

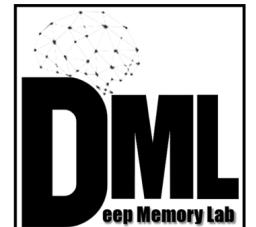
# **Memory Consolidation promotes Structured Representation of Visual Objects**

**김태훈 장하림 박선희 김구태**

Taehoon Kim, Halim Jang, Seonhwa Park, & Ghootae Kim

Deep Memory Lab, Cognitive Science Research Group

Korea Brain Research Institute

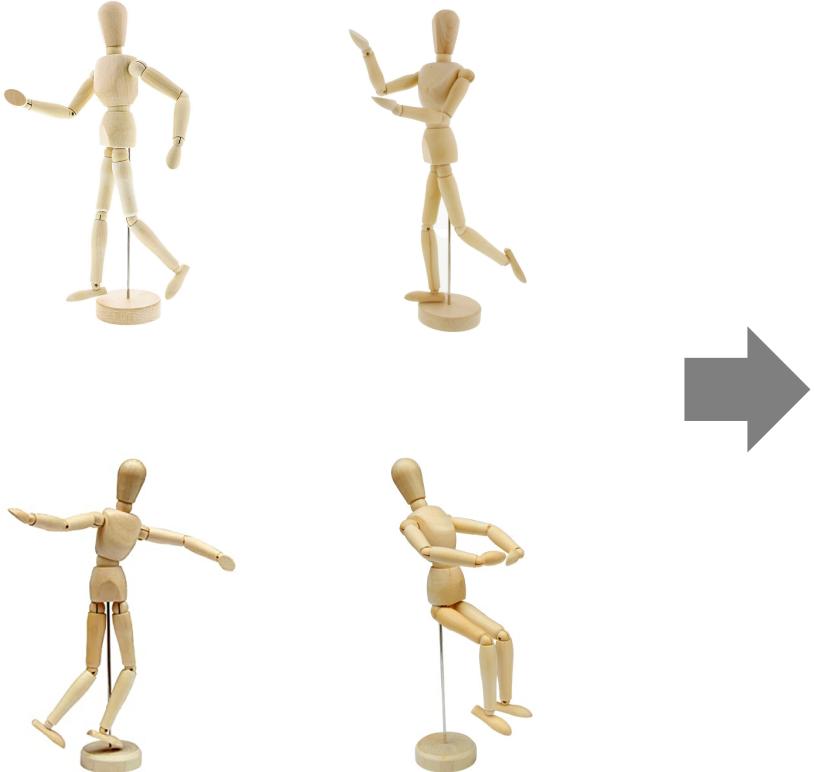


# Structured Representation

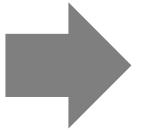
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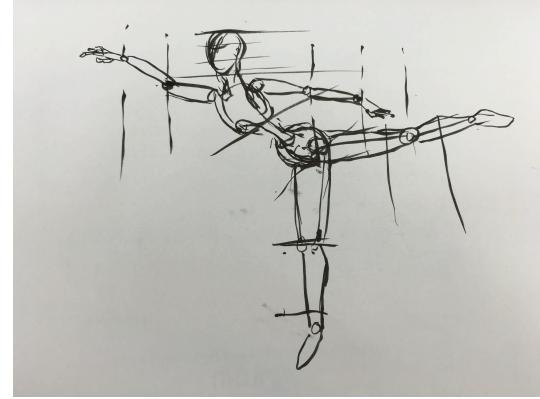
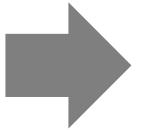
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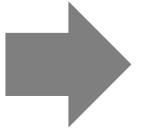
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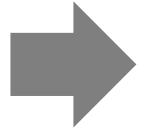
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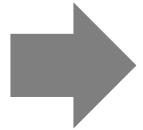
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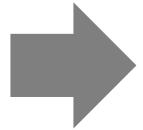
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# Structured Representation



