Structural connectivity between posterior thalamus and occipital cortices underpins visual short-term memory capacity and attentional weighting in humans

A.Menegaux[1,2,3,4], N.Napiorkowski[1,2], J.Neitzel[1], A.Ruiz-Rizzo[1,2], H.J.Müller[1,2], C.Zimmer[4], C.Sorg[4,5,*], K.Finke [1,2,6,*]

[1] Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität Munich
[2] Department of Psychology, General and Experimental Psychology, Ludwig-Maximilians-Universität, Munich
[3] TUM-Neuroimaging Center and departments of [4]Neuroradiology, [5]Psychiatry of Klinikum Rechts der Isar, Technische Universität München TUM
[6] Hans Berger Department of Neurology, Friedrich-Schiller-University Jena, Germany

Contact: aurore.menegaux@psy.lmu.de

* these authors share senior authorship

Klinikum rechts der Isar
Technische Universität München

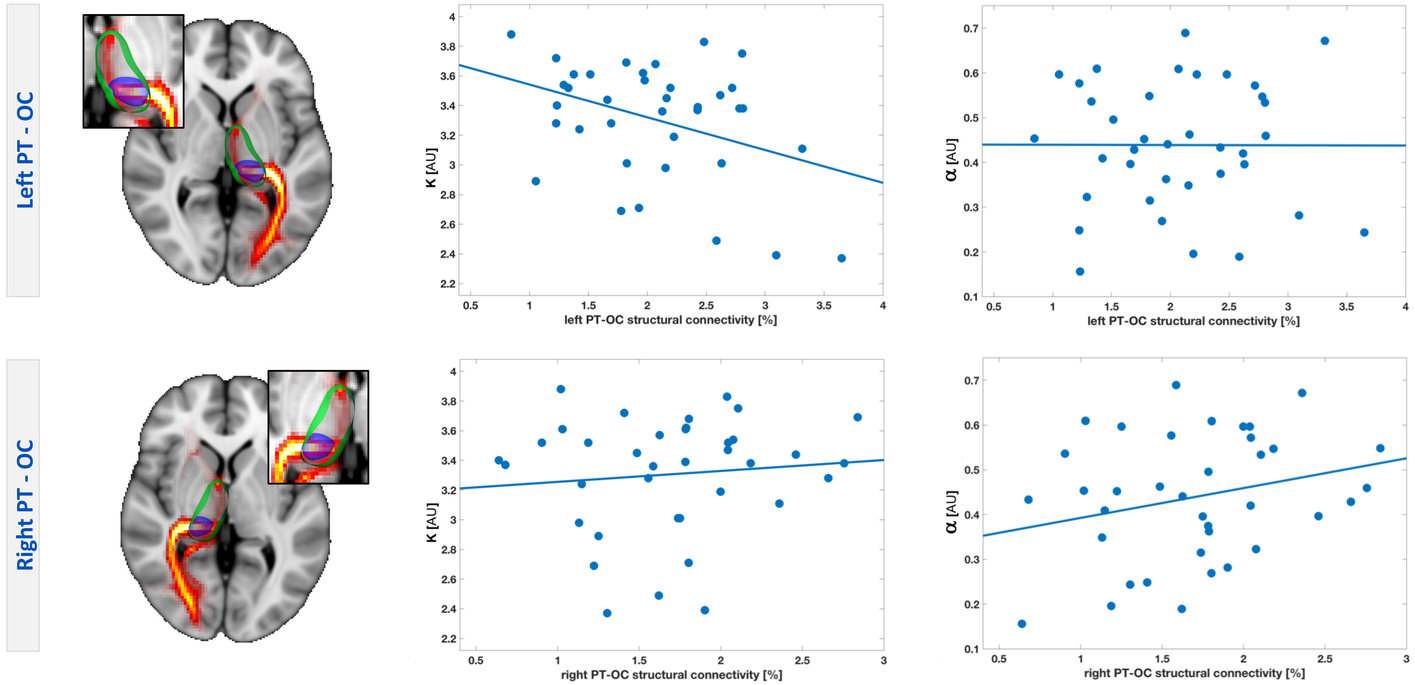
Background

Visual short-term memory (vSTM) capacity is defined by the number of items that can be consciously perceived and stored into vSTM. It can be measured using the computational Theory of Visual Attention (TVA) mathematical framework from Bundesen (1990) in which objects in a visual scene compete for representation in a visual short-term memory (vSTM) store. The race towards the store is assumed to be biased by top-down controlled weighting of objects according to task relevance.

According to the Neural interpretation of TVA (NTVA) , occipital cortices, thalamic areas and white matter tracts interconnecting these regions are of particular relevance for vSTM storage and top-down controlled attentional weighting processes (Bundesen et al., 2005). It is assumed that, following a first unselective wave of processing, attentional weights of displayed objects are computed in a priority map in the pulvinar nucleus of the thalamus. In the following and selective wave of processing, attentional weighting signals from the pulvinar lead to biased processing of objects in visual brain areas, so that objects with higher attentional weights are processed by more neurons. However, structural evidence underlying such theory is still lacking.

