Multilingualism and cognitive reserve: Evidence from cortical thickness and tissue density

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Introduction

According to the cognitive reserve hypothesis (CR; [1]), certain lifestyle factors (e.g., physical activity) can have beneficial effects on cognitive functioning that protect against brain damage. The CR hypothesis predicts that dementia patients with higher CR would demonstrate greater brain pathology while still performing at the same level as their lower CR counterparts,. This has been demonstrated for level of education (e.g., [2]). The degree to which multilingualism protects against the onset of dementia by contributing to cognitive reserve remains controversial (e.g., [3, 4]; for a review see [5]). A recent study by Schweizer and colleagues ([6]), using several linear measures of atrophy derived from CT scans, found greater atrophy in a sample of bilingual Alzheimer disease (AD) patients compared to age- and symptom-matched monolingual patients. The current study attempts to replicate these findings in participants with AD and extend them to participants with Mild Cognitive Impairment (MCI), using MRI-derived cortical thickness (Ct) grey matter density (GMd).

A second set of analyses attempted to control for the potential confound of immigration status. To do so, we focused on a subgroup of MCI patients (monolingual vs. multilingual) who were non-immigrant native speakers.

Methods

Participants

- Patients were recruited from the Memory Clinic at the Jewish General Hospital (Montréal)
- Diagnosis was made using agreed-upon diagnostic criteria (MCI:[7] AD: [8]).
- Exclusion criteria: Left-handedness, progression to non-Alzheimer dementia, reversion to non-cognitively impaired status (i.e., no longer met criteria for MCI)
- Language group was determined at neuropsychological interview and followed criteria set out by Bialystok and colleagues [9].
- Critically, monolingual and multilingual language groups were matched on: age at time of scan, symptom severity (Mini Mental status Examination), and years of education.

Table 1

	MCI					AD				
	Monolinguals N=34		Multilinguals N=34			Monolinguals N=13		Multilinguals N=13		
	mean	se	mean	se	*p*	mean	Se	mean	se	*p*
Age at scan	73.62	0.88	73.71	1.00	*.95*	78.53	1.50	78.02	1.45	*.81*
Age at Symptom Onset	67.89	1.06	67.74	1.26	*.93*	74.31	1.55	72.62	1.64	*.46*
MMSE at scan	26.68	0.40	27.59	0.34	*.09*	22.54	0.85	22.54	1.04	*1.00*
Education (yrs)	12.5	0.67	12.29	0.66	*.83*	12.69	0.96	12.08	1.11	*.68*

MRI

- Anatomical T1 weighted MRI sequences were acquired using a Siemens Sonata 1.5 T scanner
- Structural images submitted to the CIVET pipeline [10].
- Cortical thickness (Ct) at each vertex calculated using the *tlink* method, providing measurement in mm at each vertex [11].
- Grey matter density was computed at each voxel using voxel-based morphometry.

Regions of interest

ROIs were selected based on one of three conceptual frameworks. That is, we selected ROIs based on literature that either: 1) demonstrated neuroanatomical and/or cognitive differences between monolingual and bilingual brains and/or cognitive abilities (e.g., [12, 13]), 2) were brain regions associated with classical language processing brain areas (e.g., [14]); or 3) were brain regions associated with early change in MCI and AD (i.e., medial temporal regions; e.g., [15]). Within each ROI, the specific vertex or voxel chosen for analysis in the linear regression was chosen based on either a) specific coordinates reported in the published literature (when available) or the named functional or anatomical brain region, or b) guided by the results of our global regression analyses.

Statistical Analysis

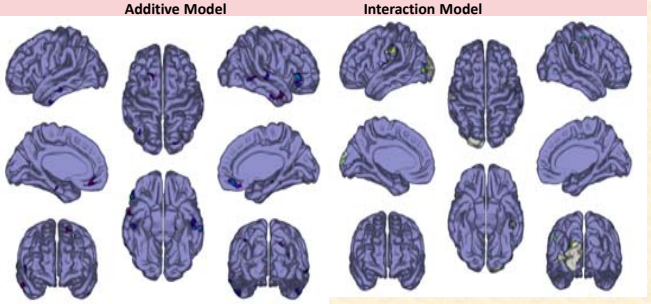
-Regressions with the dependent variable (DV) being native-space cortical thickness for the Ct analyses, and voxel-level gray matter density for the VBM analyses.

-DV regressed onto a number of predictor variables, which included age (at time of the scan), Language Group (monolingual or multilingual), and Diagnostic Group (at time of scan, MCI or AD).