# Structured Representation



# Structured Representation

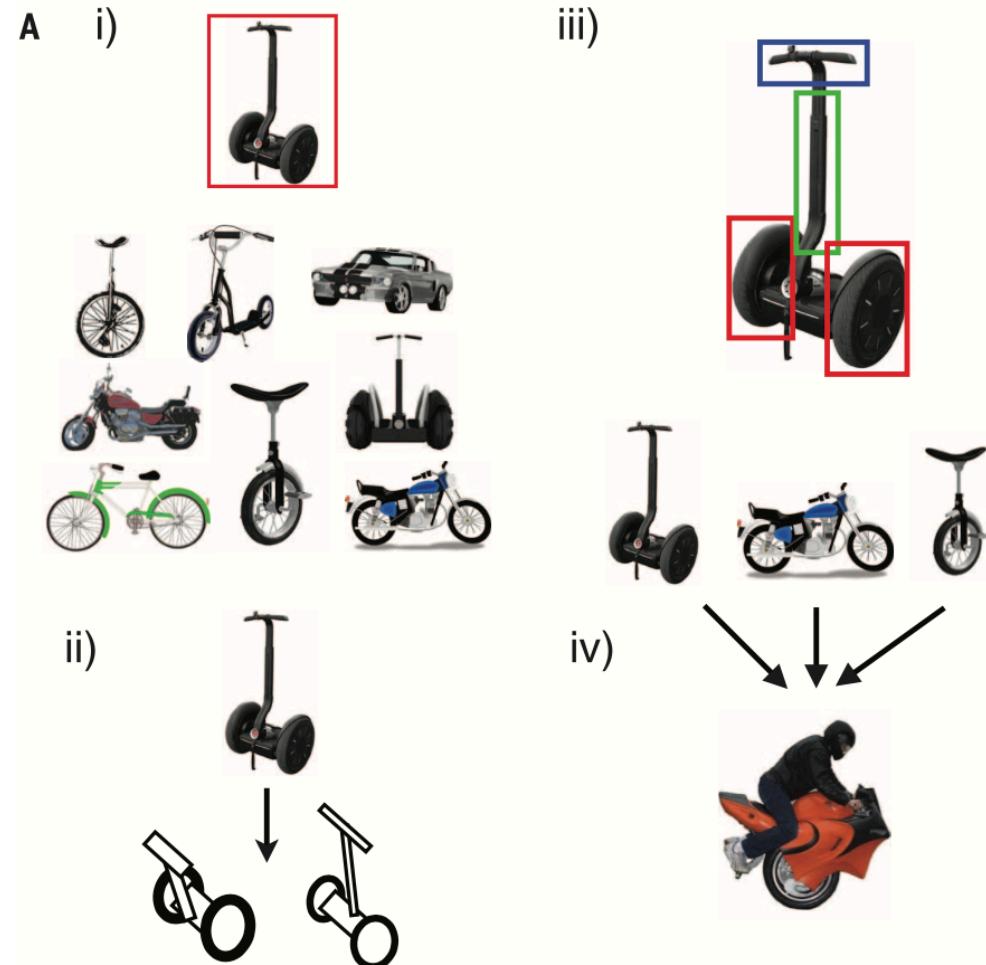
RESEARCH ARTICLES

COGNITIVE SCIENCE

## Human-level concept learning through probabilistic program induction

Brenden M. Lake,<sup>1\*</sup> Ruslan Salakhutdinov,<sup>2</sup> Joshua B. Tenenbaum<sup>3</sup>

2015, Science



# Structured Representation

RESEARCH ARTICLES

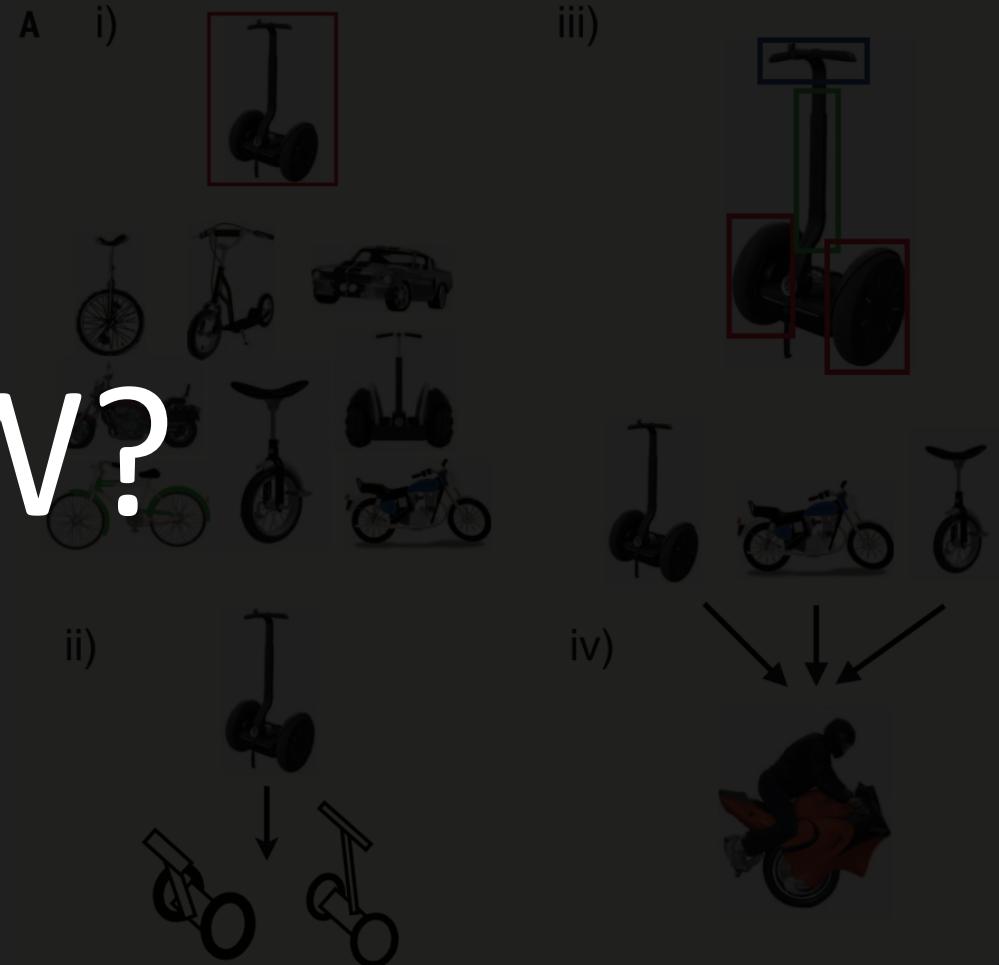
COGNITIVE SCIENCE

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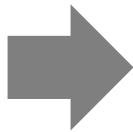
Brenden M. Lake,<sup>1\*</sup> Ruslan Salakhutdinov,<sup>2</sup> Joshua B. Tenenbaum<sup>3</sup>

