The role of the corpus callosum in dichotic listening: A combined morphometrical and diffusion-tensor MRI study

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Introduction

The commonly observed right-ear advantage (REA) in verbal dichotic listening (DL) can be modulated by instructing subjects to attend exclusively to one ear (forced attention) [1, 2]. Consequently, auditory laterality may be best understood as an interaction of two components: a bottom-up or stimulus-driven component, which favors processing of right-ear input, and a top-down component or process that allows for the attentional modulation of the laterality effect. Recent studies on patients with a severed Corpus callosum (CC) provide evidence that not only the bottom-up REA but also its top-down modulation are related to the functional integrity of the CC [3].

Objectives

The following questions were addressed: (1) Is the auditory asymmetry related not only to macro- but also to microstructural variations of the CC, and (2) does attentional modulation affect this relationship?

Material and Methods

Participants

40 right-handed males (mean age: 23.7 ± 4.1 years); normal hearing (threshold <20 db); interaural threshold difference <15 db

Bergen Dichotic Listening

108 pairs of consonant-vowal (CV)-syllables (e.g., /ba-da/, /ga-ta/), presented via headphones in 3 blocks differing in attentional instruction (NF: non-forced; FL: forced-left attention; FR: forced-right attention); order was interindividually balanced: NF/FR/FL or NF/FL/FR; parameters obtained:

- left (L%) and right ear scores (R%)
- auditory laterality: ALS = (R%-L%)/(R%+L%)
- attentional gain: e.g., LEG = (FL_L%-NF_L%)/NF_L%
- “non-attentional” reduction: e.g., LER = (NF_L%-FR_L%)/NF_L%

Magnetic-Resonance Imaging

Anatomical imaging: T1-weighted SE (TE=14msec, TR = 500 msec); 9 sagittal slices (3mm, no gap); 256 x 256 matrix within a FOV of 256 x 256 mm²

Diffusion-tensor imaging (DTI) in 6 non-collinear directions (b = 600 sec/mm²) multishot EPI (TE = 98 msec, EPI factor: 17); 3 sagittal slices (4 mm, NSA = 16); matrix: 96 x 96; FOV: 128 x 128mm²; reconstr. 128 x 128 matrix; cardiac triggering and navigator echo motion correction; Postprocessing: voxelwise estimation of the diffusion tensor and calculation of the two quantitative parameters fractional anisotropy (FA) and mean diffusion (MD) from the eigenvalues of the tensor (see Figure 1; for an introduction to DTI see Ref. [4])

Measurements of the CC

Cross-sectional area, FA and MD for the total CC and its three subregions: genu, truncus, and posterior third

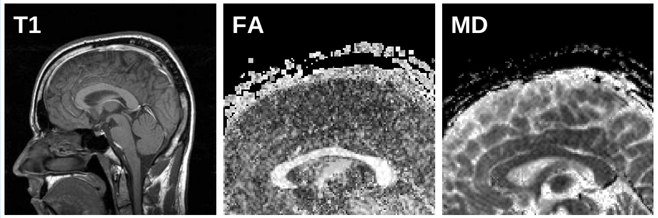
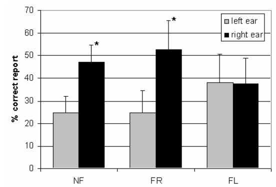


Figure 1. Midsagittal view of the anatomical T1-weighted image and of the two DTI parameter maps: MD is a scalar measure of the overall extent of molecular diffusion. FA reflects the directionality of the diffusion process. Since the diffusion process is impeded by cellular obstacles (like membrane and myelin sheaths), both parameters provide indirect information about microstructural properties of the brain tissue.

Results

DL performance: As shown in Figure 2, a significant REA was found in the NF condition. Forced attention to the right ear further increases the REA while directing attention to the left results in a loss of the ear advantage.

Figure 2. Mean percentage (±SD) of correctly reported syllables presented to the right and the left ear, separated for the three instructions. A 3x2 ANOVA revealed a significant instruction-by-ear interaction ($F_{2,78}$ = 31.72, p < 0.001, η² = 0.45). Post-hoc comparisons showed higher R% than L% in NF and FR but not in the FL condition.



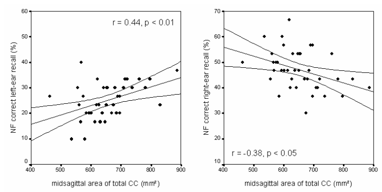


Figure 3. Scatterplots of total callosal area as related to L% and R% in the NF condition. Regression lines and hyperbolic confidence limits (95%) are also depicted

DL and CC macrostructure: For the NF condition negative correlations were found between CC area and R% as well as ALS, while positive associations were present with L% (see Table 1 and Figure 3). Although less strong, a comparable left-positive and right-negative association pattern was found in the FR condition.

Table 1: Product-moment correlations of callosal area measures and auditory performance under NF, FR, and FL attentional instruction

	NF			FR		FL	
	L%	R%	ALS	L%	R%	L%	R%
genu	0.42**	-0.24	-0.42**	0.14	-0.21	0.12	-0.20
truncus	0.40**	-0.38*	-0.48**	0.31^T	-0.38*	0.05	-0.12
pst.3rd	0.38*	-0.44**	-0.49**	0.32*	-0.45*	0.15	-0.23

^{T} p <0.10; * p<0.05; ** p<0.01

DL and CC microstructure: In the NF condition, FA of the posterior callosal third was inversely related to L% (r = -0.40, p < 0.001). With FL instruction, R% was negatively (r = -0.36, p = 0.02) and RER was positively related to MD (r = 0.34, p = 0.02) in the posterior third.

Discussion

- Substantial associations of CC area with ALS, R%, and L% in the NF condition indicate that a stronger interhemispheric connectivity allows increased left-ear and decreased right-ear performance, leading to a reduction in ALS.
- In accordance with Kimura’s structural model of DL, L% was positively related to CC area. The negative correlations with R% were, however, unexpected. It could be speculated that this association is a by-product of a “dual task”-like situation in which the “callosal” left- and “acallosal” right-ear input compete for the same processing resources in the left hemisphere.
- Since DTI-derived measures offer indirect information about brain tissue properties, the negative FA-L% correlation in the posterior third indicates that NF performance is affected by microstructural variability of the CC .
- Finding no correlation of any area or DTI measures with the REG under FR instruction there seems to be only little direct involvement of the CC in this condition.
- Contrary, concerning the FL condition, R% and RER were correlated to MD in the posterior third. Thus, it seems likely that here microstructural variations are of particularly importance, since under FL instruction the top-down modulation works against the built-in REA. However, under FR instruction a callosal involvement might be less important since both top-down and bottom-up component promote superior right-ear performance.

Conclusion

The results indicate a dual role of the CC: it not only subserves the bottom-up transfer of left-ear information to the left hemisphere, but it is also involved in the attentional modulation occurring in the FL condition. As recently proposed [2], these functions may be supported by different callosal channels, one channel consisting of large-diameter axons responsible for rapid interhemispheric transfer of sensory information, and a second channel involving the small-diameter fibers that may modulate the allocation of attention to the left ear.

References

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