Results

Cortical Thickness

Additive Model **Interaction Model**



Significance of the Language Group term alone, using an uncorrected threshold of (*p*=0.01). T-statistic colour mapping values range between 2.68 and 4.00

Significance of the Language Group by Diagnosis Group interaction, using an uncorrected threshold of (*p*=0.05). T-statistic colour mapping values range between 2.00 and 2.25

Table 2. Additive Model

Multilingualism Brain Areas

Brain Area	MNI coordinates	Brodmann	Language Group		Diagnostic Group	
			t	p	t	p
Right Inferior Frontal Gyrus	55, 30, 0	45	3.26	.002	0.35	.729
Left Rostral Temporal Gyrus	-51, -10, -40	20	2.98	.004	-1.74	.086
Right Rostral Temporal Gyrus	55, 5, -31	38	2.72	.008	-1.57	.120
Left Superior Frontal Gyrus	-6, 31, 41	08	2.67	.009	0.45	.651
Left Inferior Parietal Cortex	-39, -69, 47	39	2.98	.004	-1.19	.239
Right Ventromedial Prefrontal Cortex	33, 44, -15	10	3.28	.001	-1.11	.269

Table 3. Interaction Model

Language Brain Areas

Brain Area	MNI coordinates	Brodmann	Language Group		Diagnostic Group		Interaction	
			t	p	t	p	t	p
Left Supramarginal Gyrus	-59, -26, 35	40	2.61	.010	1.86	.066	-2.51	.014
Right Supramarginal Gyrus	62, -37, 40	40	1.65	.103	1.13	.263	-2.24	.027
Left Inferior Temporal Gyrus	-46, -27, -25	20	2.13	.036	0.87	.389	-2.34	.021

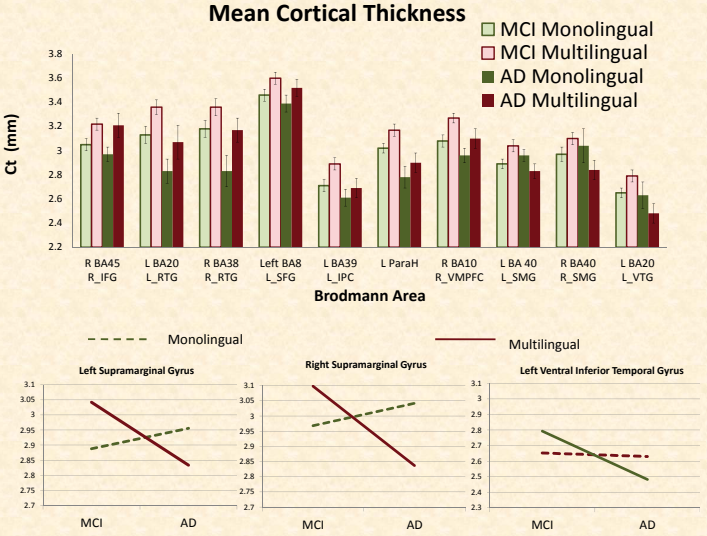
Table 4. Additive Model

Alzheimer Disease Atrophy

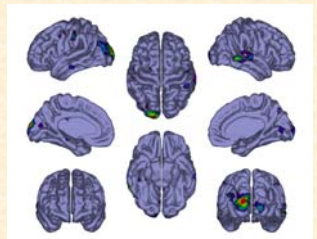
Brain Area	MNI coordinates	Brodmann	Language Group		Diagnostic Group	
			t	p	t	p
Left Rostral Parahippocampal Gyrus	-18, -20, -24	P_H	2.89	.005	-2.83	.006

Table 5. VBM Interaction

Brain Area	Language Group		Diagnostic Group		Interaction	
	t	p	t	p	t	p
Left Rhinal Sulcus	2.21	.029	1.8	.075	-2.45	.016
Right Rhinal Sulcus	1.12	.265	1.07	.289	-2.07	.041
Right Caudal Parahippocampal Gyrus	1.72	.089	1.3	.195	-3.13	.002
Left Caudal Parahippocampal Gyrus	1.62	.11	1.46	.148	-2.7	.008



Native MCI Only



Significance of the Language Group term alone, using an uncorrected threshold of (*p*=0.01). T-statistic colour mapping values range between 2.70 and 4.50

	Native MCI				
	Monolinguals N=27		Multilinguals N=14		
	mean	se	mean	se	*p*
Age at scan	73.52	1.02	72.47	1.68	*.58*
Age at Symptom Onset	67.89	1.05	68.79	1.84	*.97*
MMSE at scan	26.59	0.47	27.86	0.46	*.09*
Education (yrs)	12.41	0.77	12.57	0.99	*.90*

We investigated the cortical regions shown in Tables 2-4 in the Native MCI only group . Findings were replicated in the following regions: R_IFG, L_RTG, R_RTG, L_SFG, L_IPC (*p* = .001- .023) or were trends in the same direction (R_VMPFC, *p* = .065).

Discussion

We compared monolingual and multilingual patients who were carefully matched within diagnostic group. We observed a main effect of language status (i.e., thicker cortex in multilinguals versus monolinguals) for brain areas that have been previously reported as differing between these groups (Table 2). This result was still obtained after controlling for immigration status, as demonstrated by our findings for the MCI-only participants who were bilingual native-born Canadians.

Interestingly, for language related areas (Table 3) and medial temporal areas associated with Alzheimer's disease (Table 5), the interaction model was significant. That is, we found evidence for generally *larger* cortex in multilinguals compared to monolinguals in patients with MCI; however, the pattern reversed for AD patients such that multilinguals had *smaller* cortical thickness values. This finding provides evidence for cognitive reserve because multilingual AD patients who were matched to their monolingual counterparts (age of symptom onset, MMSE) exhibited greater evidence of cortical atrophy despite similar global presentation. It is important to note that this pattern was observed cross-sectionally; we would require a longitudinal study to conclude that MCI multilinguals who initially show greater cortical thickness would then exhibit a steeper loss of cortical tissue than their monolinguals counterparts when they decline to dementia.

References

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