2015, Science

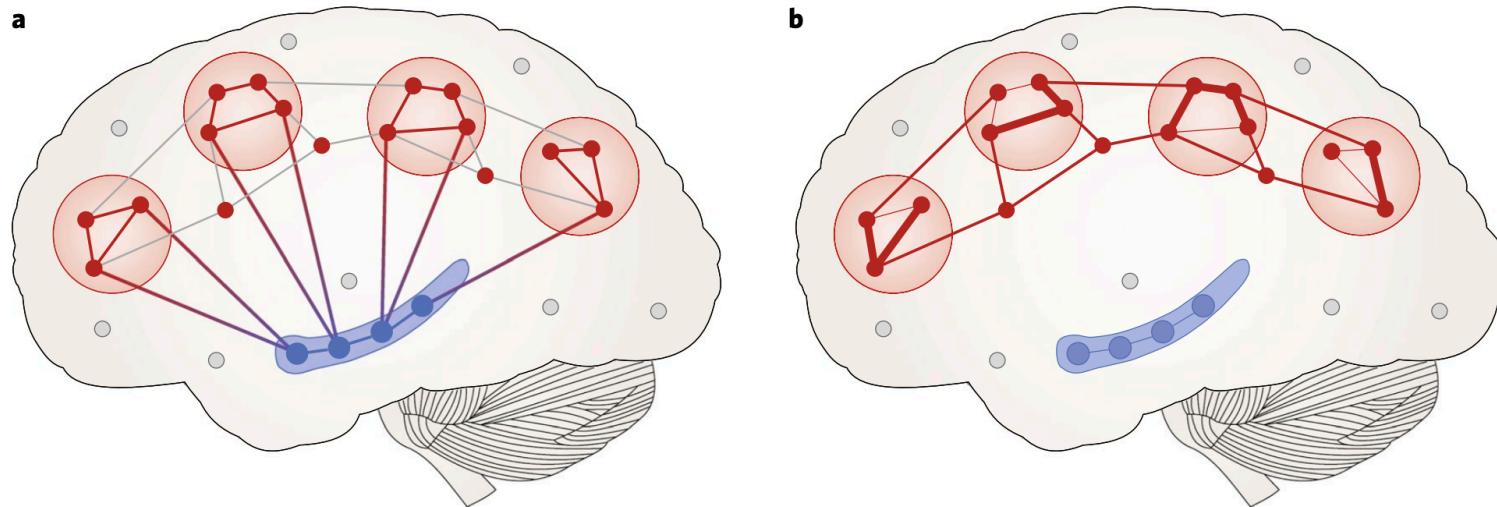
# HOW?



