularis and supramarginal gyrus (SMG), in the middle-anterior cingulate gyrus, and bilaterally in the pars triangularis and middle-anterior insula. Within the interpreters groups, the grey matter volume in a subset of these regions (the left pars triangularis, right pars opercularis and middle-anterior cingulate gyrus) and in the bilateral caudate nucleus was negatively correlated with the cumulative number of interpreting hours. These findings likely reflect experience-dependent structural plasticity in these language-related and cognitive control regions, although some of the differences may have predated the training (Elmer et al., 2014) and may thus reflect possibly innate, domain-specific aptitudes (c.f. Golestani et al., 2011).

In the present study, we examined cortical thickness changes arising from simultaneous interpretation training longitudinally, before and after our participants undertook a Master's program in conference interpreting. The longitudinal nature of our design allows for greater sensitivity to training-related changes, and mitigates against many confounding effects of cohort (Fitzmaurice et al., 2011). Due to the fact that many studies have reported positive relationships between behavioural measures and regional measures of thickness and/or volume (Blackmon et al., 2010; Foster and Zatorre, 2010; Golestani, 2014; Li et al., 2014; Wong et al., 2010), we predicted that we would find training-related increases in cortical thickness in brain regions responsible for speech production and comprehension, in ones involved in language and cognitive control, and in attentional regions. These include fronto-temporo-parietal regions, motor and premotor regions, the anterior cingulate gyrus and subcortical regions, and right superior parietal attentional regions. We expected structural modifications to at least partly converge in terms of localisation with brain regions previously found to be functionally involved in simultaneous interpreting (Hervais-Adelman et al., 2015b) and in language control (Hervais-Adelman et al., 2011), and in regions found to differ structurally between interpreters and controls by others (Elmer et al., 2014, 2011).

2. Methods

2.1. Participants

Sixty-seven individuals participated in the study. Of these, 34 were trainee interpreters, and 33 constituted a control group. For logistical reasons, participants were scanned at either of two imaging centres (see below), but all scans for a given individual always took place on the same scanner / at the same centre. The trainee interpreters were enrolled in the Master's program in conference interpreting at the Faculty of Translation and Interpreting at the University of Geneva, Switzerland. The control participants were university students undertaking post-graduate studies in a range of disciplines other than the fields of interpretation, translation or modern languages. All participants were required to be multilingual and reported mastering a minimum of three languages (Table 1). Research was carried out in accordance with the Declaration of Helsinki and approved by the research ethics committees of the Lausanne and Geneva University Hospitals. Participants gave informed consent and were free to withdraw from the study at any time. They were remunerated for their participation.

Characteristic data associated with the two groups are shown in Table 1. The groups were matched for age and gender. Both groups contained a small number of left-handed individuals (assessed using the Edinburgh handedness inventory Oldfield, 1971). Since trainee interpreters are a scarce population, we elected to be inclusive in our participant selection, and to account for this by including a matched proportion of left-handed individuals in the control group. It should be noted that since this is primarily a within-subjects design, we would not expect any particular influence of handedness on the results, especially since the proportions are matched across groups.

At baseline, both groups were scored on a compound measure of language experience and proficiency, as assessed by interview. This measure is described in Golestani et al. (2011), and was calculated as