Fractional anisotropy of the arcuate/superior longitudinal fasciculus predicts verbal working memory span in a large sample

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Introduction

- Verbal Working Memory (VWM) involves two functional components: *storage* and *rehearsal* (Baddeley, 2012).
- Storage component holds phonological information that is subject to rapid decay; rehearsal component refreshes the stored phonological information through overt or covert articulation (Baddeley, 2012).
- Cortical activations to storage in left posterior parietal regions; cortical activations to rehearsal in left inferior frontal regions (PET: Paulesu et al., 1993; fMRI: Gruber, 2001; Henson et al., 2000); double dissociation of storage and rehearsal in lesion studies (Baldo & Dronkers, 2006).
- Dorsal white matter pathway connecting posterior parietal and inferior frontal areas is assumed to mediate between storage and rehearsal (Baldo et al., 2008; Charlton et al., 2010).
- Arcuate/superior longitudinal fasciculus (AF/SLF) as anatomical link between posterior parietal and inferior frontal areas (tractography studies: Glasser & Rilling, 2008; Catani et al., 2005).

Hypothesis

VWM span as captured by tasks that require the information exchange between rehearsal and storage varies as a function of left AF/SLF fractional anisotropy (FA).

Methods

1 Principal-components analysis and descriptive statistics

	Independent component				Range		*M*	*SD*
	1	2	3	4	Min	Max		
Behavioural measures								
Reading span			0.122	0.989	2	5.5	3.40	0.75
Forward digit span	–0.328	–0.535	–0.778		6	14	9.28	2.08
Backward digit span	–0.310	–0.713	0.614	–0.136	5	13	8.71	2.19
Non-word span	–0.890	0.450			19	35	27.17	3.82
MRI measures								
Left AF/SLF median (FA)					0.43	0.53	0.48	0.02
Whole-white-matter median FA					0.20	0.34	0.27	0.03
Intracranial volume (ml)					1115.44	1931.76	1534.25	170.98

Participants

- 78 healthy adults (39♀; age: *M* 25.2 years, *SD* 3.3 years; right-handed; LQ: *M* 92.2, *SD* 11.8), German native speakers.

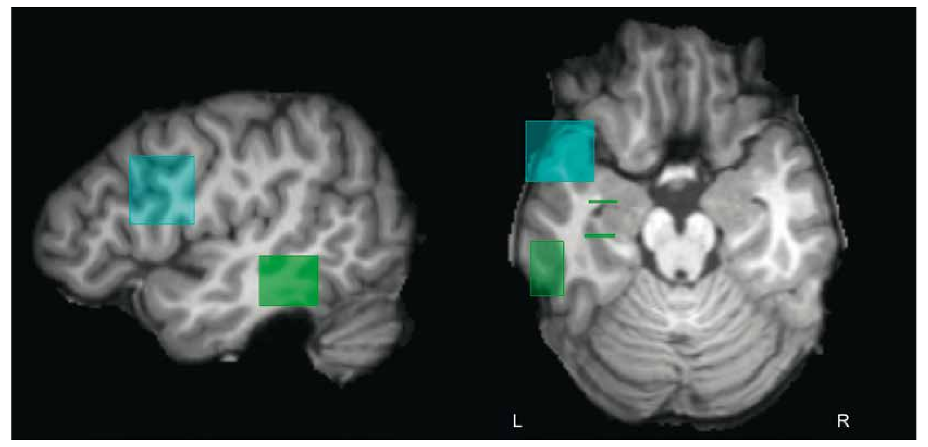
Behavioral materials

- Reading span, forward and backward digit span, non-word span (see Box 1).
- Latent-variable analysis: VWM composite score (component 1 of principal-components analysis; see Box 1).

Diffusion-weighted-imaging (DWI) data

- Whole-brain deterministic tractography.
- Manual delineation of the AF/SLF based on typical tract's templates provided by in-vivo tractography atlases (Catani & Thiebaut de Schotten, 2008; Mori et al., 2005; see Box 2).
- Multiple-region-of-interest (ROI) approach: 2 seed inclusive-waypoint ROIs (Catani & Mesulam, 2008); their position and size were finalized *ad hoc*.
- Fiber-outliers' removal and refinement (noise smoothing) by inclusive-waypoints along the tract and exclusive-waypoints around the tract.
- MRI measures: (1) median FA along the left AF/SLF (Schreiber et al., 2014), (2) whole-white-matter (WWM) median FA, (3) total intracranial volume (ICV).

