



Recruiting the “right” hemisphere in foreign language learning in ageing brain— Evidence from diffusion-MRI

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Introduction

Hemispheric Asymmetry Reduction in Older Adults (HAROLD)

- a less lateralised frontal activity during cognitive performance in response to age-related neurocognitive decline (Cabeza, 2002)

Our foreign language learning (FLL) studies

- previous:** observed structural evidence in T1-weighted image (Fong et al., 2022)
- present:** aimed to obtain converging evidence from diffusion-weighted image

Hypothesis

- The commissural (**corpus callosum, CC**) or right-hemispheric association fibres (**arcuate fasciculus, AF**; **uncinate fasciculus, UF**) are more strongly associated with FLL performance of older than younger adults.
- CC:** supporting interhemispheric communication; shown to grant older adults a performance advantage in bilateral tasks (Reuter-Lorenz & Stanczak, 2022)
- AF:** a major dorsal pathway supporting phonological and syntactic processing
- UF:** a ventral pathway supporting semantic processing

Method (I)

Participant

- 48 (older:** 13F/12M, mean age: 65.1; **younger:** 12F/11M, mean age: 23.4) cognitive-normal Cantonese-English bilinguals matched in years of education

Experiment

- three-month Italian learning programme:** The **vocabulary** and **grammar** learning performance were evaluated every three lessons and in a final test.

Data acquisition

- diffusion image:** multi shell sequence ($b=1500$ & 3000 s/mm²; direction=99; voxel size=1.5 mm)

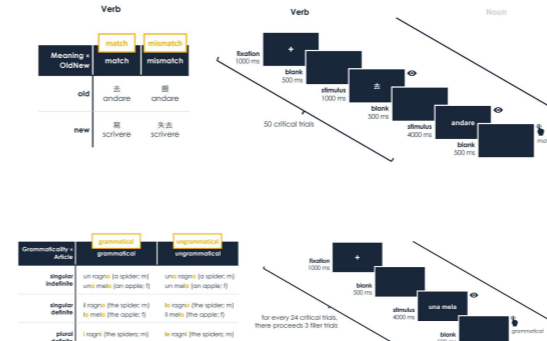
Data analysis

- preprocessing:** DSI studio
- Spearman's correlation:** custom-made Python script
- (generalised) linear mixed-effects modeling:** custom-made R script
- Specific focus was placed on number of tracks (**NT**) and fractional anisotropy (**FA**) of the selected bundles.
- Accuracy (ACC)** served as the main performance metric while reaction time (**RT**) a supporting metric since it is often muddled by processing speed.

Method (II)

Stimulus

- vocabulary:** Cantonese-Italian translation decision test of learnt words (**condition:** old/new × noun/verb × match/mismatch; **trial:** 290)
- grammar:** grammaticality judgement test of determiner-noun phrases (**condition:** singular/plural × definite/indefinite × grammatical/ungrammatical; **trial:** 240)



Result (I): Descriptive statistics

Correlation of learning performance in older adults

- vocabulary:** It is strongly benefitted by a more intact CC, as well as left UF, due to the reliance in cross-hemispheric communication and semantic processing. Yet a more bundled left UF did not contribute to a better learning outcome.
- grammar:** It is negatively influenced by a more bundled left AF and left UF, and also a more intact right UF.

Correlation of learning performance in general

- grammar:** It is negatively influenced by a more intact right UF, indicating the recruitment of semantic-related structure is not helpful to grammar learning, regardless of age.

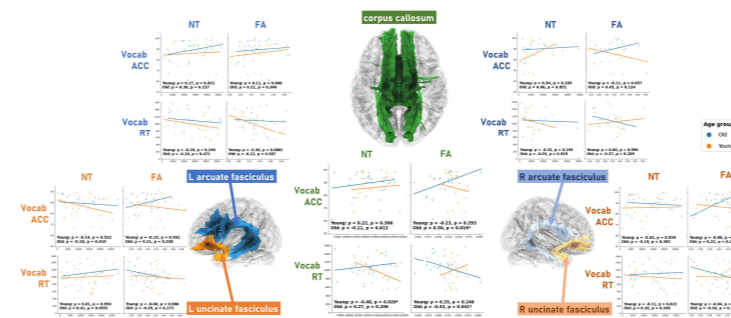


Fig. 1. Spearman's correlation between selected bundles and vocabulary learning performance during lessons among old and young learners, collapsed across conditions (old/new × noun/verb × match/mismatch)