- Based on the NTVA (Bundesen et al., 2005) we hypothesized that vSTM capacity parameter K would be associated with structural connectivity of posterior thalamus to occipital cortex (PT-OC)
- Based on macaque and human evidence on the role of the pulvinar nucleus and visual cortices in attentional selection (Saalmann et al., 2012), we hypothesized that top down control parameter alpha would be associated with the structural connectivity of posterior thalamus to occipital cortex.

Results

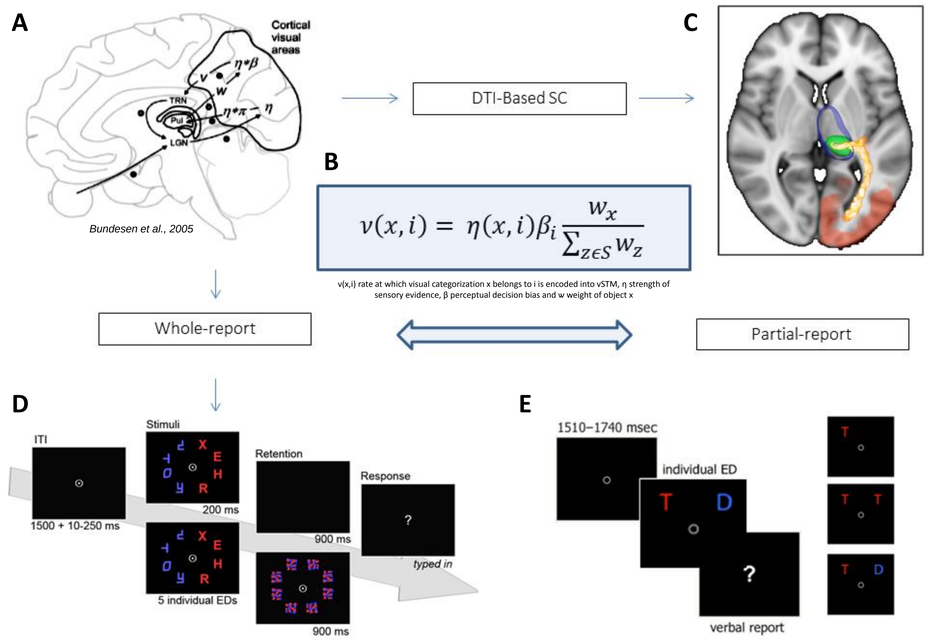


- vSTM capacity is **significantly negatively** associated with left (**r = -0,38 p = 0,030**), but not right (r = 0,02 p = 0,91) PT-OC structural connectivity.
- Top down control is **close to significantly negatively** associated with right (**r = 0,31 p = 0,08**), but not left PT-OC structural connectivity (r = -0,06 p = 0,74)

Control analysis:

- No significant association between Left (r = -0,17 p = 0,36) or Right PT-OC structural connectivity and processing speed (r = 0,09 p = 0,64)
- No significant association was found between left (r = 0,24 p = 0,19) or right PT-OC structural connectivity and spatial bias w (r = 0,13 p =0,50)
- No significant association between left (r = 0,03 p = 0,8) or right PT-Motor Cortex structural connectivity and vSTM capacity (r = -0,10 p = 0,59) nor between left (r = 0,01 p = 0,99) or right PT-Motor Cortex structural connectivity and top down control (r = -0,23 p = 0,22)

Material and Methods



Sample characteristics N=37 (22F / 15M)			
	Mean	**SD**	**Range**
Age (years)	**33.8**	±10.54	20 -53
Crystallized IQ	**95.8**	±15	72.5 – 140
K	**3.31**	±0.39	2.37 - 3.88
α	**0.43**	±0.14	0.17 - 0.67

A) NTVA model of probable distribution of visual processing
B) TVA rate equation
C) Illustration of left PT-OC structural connectivity as obtained by probabilistic tractography and
D) whole and partial report tasks

Conclusion / Discussion

- **Significant association between left PT-OC structural connectivity and vSTM capacity** in healthy adults which is **structure and function specific** in line with findings from Golestani and colleagues (Golestani et al., 2014) who found an association between performance on a visual working memory task and white matter microstructure of the optic radiations (as part of the posterior thalamic radiations) and posterior thalamus.
- **Trend of an association right PT-OC structural connectivity and top down control** in healthy adults also **structure and function specific** which is in line with results from Saalman and colleagues (2012) who combined electrical recordings in pulvinar nuclei and visual areas with tractography in monkeys and suggested that internal processes such as the maintenance of attention in expectation of visual stimuli and short term memory rely heavily in pulvino-cortical interactions
- Findings provide empirical evidence for the theoretical assumption in NTVA, that **structural connections between posterior thalamus and occipital cortices contribute to vSTM capacity and top down control** of human visual attention.