# Memory Consolidation

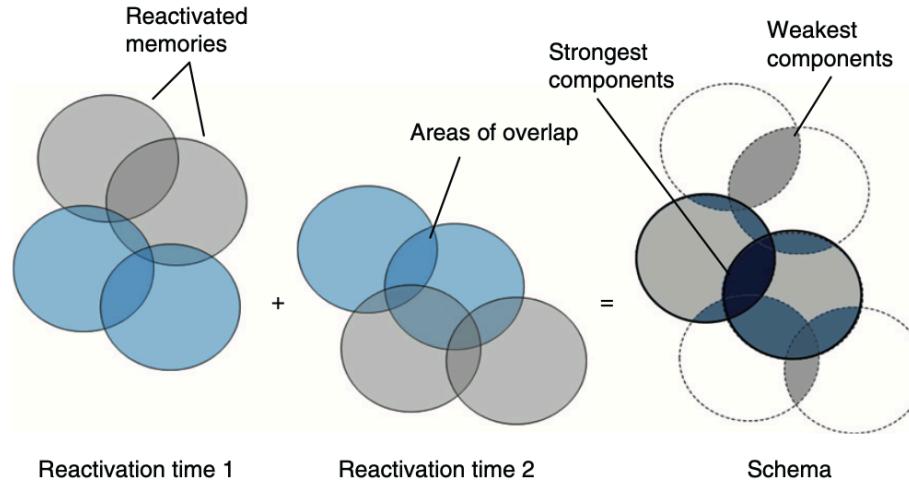


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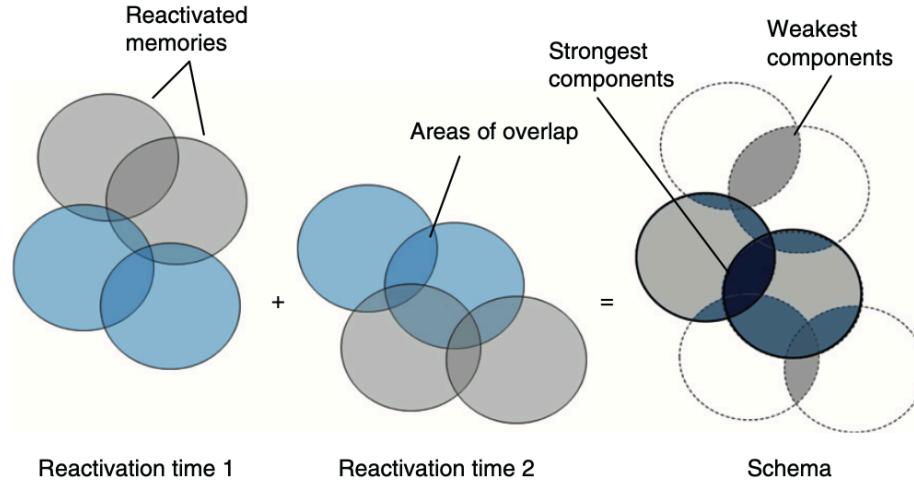


Consolidation strengthens neocortical representations

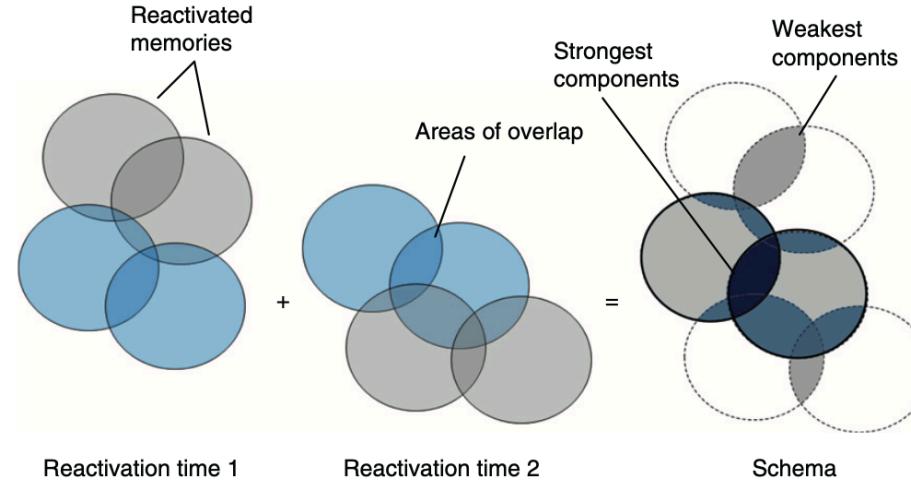
# Memory Consolidation



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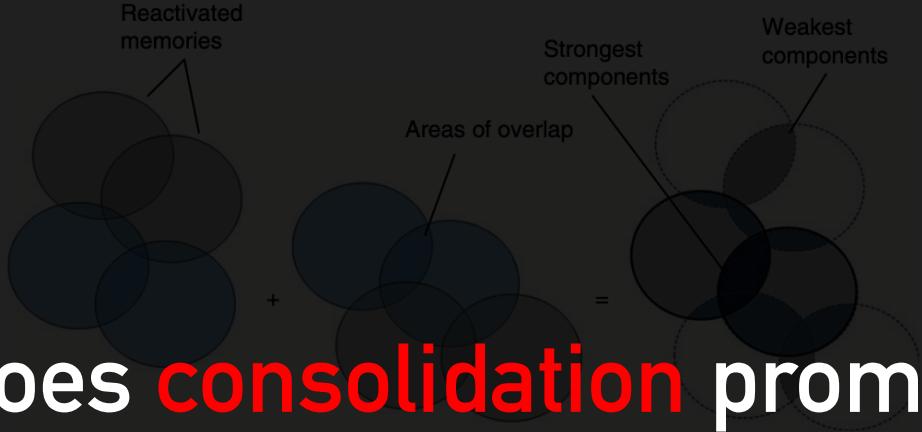


# Memory Consolidation



Lewis & Durrant, 2011, TiCS

# Memory Consolidation



Does **consolidation** promote  
structured representation of visual objects?



