Decoding of tactile WM content from PPC improves with behavioral performance

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INTRODUCTION

Working memory (WM) is a core cognitive function essential for goal-directed, adaptive behavior, involving the maintenance and manipulation of relevant sensory information [1].
Only few studies have explored WM for tactile information and in this study, we aim to replicate previous work which has identified posterior parietal cortex (PPC) activity to represent WM content [2].
Using multivariate pattern analysis (MVPA), we aimed to identify the core brain regions encoding tactospatial WM content and provide novel insights into their relation to behavioral performance.
Tactile WM was assessed by memorization of spatial layouts of Braille-like pattern stimuli delivered to the index finger.

METHODS

Nineteen healthy right-handed (EHI=87.06 $\pm$ 3.05) participants underwent two fMRI sessions with four runs each while performing a tactospatial WM task (Figure 1):
In each of 48 trials per run, two consecutive vibro-tactile sample stimuli were followed by a mask stimulus and a retro-cue ('1' or '2') to indicate which of the two sample stimuli had to be retained for a 6s WM delay period.
After the delay, participants were presented with two stimuli: the target (memorized) and a foil stimulus, and participants indicated with a right hand button press which of the two stimuli was the target.

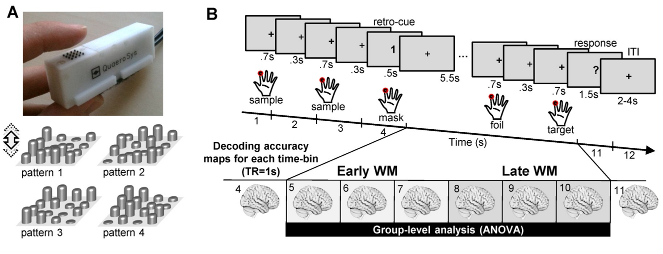

Figure 1: Stimuli and Paradigm. A) Top: Vibro-tactile Braille-like pin display presented to the left index finger. Bottom: Example stimulus set. B) Top: Retro-cued delayed match-to-sample task. Bottom: Independent decoding analyses were performed for each of the 1s time-bins during the trial time. Whole-brain searchlight decoding analyses were performed and decoding accuracy maps from the time-bins 5-10 were subjected to group-level GLM analyses.

Patterns were presented using a 4x4 pin matrix on which pins vibrated with different amplitudes but with the same frequency (30Hz).
Independent decoding analyses were performed for each 1s time-bin during the trial time.
Whole-brain searchlight decoding analyses with support vector machine (SVM) classification were performed and decoding accuracy maps from the time-bins 5-10 (representing the 6s WM delay period shifted by 2 volumes due to slow BOLD dynamics) were subjected to group-level GLM analyses.
In contrast to previous studies [2], we inspected a shorter WM delay phase (6 seconds) using high-resolution fMRI (2mm voxel size and 1s TR) in a repeated measures design.

References

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RESULTS

Our results confirm that tactospatial WM content can be decoded from both, somatosensory cortices and the PPC (Figure 2).
We thereby replicate previous findings [2] in demonstrating a temporal progression: somatosensory cortices are engaged during the initial encoding phase, while the PPC retained information later in the delay period.

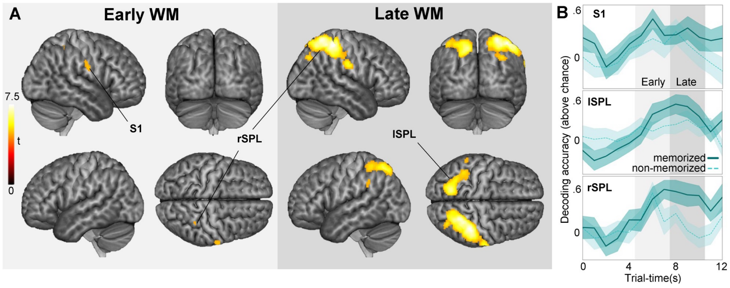

Figure 2: Decoding accuracy during early and late phases of WM. *A)* Significant above chance decoding of the memorized stimulus (p<0.05, FWE-corrected). Left (light grey): Right (contralateral to stimulation) primary somatosensory cortex (S1) and superior parietal lobe (rSPL) encode the memorized stimulus in the early phase of WM. Right (dark grey): Bilateral (left and right) SPL encode the memorized stimulus in the late phase of WM. B) Decoding accuracy across trial time. Lines show decoding accuracy averaged across participants with shadings for standard error of the mean (SEM) for memorized (solid, petrol) and non-memorized (dashed, light petrol) stimuli in peak voxels of areas S1, lSPL and rSPL. Grey shaded areas indicate early and late WM phases.

Contrasting low and high performing participants (median split cutoff: 60.16%) revealed performance-dependent decoding accuracy:
Higher-performing participants exhibited more robust content decoding in the PPC (Figure 3).

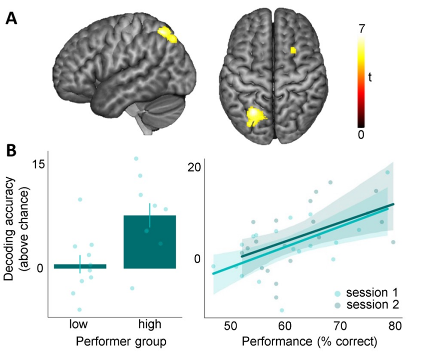

Figure 3: Performance dependent decoding. *A)* Significant above chance decoding accuracy for the contrast high > low performers (p<0.05, FWE-corrected) defined by median split of the data. B) Relation between decoding accuracy and individual performance. Left: Bars indicate mean decoding accuracy (above chance) with SEM for low and high performers. Right: Scatter plot of individual decoding accuracy and performance (% correct responses) for session 1 (light petrol) and session 2 (petrol) with regression line indicating a positive correlation.

These results suggest a transformation process of sensory to parietal representations of tactile WM content (tactospatial sketchpad [2]).
Particularly the (left) PPC might play a key role in higher order WM processing and abstraction of content, supporting a distributed account of WM function across the brain [3,4].

CONCLUSION

Our findings confirm that tactospatial WM engages a distributed neural network, with somatosensory cortices contributing to an initial encoding and the PPC supporting later maintenance.
Performance-dependent decoding accuracy highlights individual differences in WM efficiency, emphasizing the (left) PPC's critical role in task-relevant WM processing. [4]

- These results not only reinforce the parallels between tactile and visuospatial WM networks [3] but provide novel insights into the temporal dynamics and localization of task-relevant tactile WM processing, offering a foundation for future investigations into WM enhancement strategies [5].