Role of perisylvian white matter microstructure on speech perception difficulties in aging

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Introduction

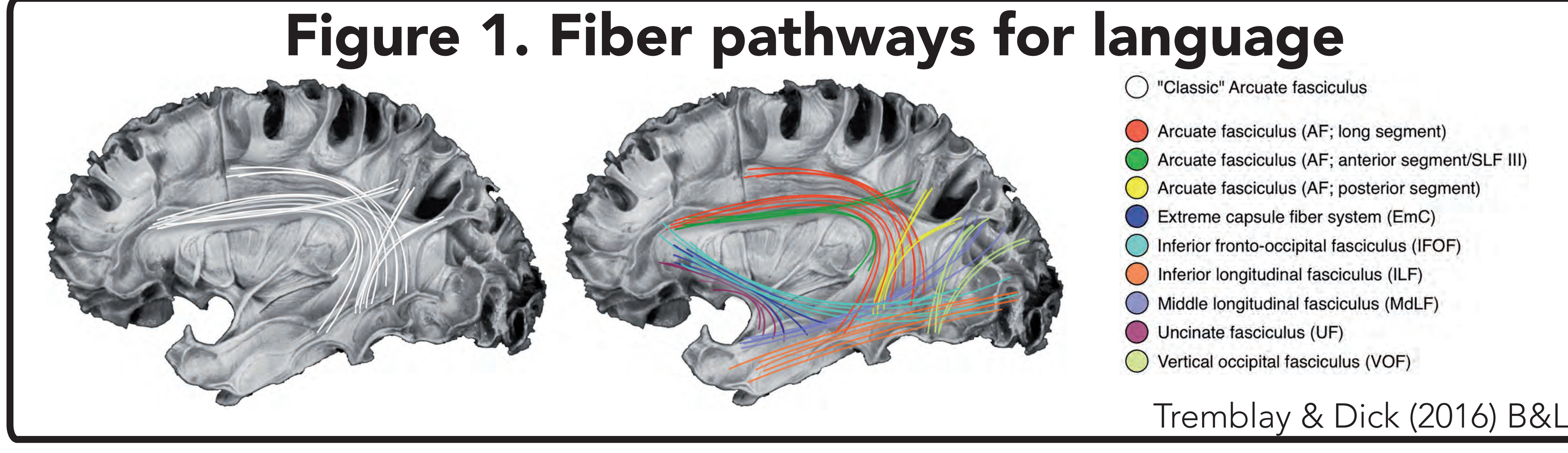
Over the course of the life span, the human brain undergoes significant white matter (WM) changes. Such changes have been linked with cognitive decline in aging. One such decline is the ability to perceive speech in the presence of noise. Traditionally seen as related to hearing loss, it is now known that speech perception difficulties occur even in those with normal hearing, suggesting a central cause.

The objective of this study is to examine the relationship between WM aging and speech perception decline.

Our hypothesis is that age-related difficulties perceiving speech in noise are related to age-related differences in the microstructural properties of the white matter tracts of the perisylvian region (Fig. 1).

To test this hypothesis, we used High Angular Resolution Diffusion Images (HARDI) with advanced tractography methods to investigate aging of two perisylvian WM fascicles that are thought to be involved in speech and language functions: the arcuate fasciculus (AF) and the middle longitudinal fasciculus (MdLF).