# Stimuli

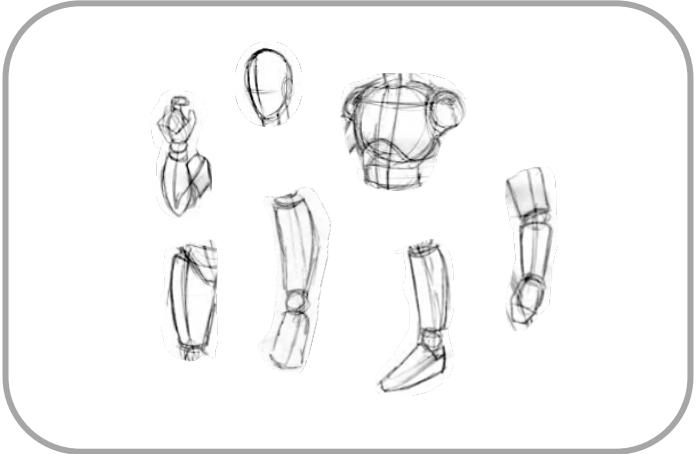
# Stimuli



Object

# Stimuli

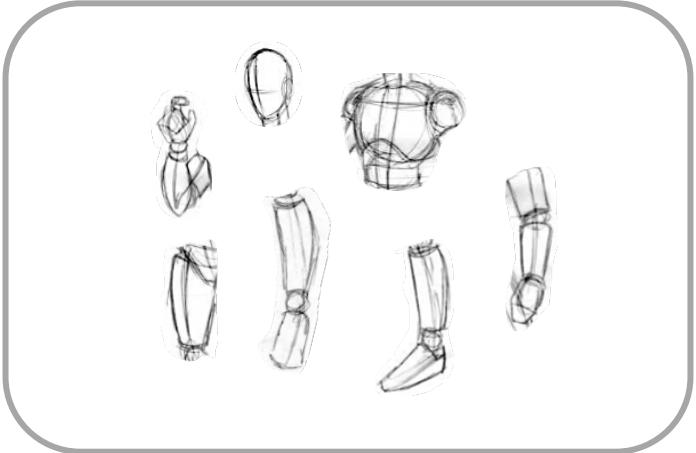
Constituent



Object

# Stimuli

Constituent



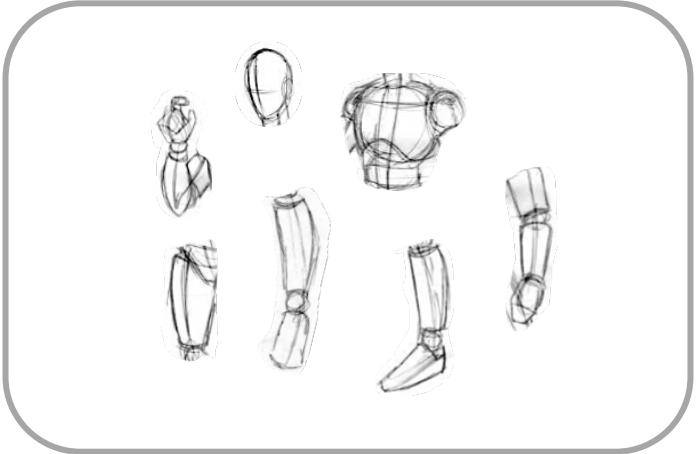
Object

Constituent



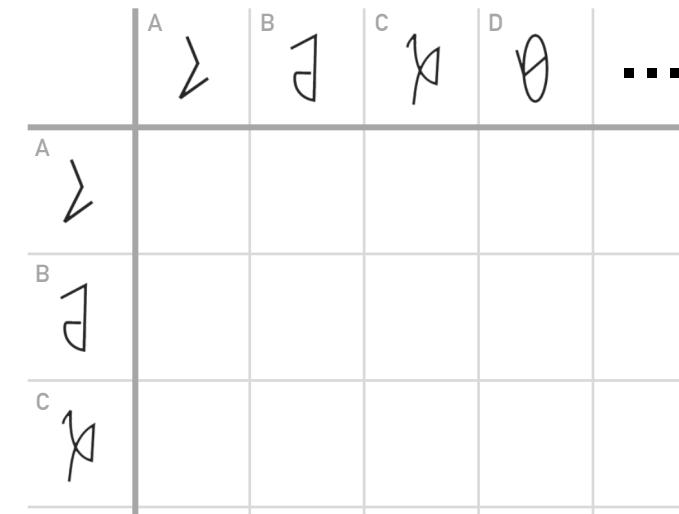
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Constituent



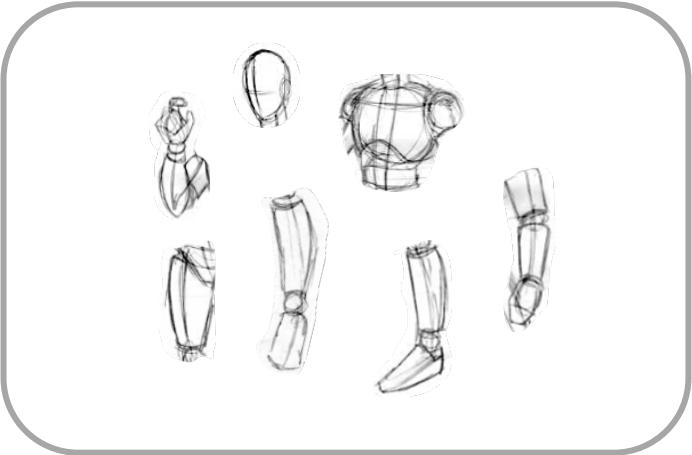
Object

Constituent



# Stimuli

Constituent



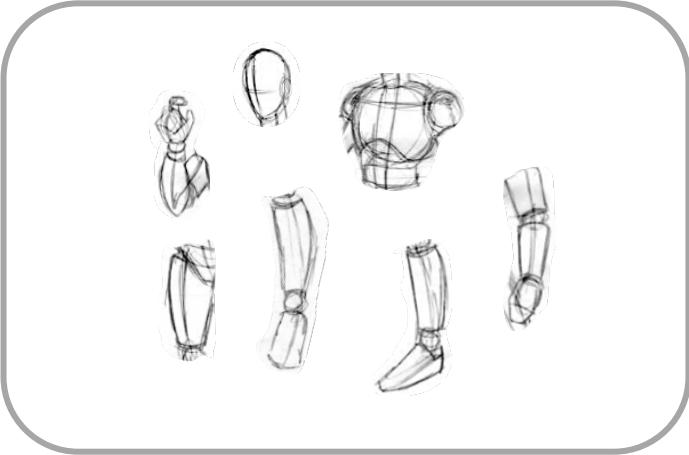
Object

Constituent

	A	B	C	D	...
A	>		χ	θ	
B		Δ			
C	χ				...

