The Role of Handwriting in Shaping early Neural Systems in Literacy

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Handwriting is a complex task

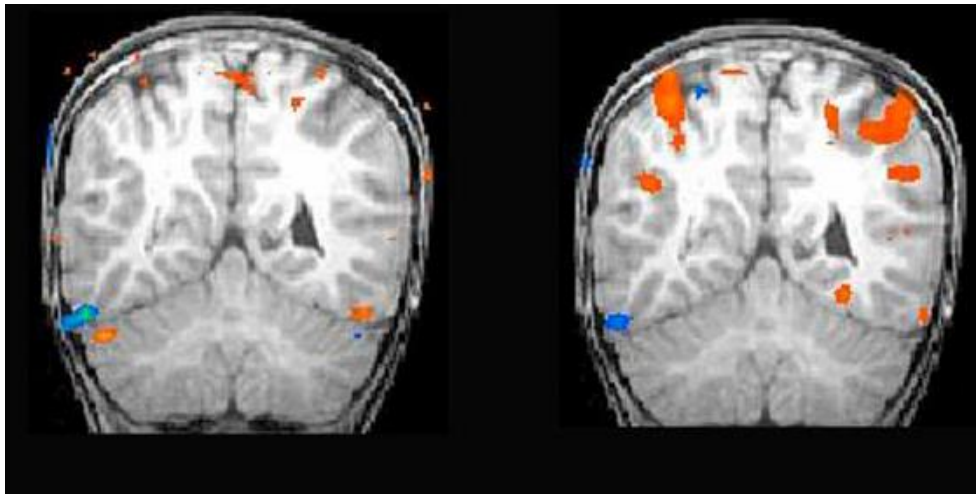
Handwriting practice and reading acquisition are correlated

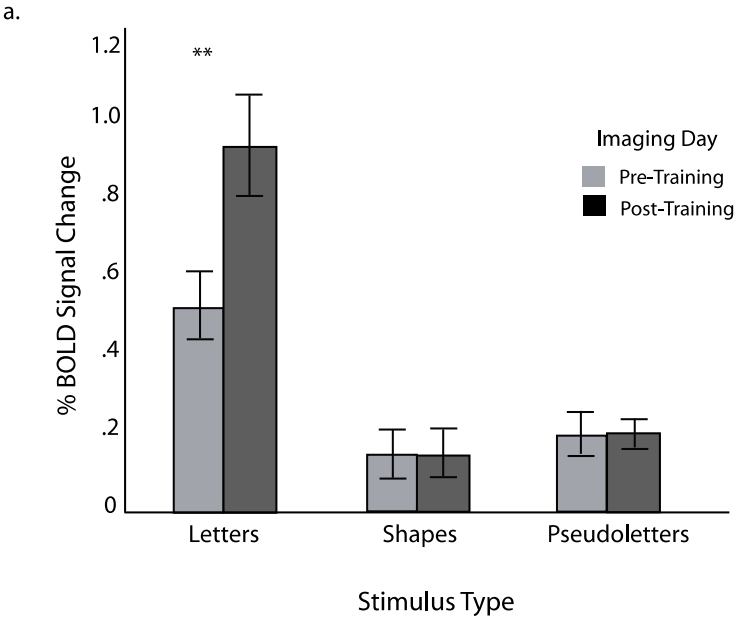
- Writing and reading skills are correlated (Berninger et al., 1993,2000, 2006)
- Those with reading delays have low writing ability (Berninger, 2008)

Handwriting practice increases letter recognition more than other forms of learning (Longcamp et al., 2006, Molfese et al., 2011, James & Atwood, 2009,Zemlock & James, 2018)

Handwriting practice changes the brain

- Our previous work has focused on how learning letter forms through handwriting changes the activation of important brain structures that are used for reading.
- This change in activation does not occur when learning letters and symbols through typing or through "see and say" methods





See James, 2017 for review

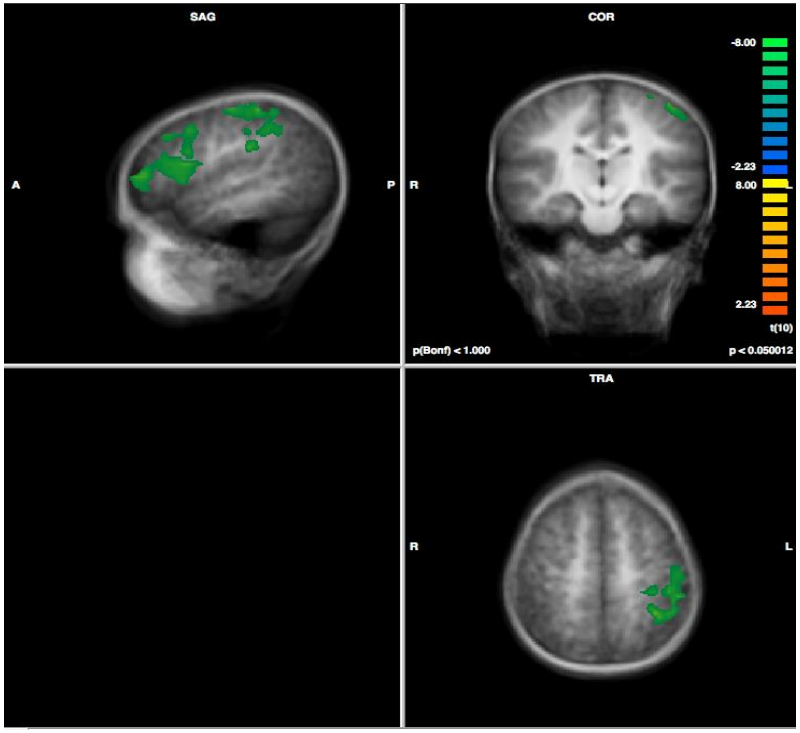
WHY and HOW?

- Creating a letter by hand involves:
  - Perceiving the letter to be reproduced
  - Perhaps a motor plan depending on skill
  - Fine motor skill to create the strokes
  - Visual guidance of hand
  - Constant interplay of visual and motor input and output

- How does this process affect subsequent visual perception?