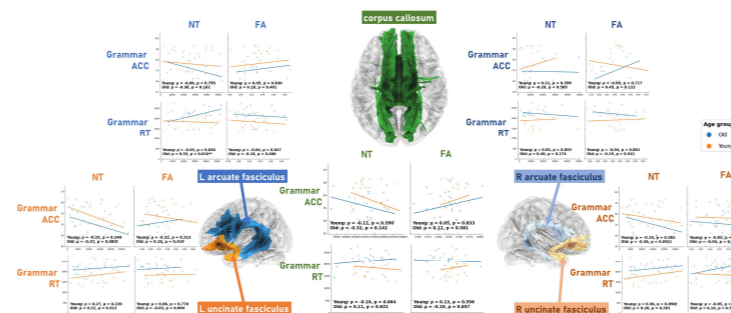


Fig. 2. Spearman's correlation between selected bundles and grammar learning performance during lessons among old and young learners, collapsed across conditions (singular/plural × definite/indefinite × grammatical/ungrammatical)

Result (II): Hypothesis testing

Linear mixed-effects modelling of learning performance

- vocabulary:** NT of almost all selected bundles and FA of right UF and CC showed the strongest improvement in prediction over baseline model.
- grammar:** NT and FA of all bundles significantly improve the prediction.

	NT	FA		NT	FA
L AF	<.001***	.002**	L AF	<.001***	<.001***
R AF	.006**	.183	R AF	<.001***	<.001***
L UF	<.001***	.170	L UF	<.001***	<.001***
R UF	0.005***	<.001***	R UF	<.001***	<.001***
CC	<.001***	<.001***	CC	<.001***	<.001***

Fig. 3. *p* values for likelihood ratio test comparing the extended model against the baseline model on learning performance

Log-odds of learning performance

- vocabulary:** FA of all bundles, including those on right hemisphere, showed higher FA associated with higher odds of better learning performance in all conditions in old learners, vice versa for young learners.

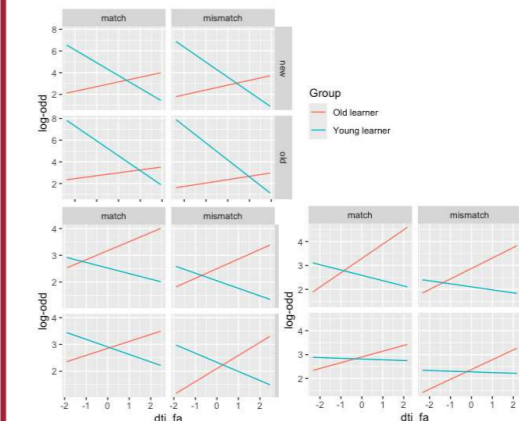


Fig. 5. An interaction plot of FA of CC (top), right AF (bottom left), and right UF (bottom right) against the log-odds of vocabulary accuracy

Discussion

- Vocabulary learning in older adults is facilitated by a more preserved white matter integrity in commissural fibre and bilateral language-related association pathways. However such trend did not reflect on grammar learning.
- The right hemisphere should be incorporated in future neurolinguistic studies on ageing.

Reference

- Cabeza, R. (2002). Hemispheric asymmetry reduction in older adults: the HAROLD model. *Psychology and Aging, 17*(1), 85-100.
- Fong, M. C. M., Ma, M. K. H., Chui, J. Y. T., Law, T. S. T., Hui, N. Y., Au, A., & Wang, W. S. (2022). Foreign language learning in older adults: Anatomical and cognitive markers of vocabulary learning success. *Frontiers in Human Neuroscience, 16*, 787413.
- Reuter-Lorenz, P. A., & Stanczak, L. (2000). Differential effects of aging on the functions of the corpus callosum. *Developmental Neuropsychology, 18*(1), 113-137.