White matter and learning

wml

# Example abstract

The posterior vertical pathway (PVP) is a set of white matter tracts that directly connect cortical regions associated with the dorsal and ventral visual streams. By traveling *between* action-oriented regions in the dorsal stream and perception-oriented regions in the ventral stream, white matter tracts in the PVP may be particularly important for performing tasks that link action and perception. Here, we tested whether the tissue properties of PVP white matter tracts predict learning to draw novel symbols, a motor task strongly associated with visual perception processing. Using advanced diffusion tractography, we measured fractional anisotropy (FA) in the PVP tracts (i.e., TPC, pArc, MdLF-SPL, MdLF-Ang) as well as major white matter tracts *within* the dorsal (i.e., SLF1and2, SLF3) and ventral streams (i.e., ILF, IFOF) in 30 adult participants before they were trained on drawing novel symbols. Training consisted of 1600 symbol drawing trials, evenly distributed over the course of 4 days. We measured learning as the trial-to-trial change in symbol drawing duration. Learning occurred most rapidly during the first day of training, with significantly less learning in the following training days. Pre-training FA in the PVP tracts that travel *between* the dorsal and ventral streams predicted learning; pre-training FA in tracts that travel *within* the dorsal and ventral streams did not significantly predict learning. Overall, our results suggest a key role for the PVP in learning that may be related to its ability to facilitate interactions between dorsal and ventral streams during action. (Note: This abstract does not mention the recognition behavioral measures.)

# Relevant data collection procedures

### Neuroimaging data (in brief)

Tract-profiles were generated for each major tract [(Yeatman, Dougherty, Myall, et al., 2012)](https://paperpile.com/c/JOnFmx/1JQIc) as well as the additional PVP tracts. We first resampled each streamline in a particular tract into 200 equally-spaced nodes. At each node, we estimated the location of the tract’s ‘core’ by averaging the x, y, and z coordinates of each streamline at that node. We then estimated measurements of tissue microstructure (FA, AD, MD, RD, NDI, ODI, ISOVF, at each node of the core by averaging across streamlines within that node weighted by the distance of the streamline from the ‘core’. Averages for each tract were calculated by averaging across the central 160 nodes, excluding the first and last 20 nodes to avoid partial voluming effects from the cortex.

### Behavioral procedures

Participants first performed a 30 minute training session (Production Training) followed by a visual recognition test (Recognition testing).

#### Stimuli

Stimuli included 200 novel symbols. Participants learned 40 symbols during production training and were exposed to an additional 40 symbols that were presented as distractors during recognition testing. The set of 40 symbols learned by participants was counterbalanced across participants.

#### Production training

When participants arrived they were seated at a desk with a digital Wacom writing tablet. Participants were told that they would be asked to copy novel symbols using the tablet and that they should make their productions as quickly and as accurately as possible. When ready, an experimenter began the training block. A Matlab script displayed one of the typed symbols at the top and center of the tablet screen and a box simultaneously appeared below the symbol into which the participants were instructed to make their production of the symbol above. Only one symbol was displayed per trial and each trial lasted 4 seconds. Each block included 40 symbols and there were 10 back-to-back blocks. After completing 5 blocks, participants were given a mandatory 3 minute break before completing the final 5 blocks. The ordering of symbols within each block was randomized. Production duration time was measured for each symbol production trial.

#### Recognition testing

Participants were asked to perform an old/new recognition judgment immediately following the training session. During recognition testing, participants were presented with static, typed versions of the 40 learned symbols along with 40 novel distractors one at a time in random order. Each symbol was only presented once at each test. For each symbol, they were instructed to answer yes if they had learned the symbol or no if they had not by pressing the ‘yes’ or ‘no’ button on a computer keyboard. Before the first recognition task on each training day, a practice task was administered that consisted of letters and common shapes (e.g., square, triangle) that helped orient participants to the testing context.

The stimulus presentation time in the recognition test was experimentally determined to ensure that our test was sensitive enough to detect a learning effect from the first to last training days, preferably with a linear slope, and that participants would not reach the ceiling too quickly. Each trial began with a 500 ms fixation cross, followed by a 500 ms blank screen, and then a 25 ms stimulus presentation during which a stationary symbol was displayed in the center of the screen. After the stimulus presentation ended, the symbol was replaced by a noise mask until the participant responded or until the trial timed-out. Each trial timed-out after 1 second when participants received feedback that prompted them to respond faster in the next trial (i.e., “Too Slow!”). Trials that reached the time-out limit were re-presented at the end of the test. If the participant responded before the symbol was replaced by the noise mask, the program advanced to the blank screen until the trial time-out criteria was met before moving on to the next trial. Reaction time and accuracy were measured.

# Description of csv file contents

## wml\_data\_beh\_write\_n39\_20220314.csv

### subID

unique subject identifier

### stimulus

the symbol presented to the participant for that trial

there were 400 total trials, that’s 40 unique symbols that were each drawn 10 different times

### block

block 1 included 40 unique symbols, block 2 included the same 40 symbols in a different random order, block 3 included the same 40 symbols in a different random order… and so on

there were 10 blocks

### trial

trial counter within a block

### drawduration

time from the start of the symbol drawing (pen down) to the end of the symbol drawing (pen up)

measured in seconds

a time out happend at 4 seconds

NaNs happen rarely, but mean that the data are missing for some reason

## wml\_data\_beh\_recog\_n39\_20220314.csv

### subID

unique subject identifier

### trial

trial counter

first response is trial = 1 and last response is trial = 80

includes 40 trials that are targets and 40 trials that are distractors

### stimulus

the symbol presented to the participant for that trial

stimuli that start with S were learned during the drawing training

stimuli that start with D were used as distractors during the recognition testing

### response

keypress that the participant made to the question of, “Did you learn this symbol?”

j = yes, f = no

the correct answer is “yes” or “j” for target symbols (i.e., symbols that start with S)

the correct answer is “no” or “f” for distractor symbols (i.e., symbols that start with D)

RT

reaction time

time between stimulus presentation onset and participant response

a time out happened at 1 second

*Note:* I did not remove the reaction times for inaccurate responses, as is the standard practice.

### acc

accuracy

if imageFile starts with S and response is j, then correct and acc = 1

if imageFile starts with D and response is f, then correct and acc = 1

## wml\_data\_mri\_tractprofiles\_n39\_20220314.csv

### subID

unique subject identifier

### tractname

the name of the white matter tract

we only really care about these tracts: TPC, pArc, MdLF-SPL, MdLF-Ang, SLF1and2, SLF3, ILF, IFOF, VOF, Aslant

### nodeID

a tractprofile includes 200 samples, where node 1 is one endpoint and node 200 is at the other endpoint and node 100 is in the center of the two endpoints

*Note:* I have not removed the first 20 and last 20 nodes, as is the standard practice.

### ad, ad\_sd

axial diffusivity, a tensor-based measure of white matter tissue structure

mean, standard deviation

### fa, fa\_sd

fractional anisotropy, a tensor-based measure of white matter tissue structure

mean, standard deviation

### md, md\_sd

mean diffusivity, a tensor-based measure of white matter tissue structure

mean, standard deviation

### rd, rd\_sd

radial diffusivity, a tensor-based measure of white matter tissue structure

mean, standard deviation

### ndi, ndi\_sd

neurite density index, a compartmental-based measure of white matter tissue structure

mean, standard deviation

### isovf, isovf\_sd

isometric volume fraction, a compartmental-based measure of white matter tissue structure

mean, standard deviation

### odi, odi\_sd

orientation dispersion index, a compartmental-based measure of white matter tissue structure

mean, standard deviation