Figure 1. Fiber pathways for language

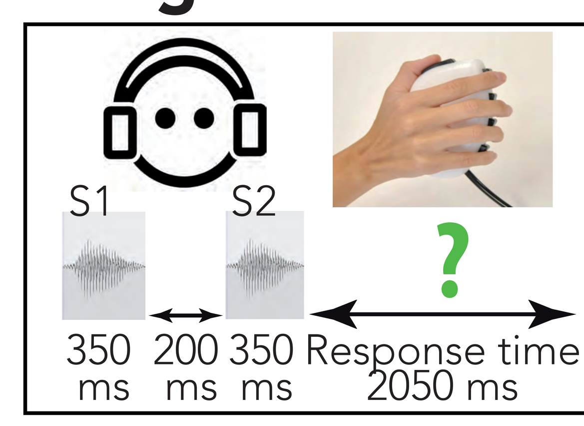


Tremblay & Dick (2016) B&L

Table 1. Participants

Age group	Younger (N=14; 5F)			Older (N=15; 3F)		
	M	SD	Range	M	SD	Range
Age	29.43	10.49	19-46	71.93	5.85	65-84
Handedness	83.78	18.27	50-100	96.24	8.87	68.42-100
Education (years)	16.92	2.34	13-21	16.40	4.60	10-30
GDS	3.79	3.68	0-12	2.53	3.07	0-8
MOCA	28.57	1.09	27-30	27.47	1.68	25-30
Right ear PTA	4.95	9.58	1-37	13.76	8.21	3-32
Left ear PTA	3.00	8.24	4-29	15.64	9.74	2-43
SRT	27.04	8.56	15-52	41.50	7.74	30-55

Figure 2. Task



Methods

Participants. 14 young and 15 older healthy right-handed adults (Table 1).
Tasks. Hearing (pure tone thresholds or PTA) and cognitive evaluations (MOCA) (Table 1). Speech perception: auditory syllable pairs discrimination with fricative (e.g. /sa/) and stop (e.g. /ta/) consonants (Fig. 2).
Image acquisition and preprocessing. Philips 3T Achieva TX: MPRAGE (1 mm3); HARDI sequence (TR = 8,5 ms; TE = 76.7 ms; b=1500 s/m2, 60 directions, 128 volumes, no gap, 1.8 mm). Preprocessing using Freesurfer (Fig. 3) and FSL.
Tractography. Tractography computed using DIPY (Descoteaux et al., 2008; Garyfallidis et al., 2014). (Desikan et al., 2006) and the « White Matter Query Language (WMQL) » (Wassermann et al., 2016). Two tracts: (1) **AF** (anterior, posterior and direct tracts) and (2) **MdLF** (one tract connecting the temporal pole (TP) to the inferior parietal lobule (IPL) and one connecting TP to the superior parietal lobule (SPL) (Makris et al., 2013) (Fig. 1).
Statistical analyses. ANCOVAs were run to examine the impact of aging on the AF and MdLF using tract volume, DTI metrics (FA, MD, RD and AD) and more robust ODF metrics (Nufo and AFD) (Fig. 4-5). A moderation analysis framework (Fig. 6A) was used to establish whether WM differences in AF and MdLF contribute to age-related decline in the perception of speech in noise. Results are presented in Fig. 6B.

