Parametric Working Memory Coding During Motor Preparation

Guido Caccialupi[12], Timo Torsten Schmidt[1], Till Nierhaus[1], Sara Wesolek[1], Felix Blankenburg[12]

[1] Neurocomputation and Neuroimaging Unit (NNU), Freie Universität Berlin, Germany

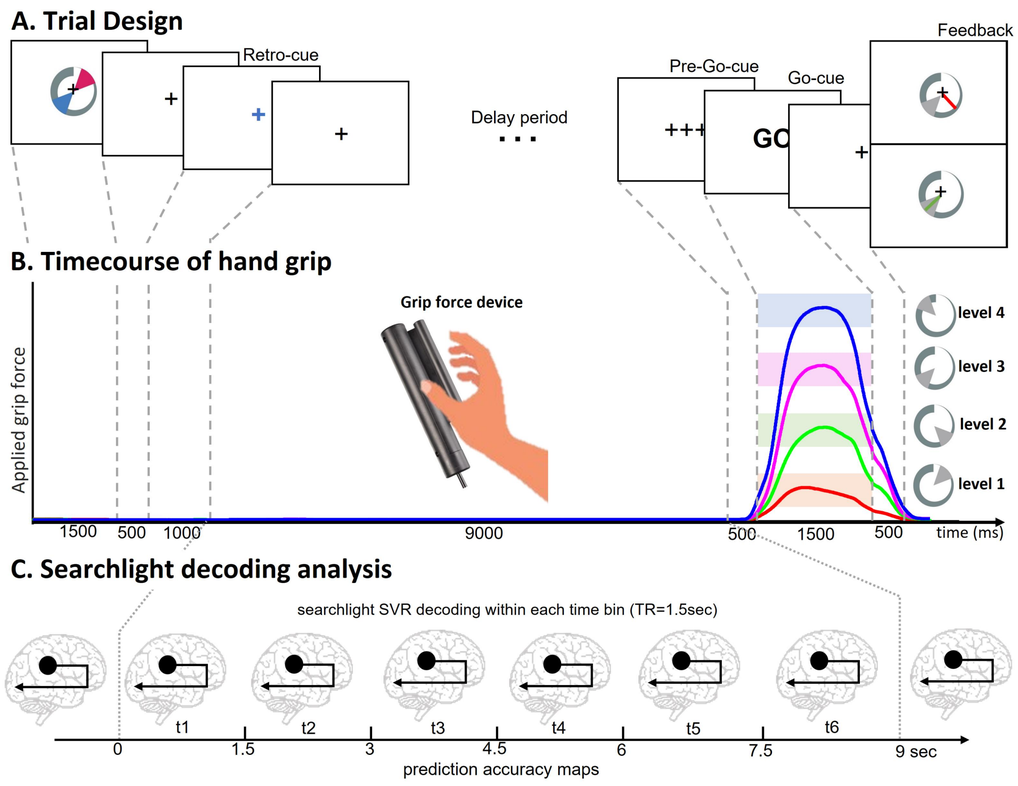
[2]Humboldt-Universität zu Berlin, Berlin School of Mind and Brain, Berlin, Germany

INTRODUCTION

- Parametric sensory working memory content has been extensively studied in recent years (*e.g. Romo et al.,* 1999, Schmidt *et al.*, 2017).
- It has been shown using multivoxel pattern analysis (MVPA) that these representations are maintained in the right inferior prefrontal cortex (and premotor areas) during the working memory period (*e.g.* Wu *et al.*, 2020).
- The question of whether similar parametric representations can also be found for the retainment of simple movement parameters as the strength of handgrips during the *working memory delay period* has not yet been investigated.
- Our hypothesis is that gradual representations of movement parameters can be decoded from effector-specific brain areas, such as the motor and premotor cortex, parietal brain areas, and supplementary motor areas.