1. Sensory – Motor interactions change visual recognition processes

- Visual processing will be enhanced after the pairing of visual and motor behaviors
- We know that only after handwriting practice (not typing or see and say) do functional connections occur between visual and motor systems (Vinci-Booher, James & James, 2016)



2. Motor production changes visual recognition processes

- Motor production itself can change visual processing
- (letter production without seeing visual output will result in enhanced visual processing)

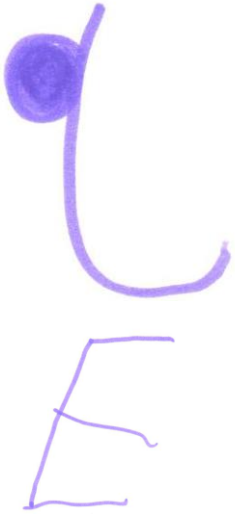
3. The visual output of motor acts changes visual recognition processes

- Simply viewing the output of motor production will enhance visual processing (Li & James, 2016)

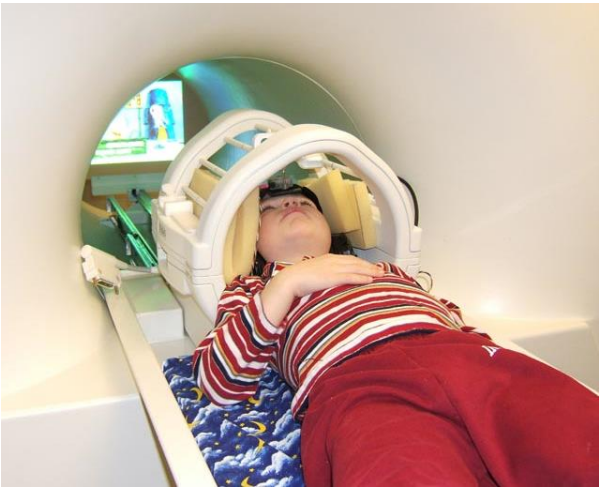
3 yr old

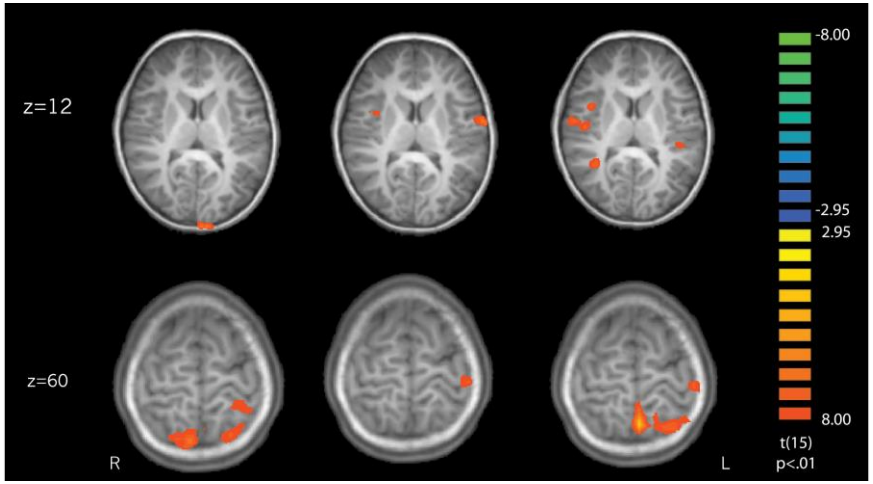
4 yr old

5 yr old



Measuring Brain activation using fMRI

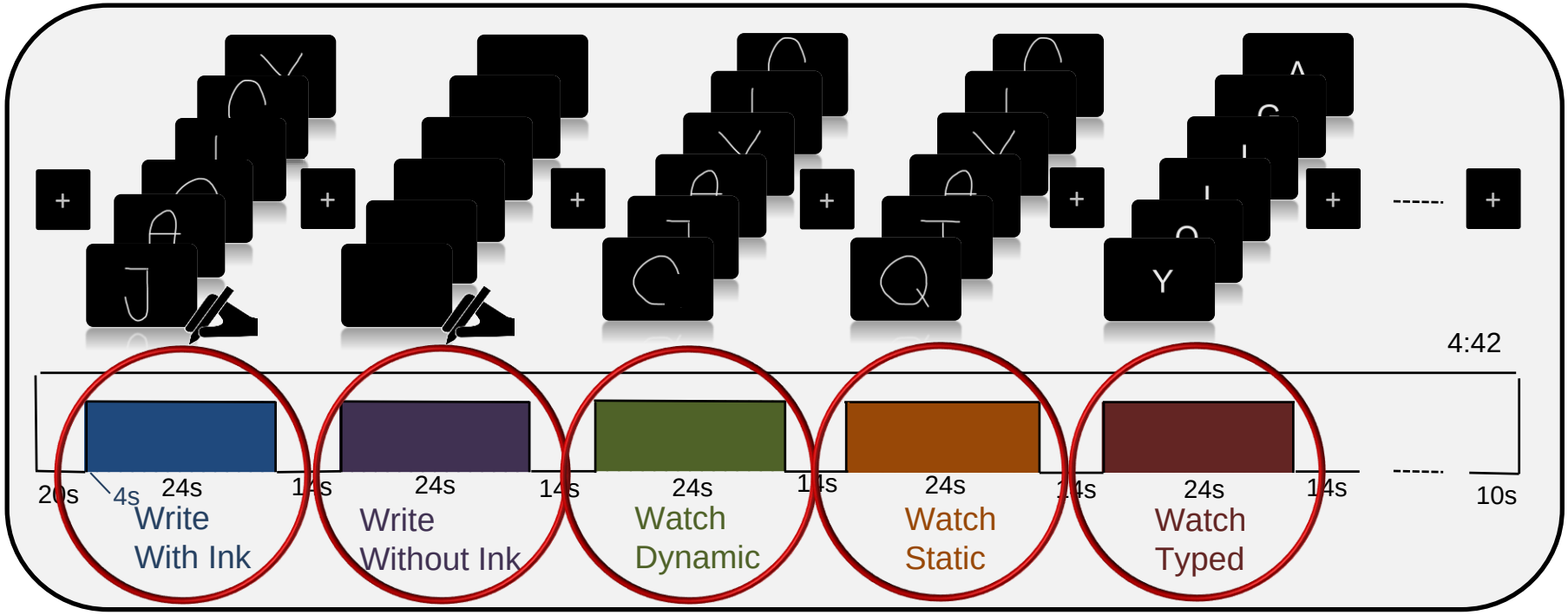




Mechanisms supporting handwriting components

- The visual, motor and visual-motor interactions that occur during handwriting may have different effects on cortical responses
- We can separate these components with a specific fMRI design and determine neural responses during the act of handwriting

14 literate adults, 19-25 yrs.