Figure 3. T1 image processing

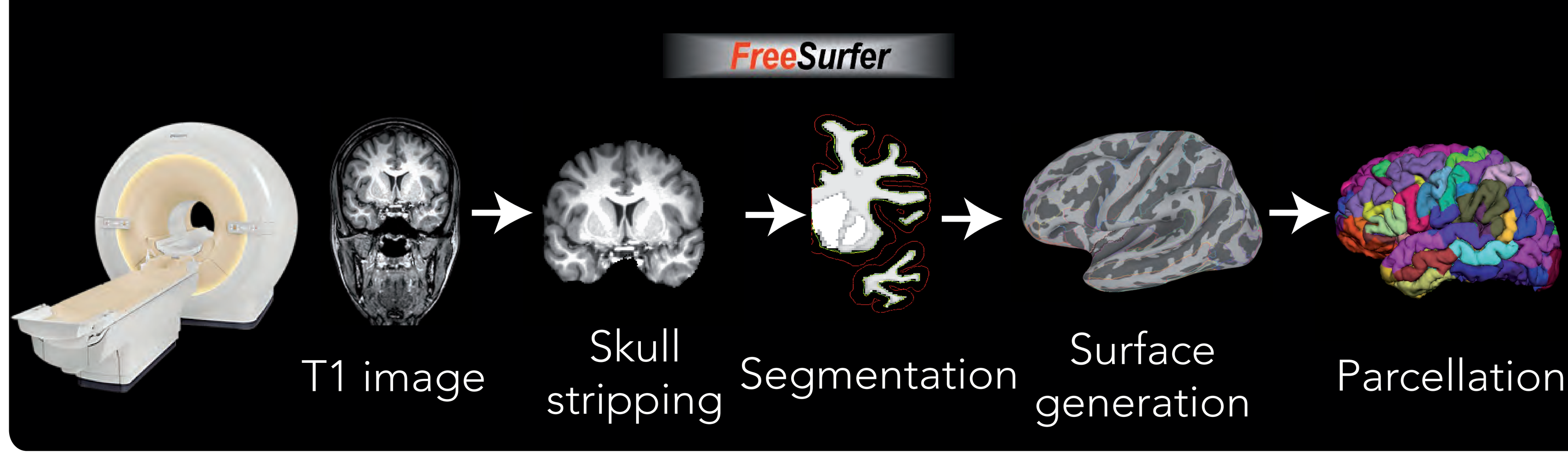
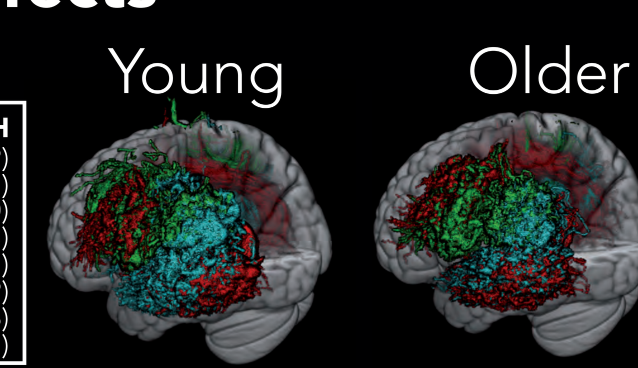


Figure 4. Age effects

A. AF

Metrics	Group	Segment	Hemi	G x S	G x H	S x H	G x S x H
FA	.036[a] (.17)[b]	.026 (.141)	.323 (.041)	.072 (.104)	.331 (.039)	.521 (.027)	.386 (.039)
RD	.653 (.008)	.013 (.154)	.334 (.034)	.034 (.122)	.436 (.023)	.978 (.001)	.260 (.051)
MD	.023 (.182)	.008 (.171)	.148 (.079)	.375 (.037)	.660 (.008)	.377 (.037)	.510 (.020)
AD	.570 (.015)	.010 (.190)	.342 (.041)	.012 (.182)	.228 (.050)	.023 (.158)	.081 (.108)
Volume	.437 (.023)	.942 (.002)	.364 (.032)	.001 (.261)	.138 (.083)	.138 (.083)	.839 (.007)
NuFO	.219 (.065)	.086 (.101)	.058 (.148)	.002 (.245)	.140 (.092)	.264 (.056)	.194 (.069)
AFD max	.354 (.045)	.085 (.121)	.975 (.001)	.056 (.141)	.228 (.076)	.479 (.038)	.722 (.016)
AFD total	.077 (.141)	.761 (.013)	.099 (.124)	.170 (.081)	.737 (.005)	.872 (.007)	.788 (.011)