METHODS

Figure 1



In an fMRI experiment, participants performed a delayed grip force task. Each trial (illustrated in **Figure 1A**) started with the presentation of a *strength-indicator,* which represents two of four possible force levels as coloured slices (their colours were either cyan or blue). A *retro cue* indicating which of two levels of grip-force had to be maintained during a subsequent *delay period* of 9 seconds. Participants performed the hand squeezing task upon display of a *pre-Go* (0.5 s) and a *Go-cue*. *Feedback* was provided by showing if the applied force was correct. Grip force was assessed by a non-magnetic grip-force transducer (Current Designs, HHSC-1x1-GRFC-V2). For illustration of the applied grip force within a trial see **Figure 1B**.

fMRI Data was acquired in four functional runs à 18.30min with an EPI sequence (64 channel head coil, 37 slices, TR= 1.5 sec, 2.5x2.5x2.5 voxels) on a 3T Siemens Prisma fit at the *Center for Cognitive Neuroscience Berlin* (*CCNB*).

We applied a multivoxel pattern analysis (MVPA) searchlight (r=3voxel) approach to test which brain regions exhibited multivariate parametric WM codes of grip-force preparation during the *delay period*. Preprocessing was limited to realignment; Beta-estimates of a finite impulse response model (each of the four trial types across the 9s WM delay and 6 consecutive time bins; **Figure 1C**) were entered to a four-fold cross-validated support vector regression (*SVR*) decoding schema as implemented in The Decoding Toolbox (Hebart *et al.*, 2015). We applied a time resolved approach, namely performing a decoding analysis within every time-bin of the delay phase (e.g., Schmidt *et al.* 2017)

RESULTS

Participants (N=14) managed to perform the challenging task. The applied grip-force was in the target range on average in 55% of trials. Violin plots in **Figure 2A** display the distribution of responses in terms of applied force on the hand-grip device for the respective trial types. We further ensured that participants did not apply force during the *delay period* (see **Figure 2A**, lower display). For the fMRI analysis all trials were included where the applied force was within the target range $\pm$ 20°, resulting in the inclusion of overall 70% of trials.

Figure 2

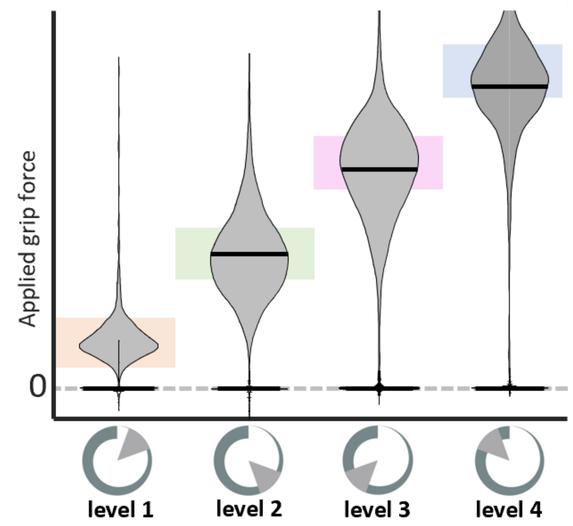
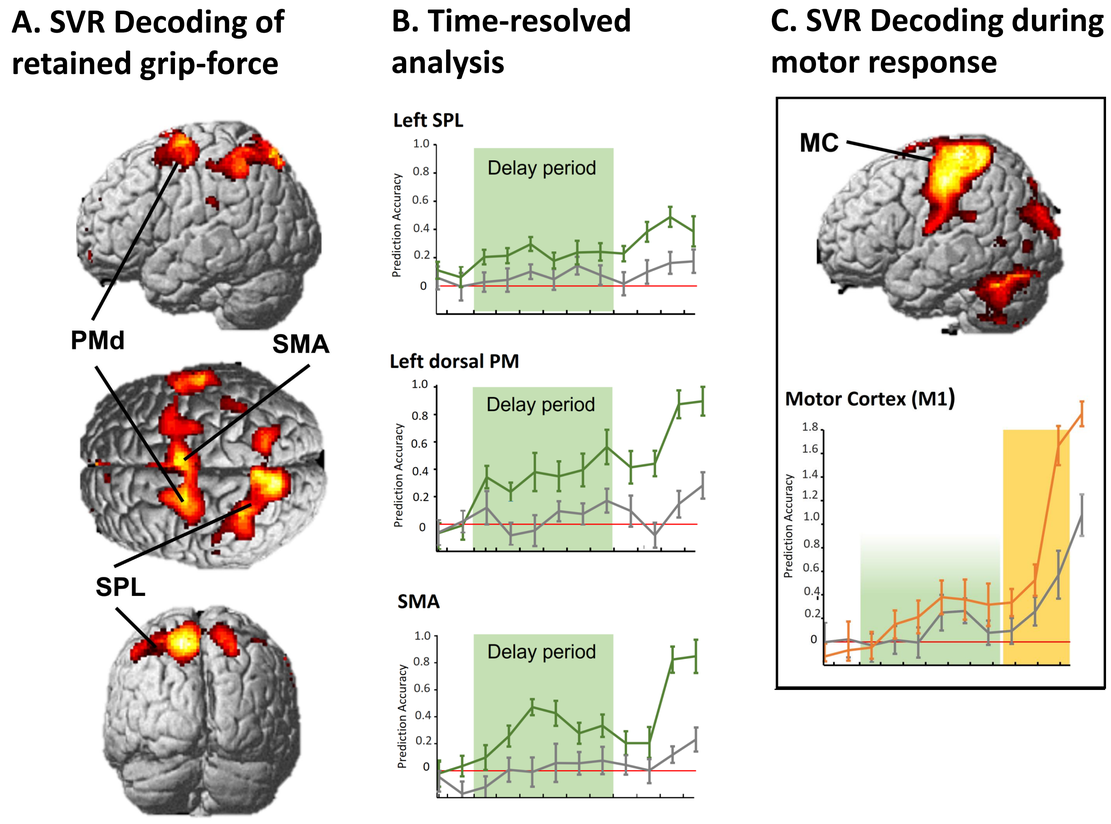