Visual Component

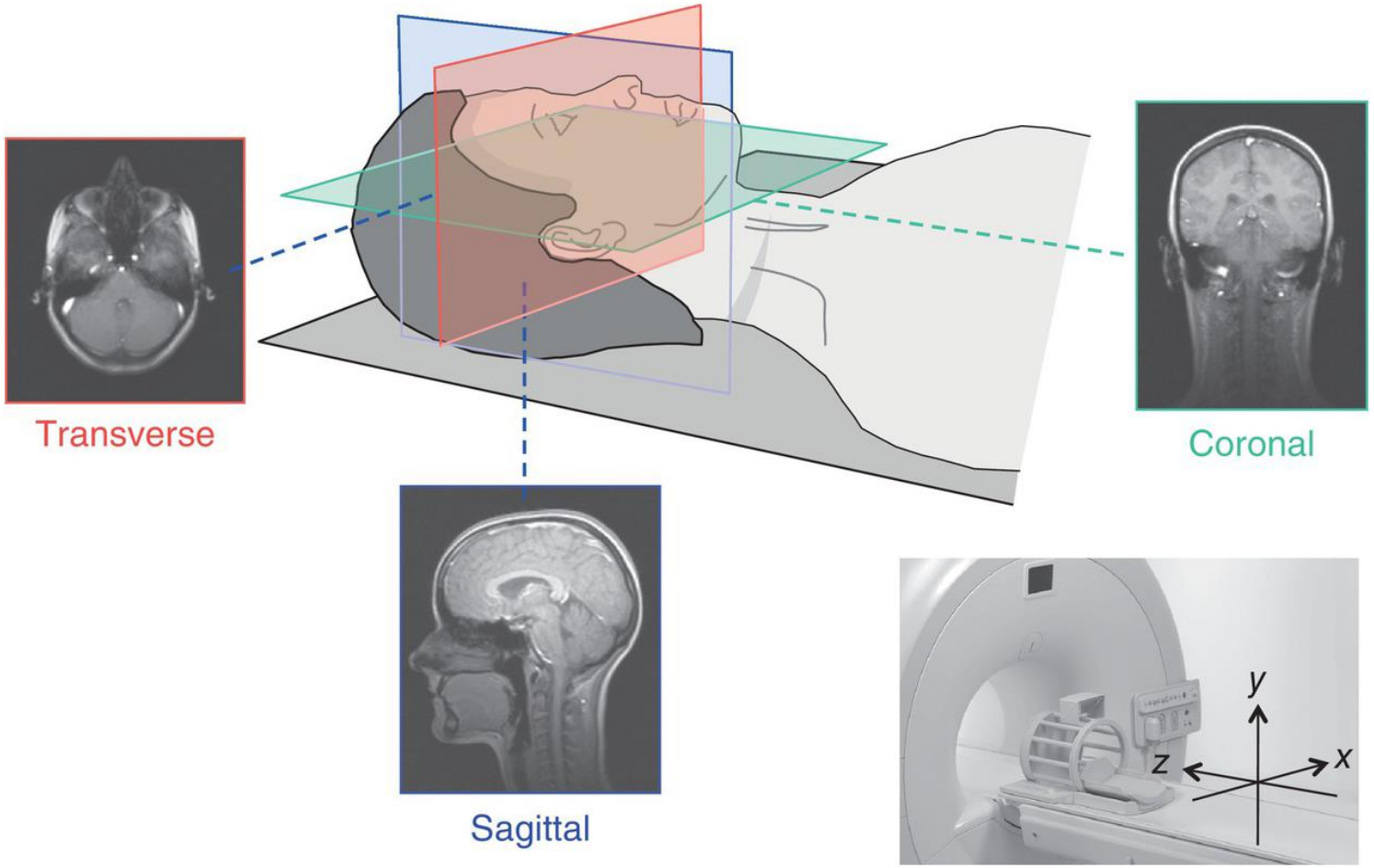
Motor Component

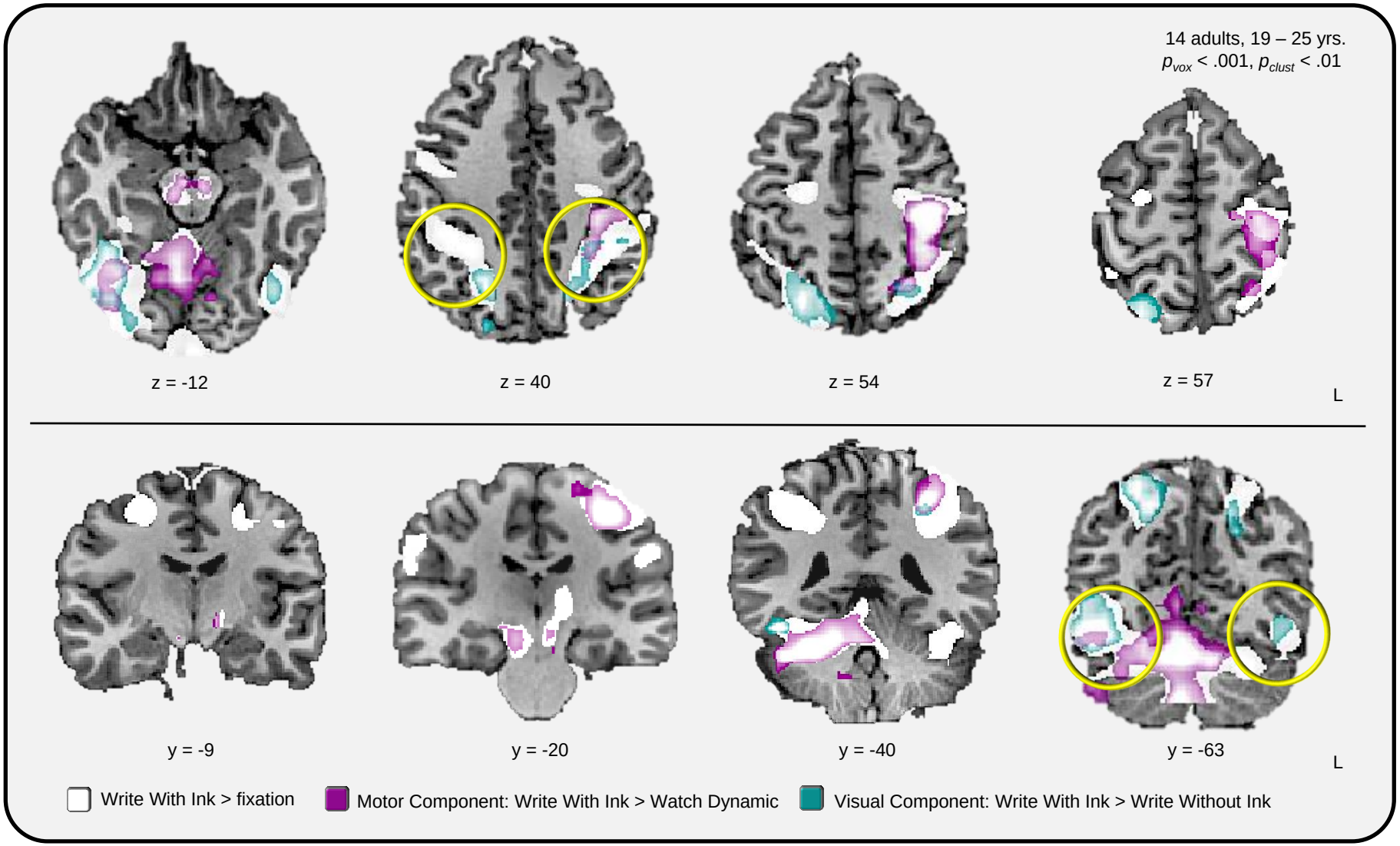
Dynamic Unfolding

Handwriting Perception

Typed Letter Perception

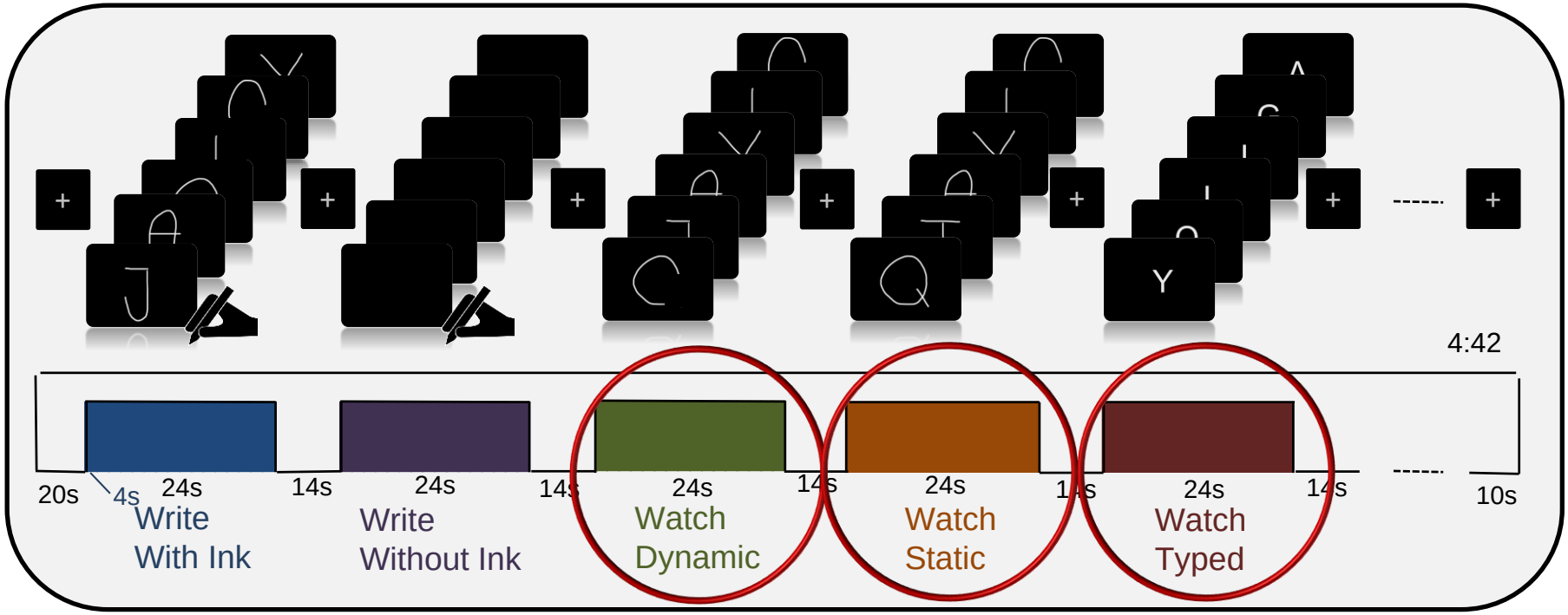