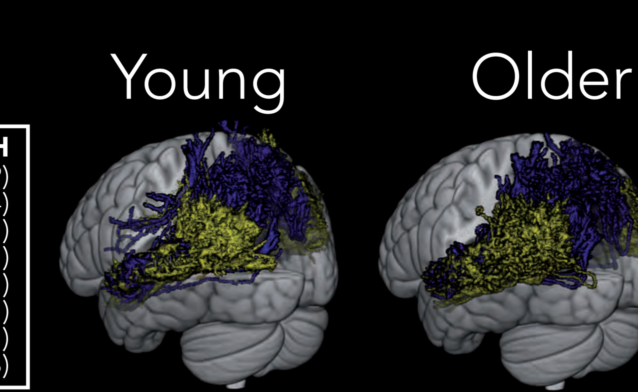
a. p-value b. effect size



B. MdLF

Metrics	Group	Segment	Hemi	G x S	G x H	S x H	G x S x H
FA	.008[a] (.24)[b]	.009 (.231)	.460 (.021)	.015 (.208)	.850 (.001)	.620 (.010)	.628 (.009)
RD	.580 (.012)	.082 (.112)	.157 (.076)	.829 (.002)	.528 (.016)	.091 (.106)	.135 (.084)
MD	.035 (.166)	.333 (.037)	.010 (.238)	.008 (.248)	.508 (.018)	.440 (.024)	.054 (.141)
AD	.111 (.116)	.058 (.160)	.453 (.027)	.002 (.362)	.947 (.001)	.039 (.187)	.233 (.067)
Volume	.076 (.116)	.501 (.018)	.505 (.017)	.460 (.021)	.061 (.128)	.951 (.001)	.887 (.001)
NuFO	.040 (.171)	.748 (.005)	.258 (.055)	.007 (.279)	.897 (.001)	.714 (.006)	.300 (.047)
AFD max	.795 (.003)	.498 (.019)	.785 (.003)	.014 (.226)	.475 (.002)	.648 (.009)	.980 (.001)
AFD total	.164 (.090)	.420 (.031)	.175 (.086)	.087 (.133)	.393 (.035)	.279 (.055)	.694 (.008)