2 Definition of inclusive-waypoint ROIs

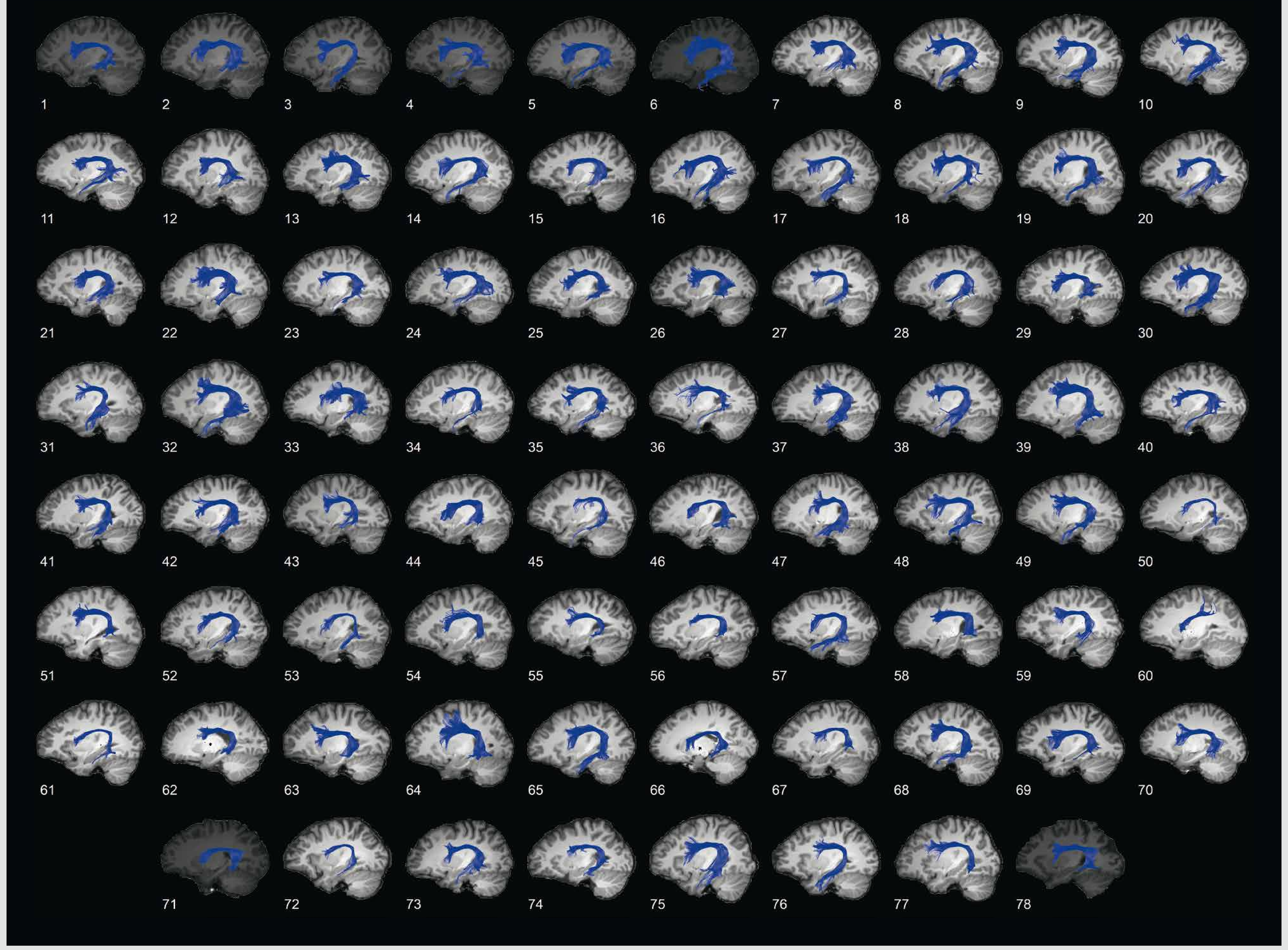


- Anterior dorsal ROI (blue box): middle precentral frontal gyrus (premotor cortex and BA 44).
- Posterior ventral ROI (green box): posterior superior-middle temporal gyrus.
- Additional inclusive-waypoints (green lines) for fiber-outliers' removal.