Vinci-Booher Cheng & James, 2018


Transverse
Coronal
Sagittal
y
z
x



Visual component: ventral temporal cortex (VTC) and Intraparietal Sulcus (IPS)

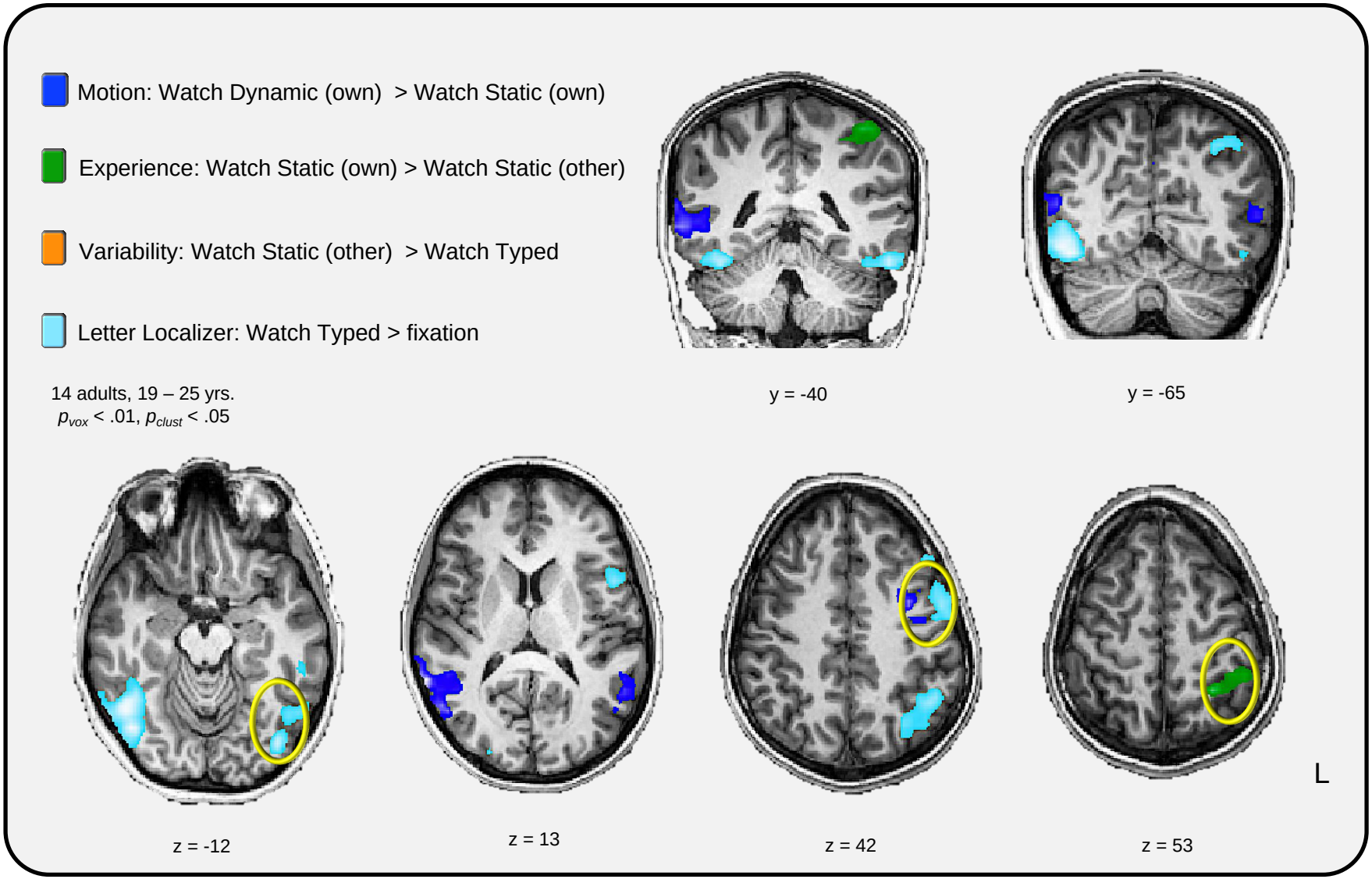
14 literate adults, 19-25 yrs.