a. p-value b. effect size



Results

Figure 5. Subject data

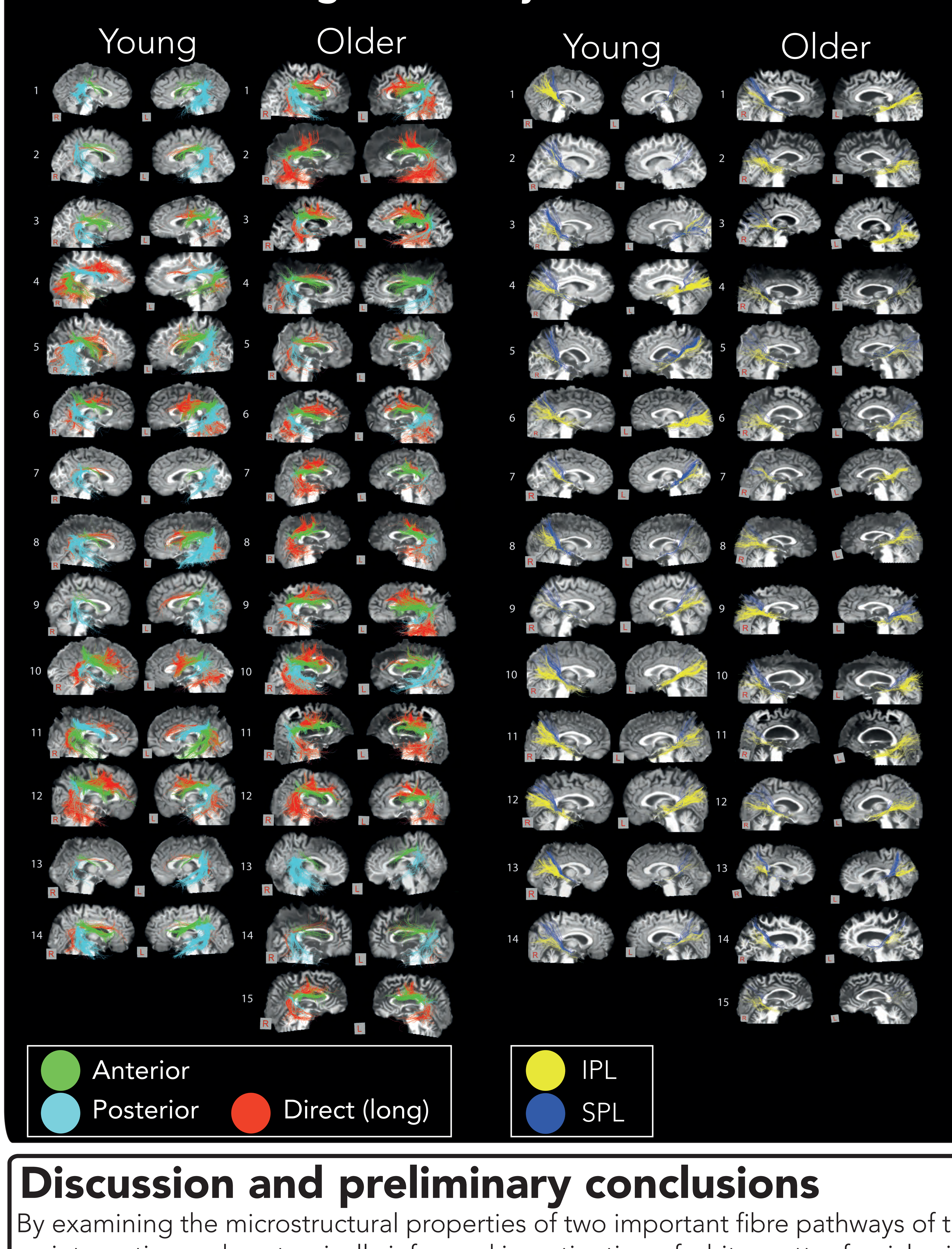
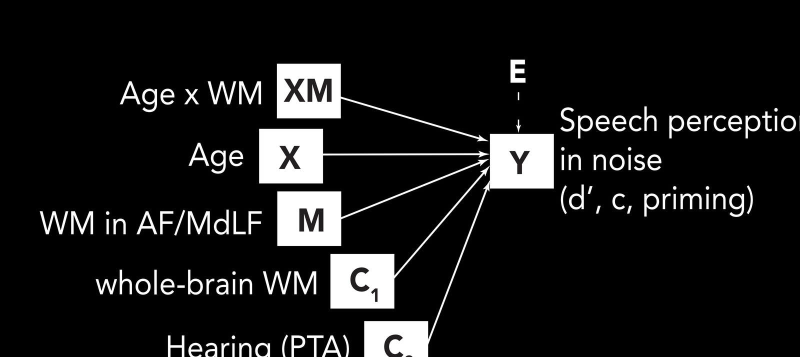