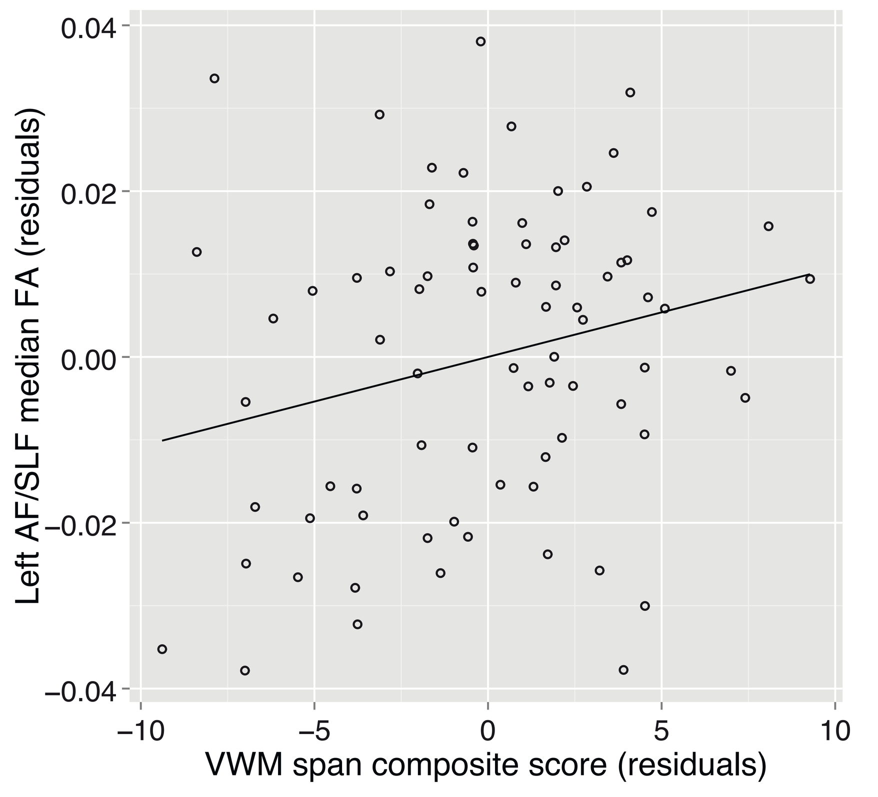
Results

- Topographical and morphological variability in the resulting left AF/SLF volumes (see Box 3).
- Linear regression analysis (partial correlation): Significant correlation coefficient (r = 0.24, p = 0.04) between left AF/SLF median FA and VWM span composite score, controlling for participants' age, gender, LQ, WWM median FA, and total ICV (see Box 4).

3 Sagittal slices of the individual delineated AF/SLF volumes superimposed on participants' native T_1-weigthed images



4 Partial correlation analysis (r = 0.24, p = 0.04)



• Controlling for age, gender, LQ, WWM median FA, and total ICV.

Discussion

- Previous research has assumed that the left AF/SLF is functionally involved in the VWM circuitry (Baldo et al., 2008; Charlton et al., 2010; Vallar & Papagno, 2002).
- Current results show significant positive correlation between median FA along the left AF/SLF and VWM span: relationship between fiber integrity and axonal myelination of the left AF/SLF and an individual ability to efficiently coordinate the storage and rehearsal components of VWM.
- Supporting role of AF/SLF in left fronto-parietal VWM circuitry: in line with prior functional-connectivity data (Woodward et al., 2006; Ma et al., 2011), intracranial recordings in humans (Matsumoto et al., 2012), clinical data from AF/SLF-disconnection patients (Baldo et al., 2008; Meyer et al., 2014; Yamada et al., 2007), intraoperative-electrical-stimulation studies (Duffau, 2008; Duffau et al., 2003).

Conclusion

Our finding is strong indirect evidence for the supporting role of the left AF/SLF in the cortical circuitry of VWM.

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