Handwriting Perception

Dynamic Unfolding

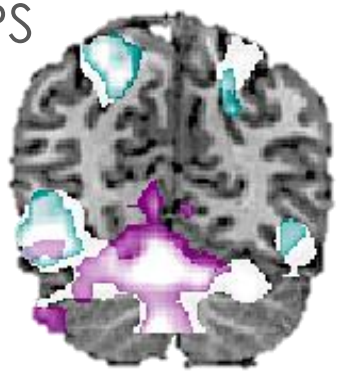
Typed Letter Perception



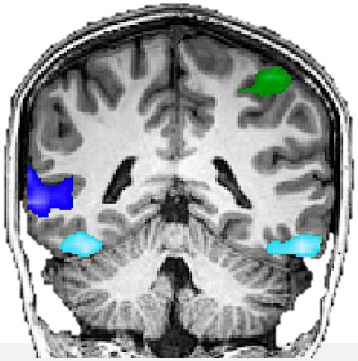
No greater response to viewing handwritten letters (orange) unless own

Summary of adults

- Handwriting network shows differential responses depending on motor vs visual component
- Overlap of visual and motor components in VTC and IPS

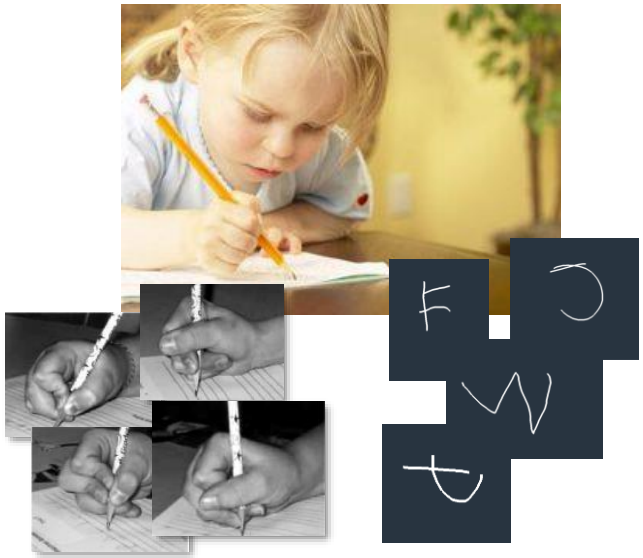


- No specific response (more than other letter forms) to handwritten letters unless they are one's own