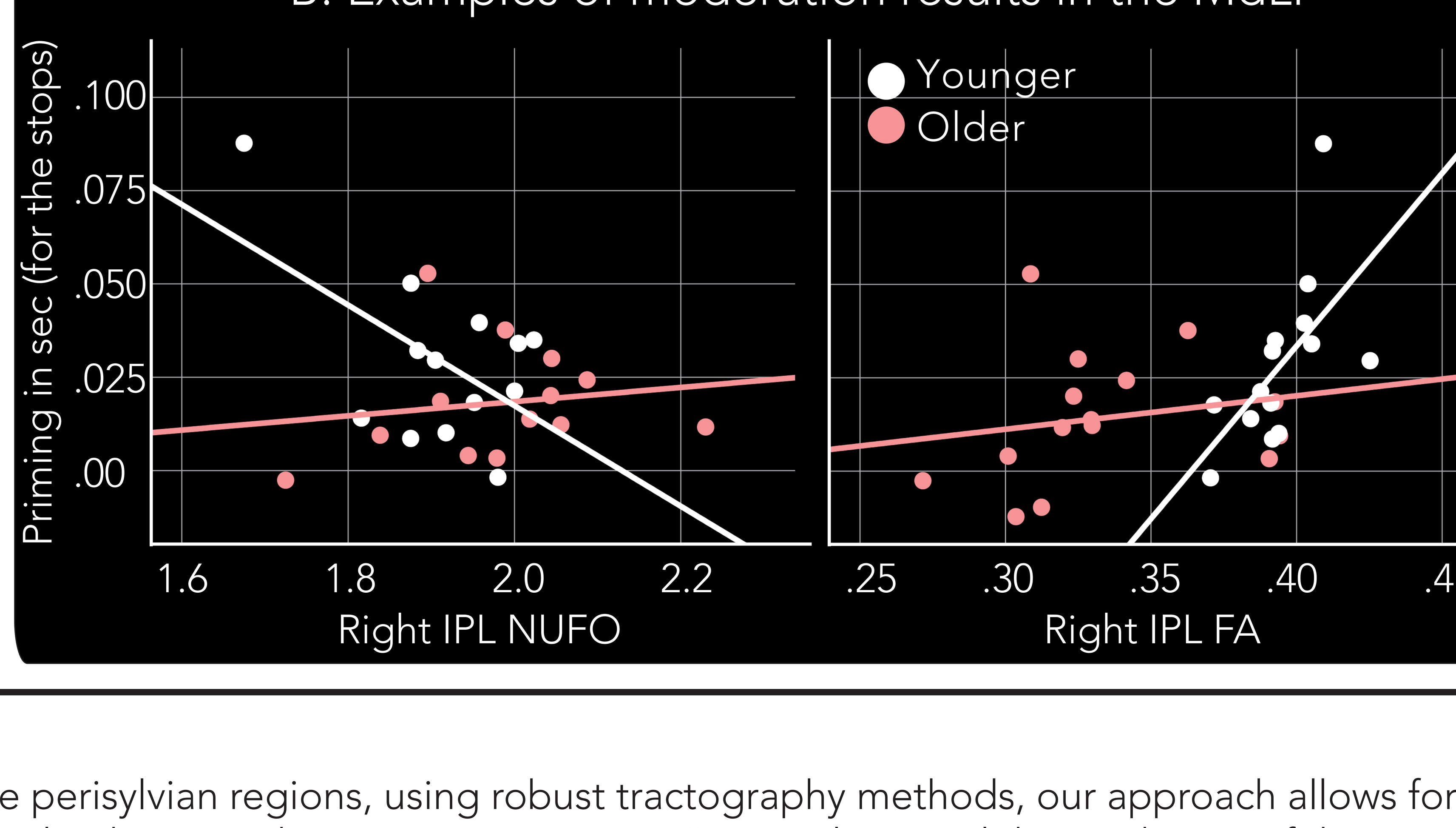
Figure 6. Moderating effects on speech perception

The moderation analyses show that age differences in WM microstructure are associated with the perception of speech in noise, as measured in terms of sensitivity (d') and phonological repetition priming, in particular for the perception of stop consonants. We found that speech perception was moderated by WM in the bilateral IPL tract (AFD max, FA, NuFO), left direct AF tract (MD, AD) and right Anterior AF tract (FA). Different moderation patterns were found; two of them are illustrated below.

A. Statistical moderation model



B. Examples of moderation results in the MdLF



Discussion and preliminary conclusions

By examining the microstructural properties of two important fibre pathways of the perisylvian regions, using robust tractography methods, our approach allows for an integrative and anatomically informed investigation of white matter fascicles involved in speech perception in noise. Our results reveal that pathways of the perisylvian region decline with normal aging (Figures 4 & 5) and that this decline contributes to age-related speech processing difficulties, particularly in terms of reduced phonological priming (Figure 6), which suggests a complex contribution of both phonological and cognitive processes. To our knowledge this is the first study to reveal a relationship between these pathways and speech perception performance in cognitively healthy older adults.

References

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