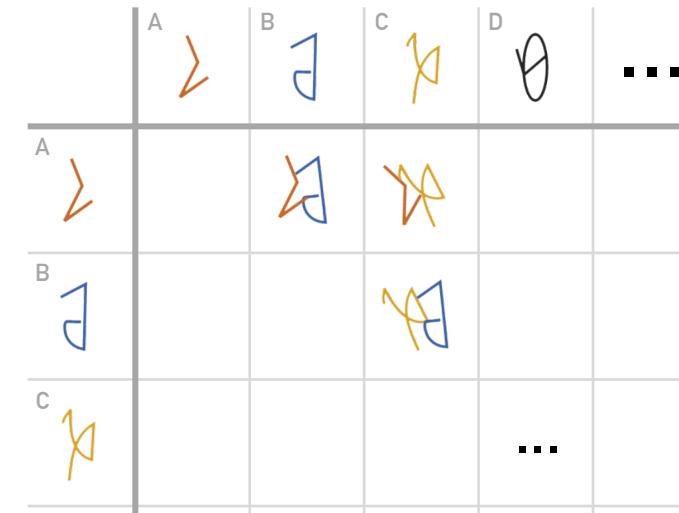
# Stimuli

Constituent



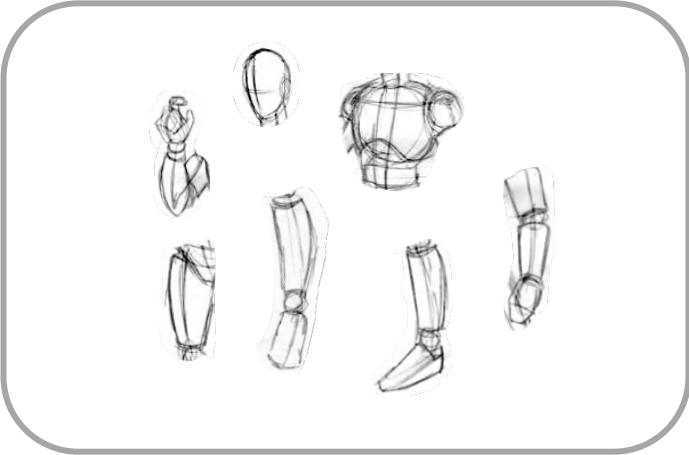
Object

Constituent



# Stimuli

Constituent



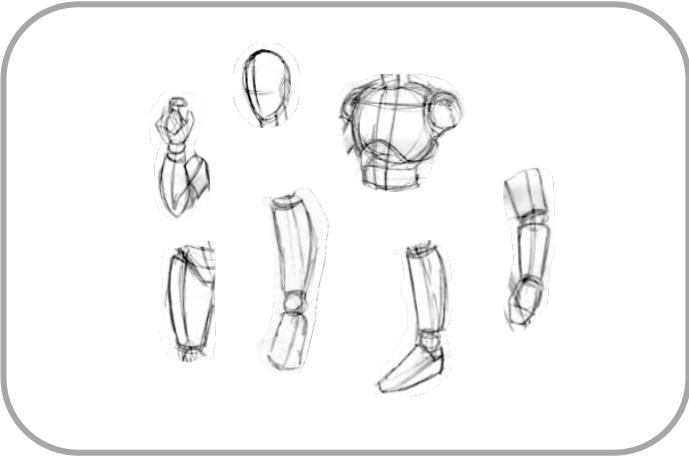
Object

Constituent

	A	B	C	D	...
A	>	ʃ	χ	θ	
B	ʃ	ʒ	χ	θ	
C	χ	ʒ	χ	θ	...

# Stimuli

Constituent



Object

Constituent

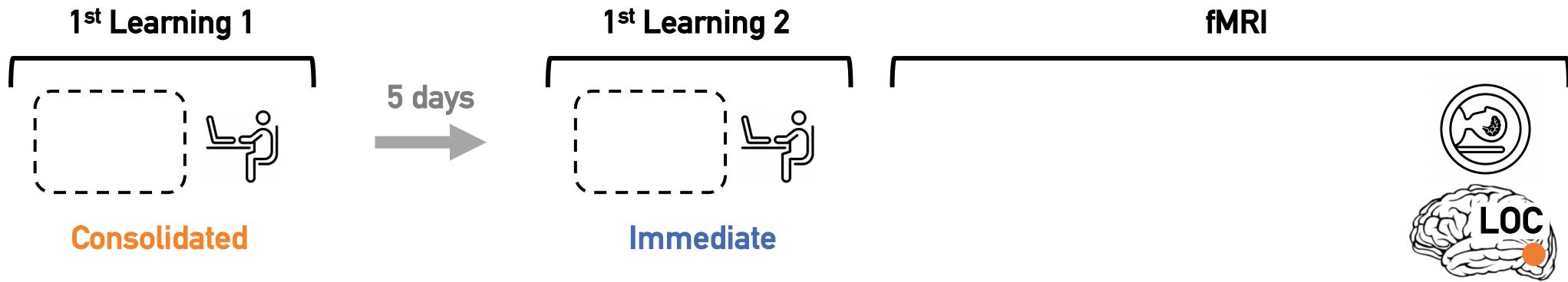
	A	Y	E	X	O	...
A	Y		Y	X	O	
B	E			Y	Y	
C	X					...