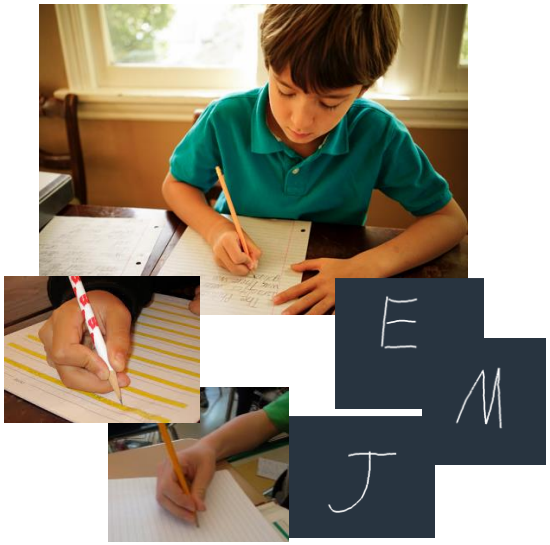


The relative importance of these may change through development

Early-literate
5 – 6 years

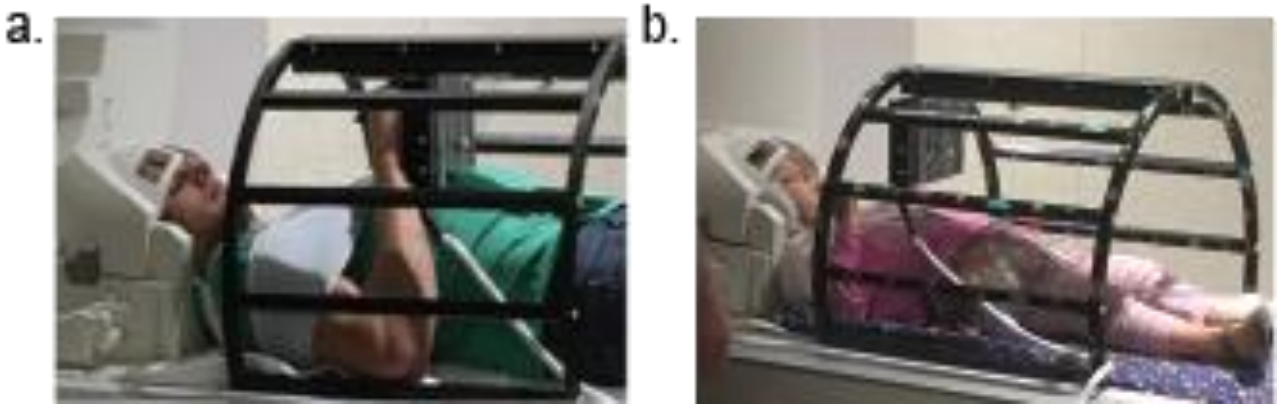


Literate
7 – 8 years



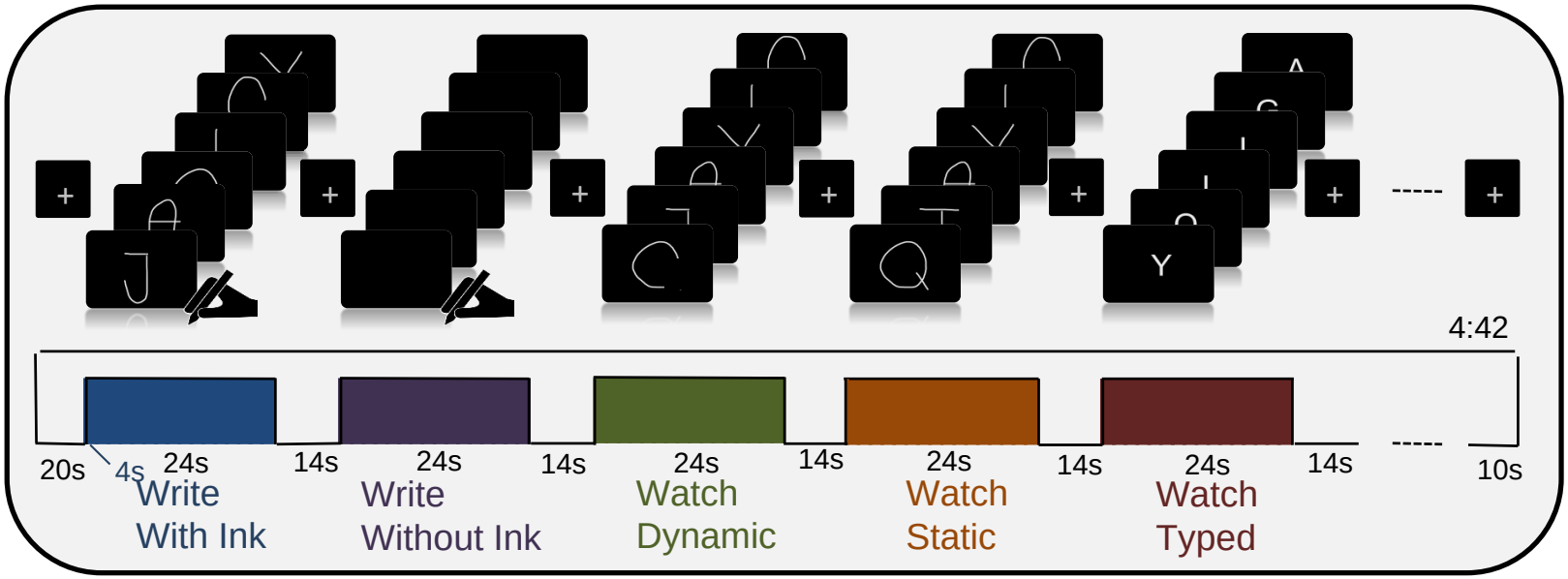
Literate
19 – 25 years

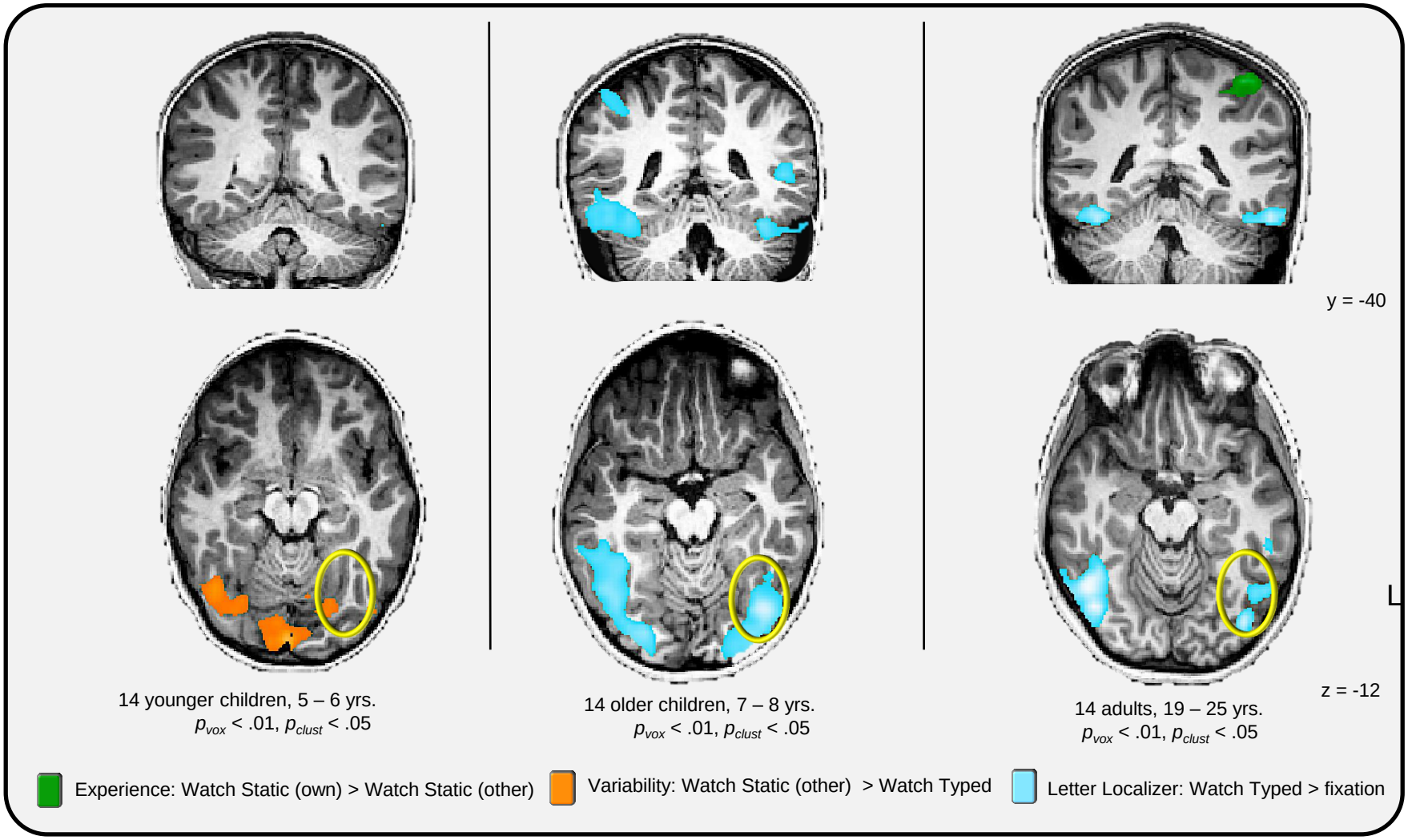
Vinci-Booher et al., 2018

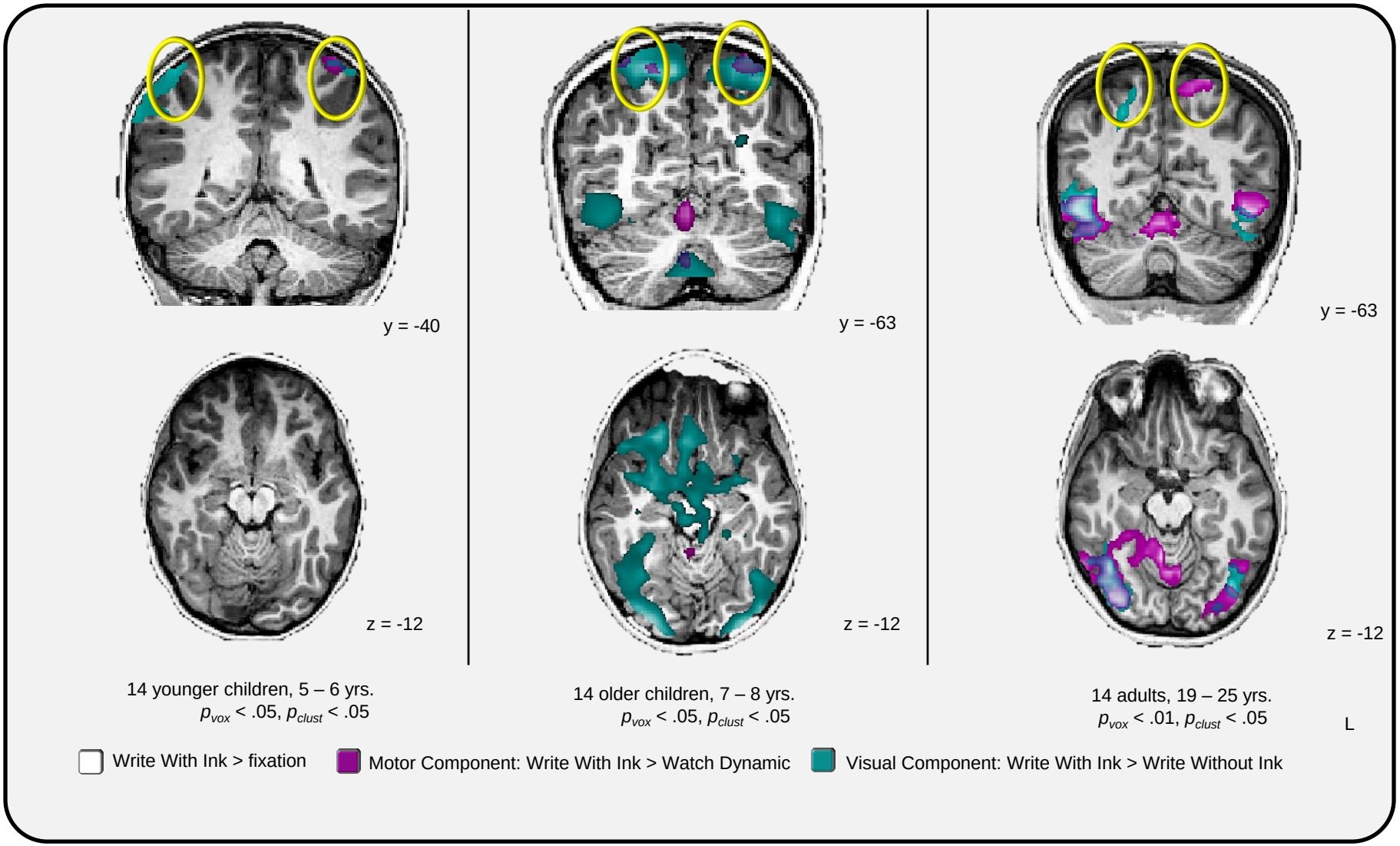


Standardized tests

- After scanning, one hour of standardized battery:
  - Woodcock Johnson 4 Tests of Achievement: letter-word identification, spelling, word attack, spelling of sounds.