Figure 3



To test for regions that exhibit above chance decoding during the delay phase, we computed t-contrast across the WM phase for every time bin. The preliminary group-level analysis with 14 participants revealed a network comprised of dorsal pre-motor cortex (PMd), supplementary motor area (SMA), and bilateral superior parietal regions, as shown in **Figure 3A** at p<0.05 FWE corrected. Time courses of the evolution of prediction accuracy of the applied SVR approach across the *delay period* and response phase are displayed (green). Performing the same analysis on the non-prepared compression strength (grey) does not reveal above chance decoding (as shown in **Figure 3B**). There is a strong increase in the decoding accuracy in the primary motor cortex when the motor response was given (**Figure 3C**).

CONCLUSION

- These results extend the current literature on parametric WM representing by showing a distributed network of effector-related brain areas to contribute to the graded representation of the preparation of grip-forces with different strength.
- This preliminary evidence is in line with previous studies (Wu *et al*., 2020), which suggest that besides the performance of concrete actions, the PMC could also contribute to the maintenance of more abstract representations necessary to prepare future actions.

Christophel *et al.* (2017), The distributed nature of working memory TICS, 0, 115-142.
Hebart *et al.* (2015), The Decoding Toolbox (TDT): a versatile software package for multivariate analyses of functional imaging data, Frontiers in Neuroinformatics,
Schmidt TT (2017), Content-Specific Codes of Parametric Vibrotactile Working Memory in Humans, The journal of Neuroscience, 9771–9777.
Romo *et al.* (1999), Neuronal correlates of parametric working memory in the prefrontal cortex, Nature, 399, 470-473.
WU *et al.* (2020), Context-Dependent Decision Making in a Premotor Circuit, Neuron, 316-328.

NEUROCOMPUTATION NEUROIMAGING UNIT

DAAD Deutscher Akademischer Austausch Dienst German Academic Exchange Service

BERLIN SCHOOL OF MIND AND BRAIN

HUMBOLDT-UNIVERSITÄT ZU BERLIN

Freie Universität Berlin