Object

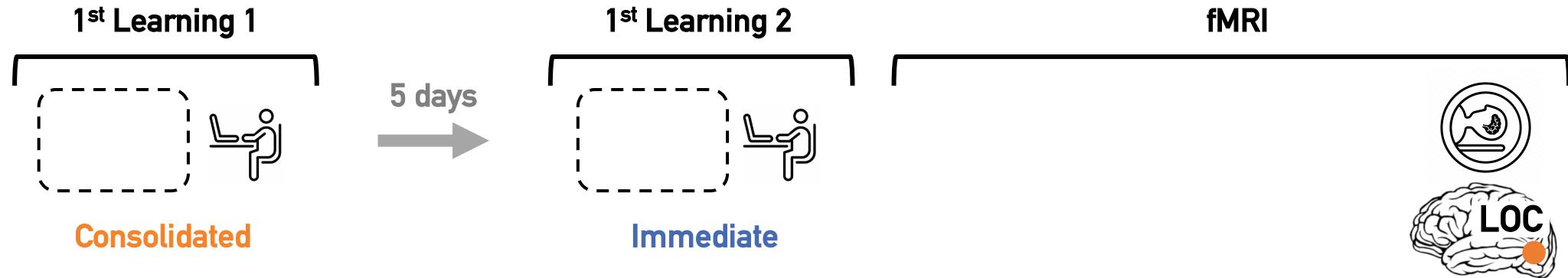
# Design

\* Within-subjects design



# Design

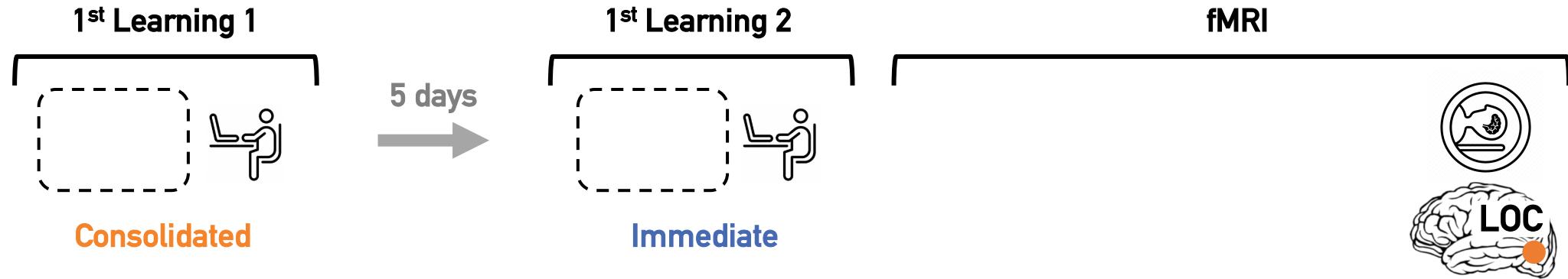
\* Within-subjects design



	Y	E	X	Ø	...
Y					
E					
X					
...					

# Design

\* Within-subjects design

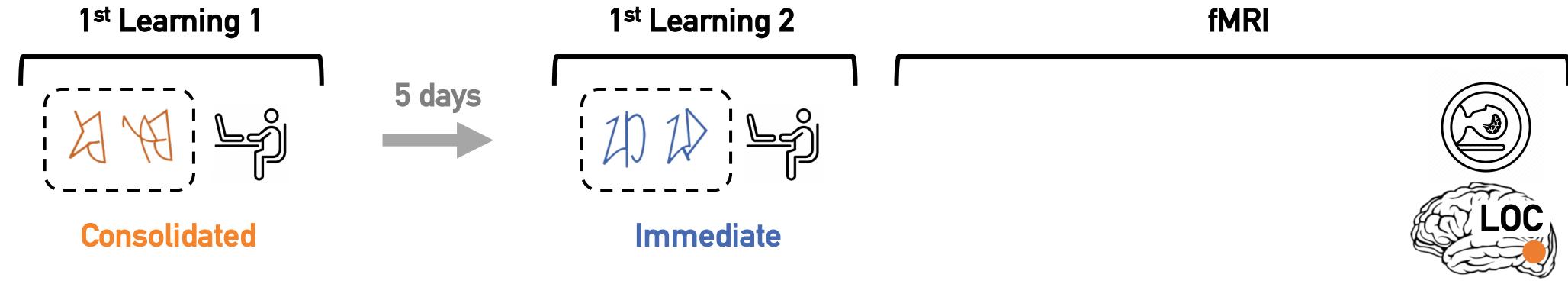


	Y	E	X	Θ	...
Y					
E					
...					