  - Beery tests of visual perception, Motor production and visuo-motor integration
  - Grooved pegboard test

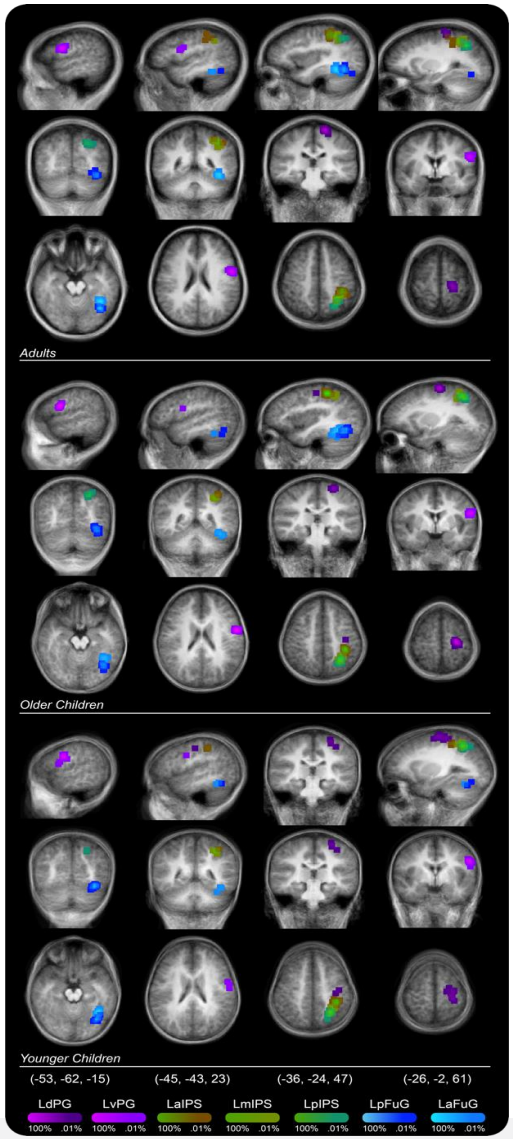

4:42
20s
4s
24s
Write
With Ink
14s
24s
Write
Without Ink
14s
24s
Watch
Dynamic
14s
24s
Watch
Static
14s
24s
Watch
Typed
14s
10s


y = -40
L
z = -12
14 younger children, 5 – 6 yrs.
p_{vox} < .01, p_{clust} < .05
14 older children, 7 – 8 yrs.
p_{vox} < .01, p_{clust} < .05
14 adults, 19 – 25 yrs.
p_{vox} < .01, p_{clust} < .05
Experience: Watch Static (own) > Watch Static (other)
Variability: Watch Static (other) > Watch Typed
Letter Localizer: Watch Typed > fixation



Vinci-Booher et al., 2020

Region of Interest Analysis



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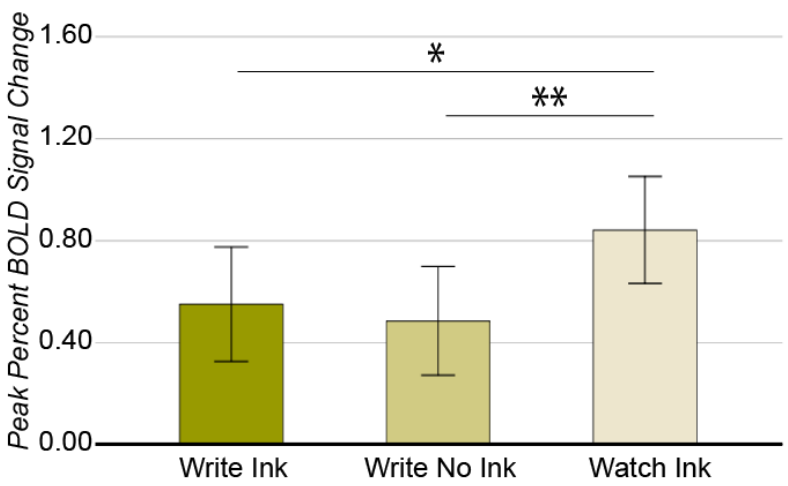
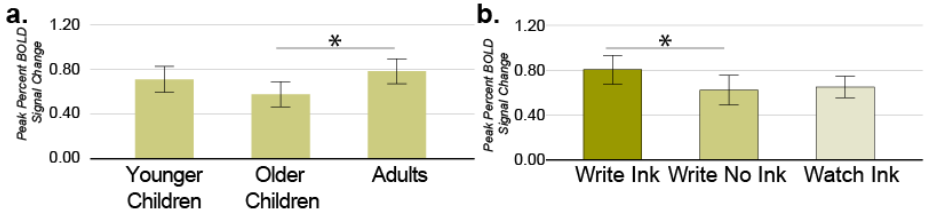
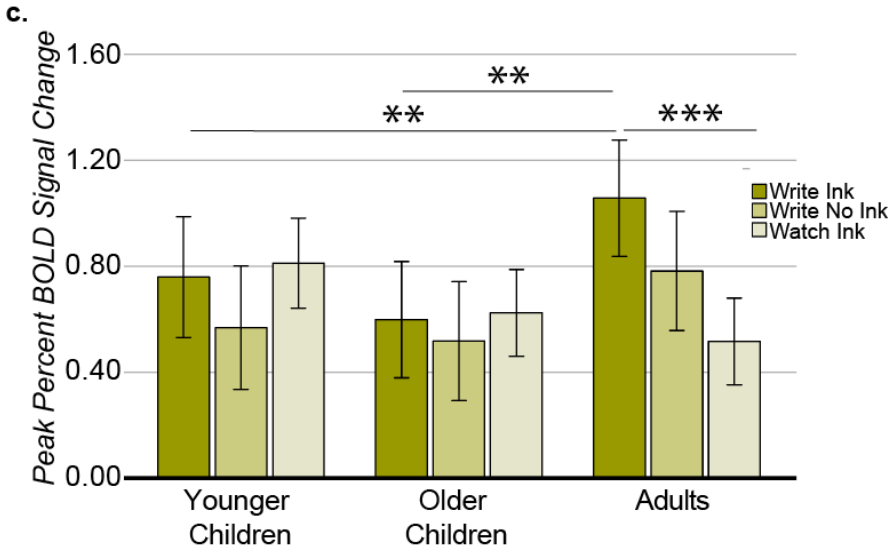
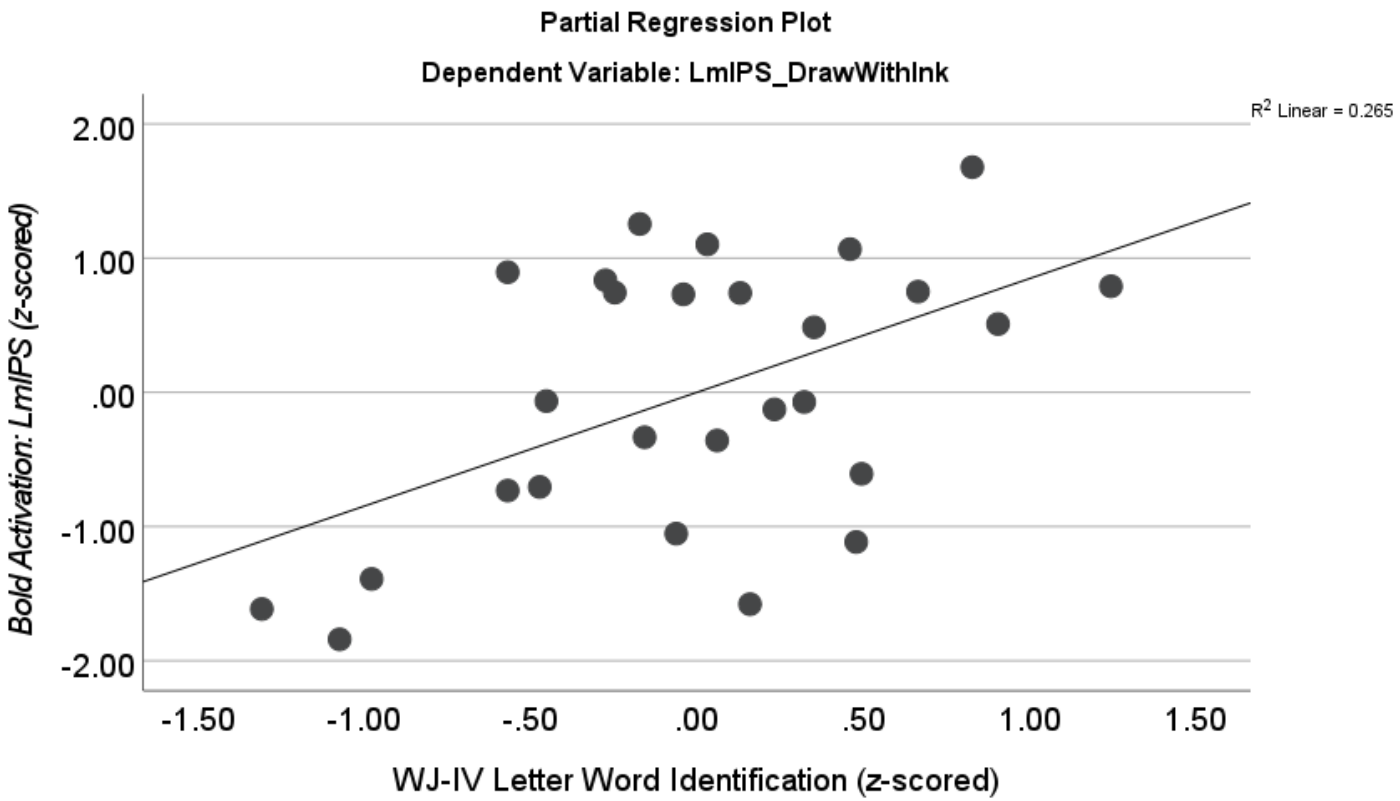




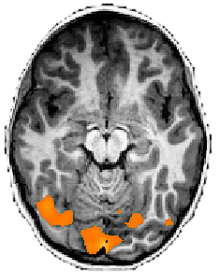


Brain activation correlates with literacy

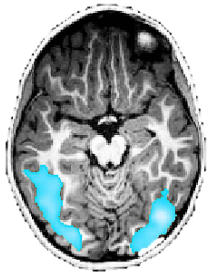


Summary of developmental results

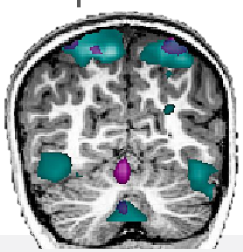
- Pre-literate children only show response to handwritten letters

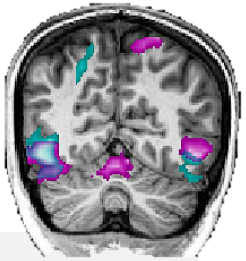


- Early literate children show a generalized visual response to letters similar to adults



- Early literate children only show visual motor overlap in IPS not in VTC

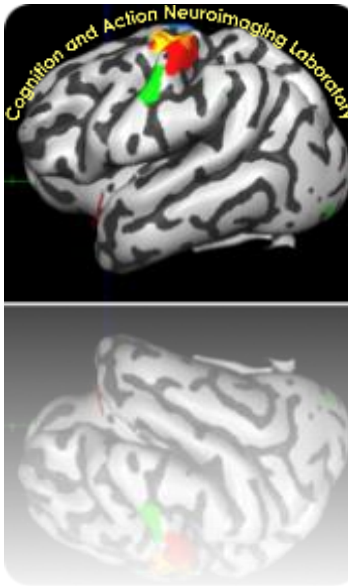




Conclusions…

- When learning a category (letters) the VTC is sensitive to variability
- Once letter categories are learned, the VTC responds to all types of letter forms
- The IPS supports both visual and motor components of handwriting throughout development

PIs: Karin James, Sophia Vinci-Booher, Thomas James, Franco Pestilli, Anatasia Nikolini, Hu Cheng



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Sarah Harris
Charles Durbin
Taylor Pamplin

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