D	Z	Y	H	...
Z				
Y				
H				

# Design

\* Within-subjects design

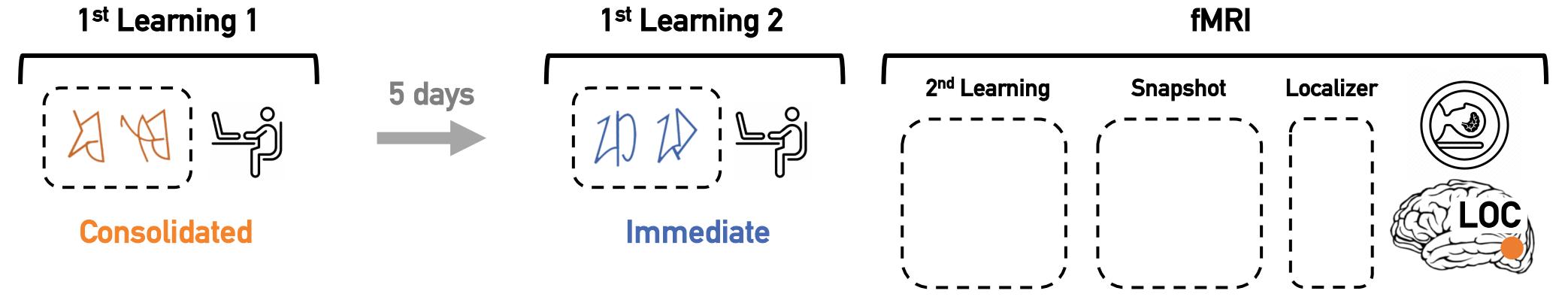


	Y	E	A	O	...
Y		A	X	O	Learning
E			A	X	
A				A	
...					

D	Z	Y	H	...
Z		D	Y	Learning
Y			D	
H				
...				

# Design

\* Within-subjects design

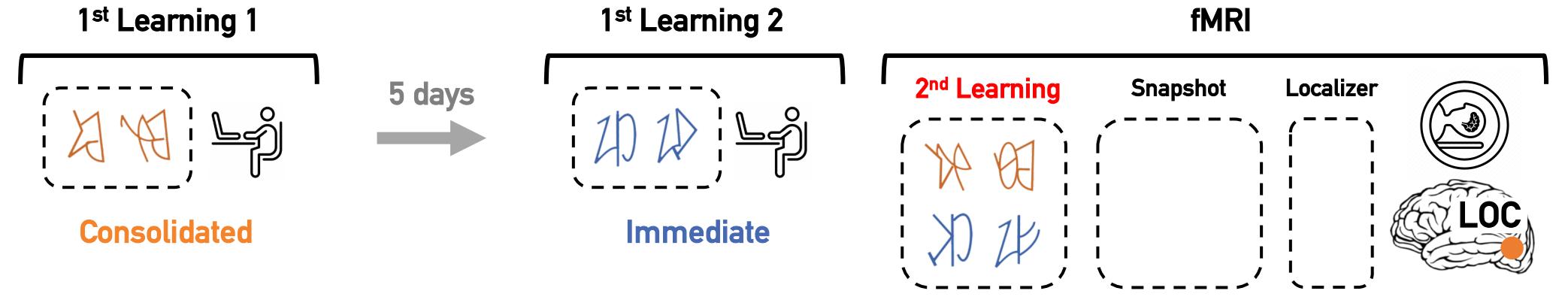


	Y	E	X	Θ	...
Y		X	Y	X	Learning
E			X	Y	
X				X	

	D	Z	>	H	...
D		Z	>	H	Learning
Z			Z	H	
>				H	

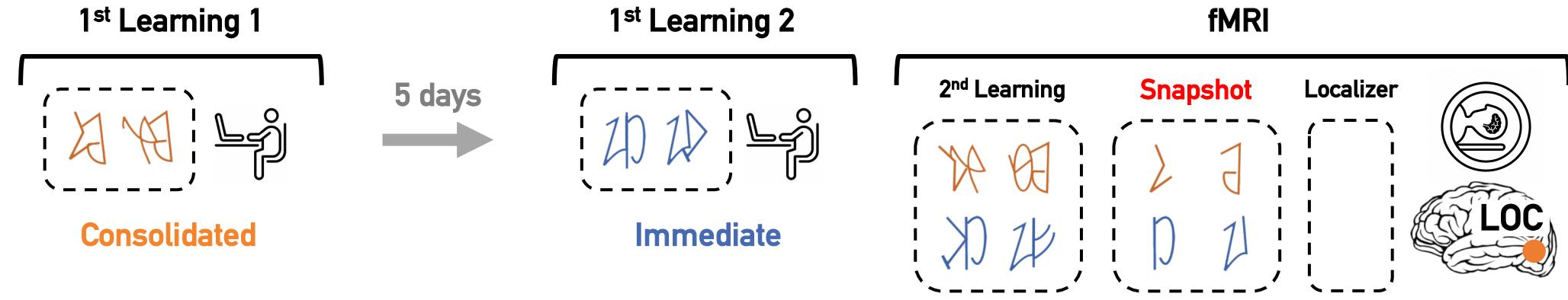
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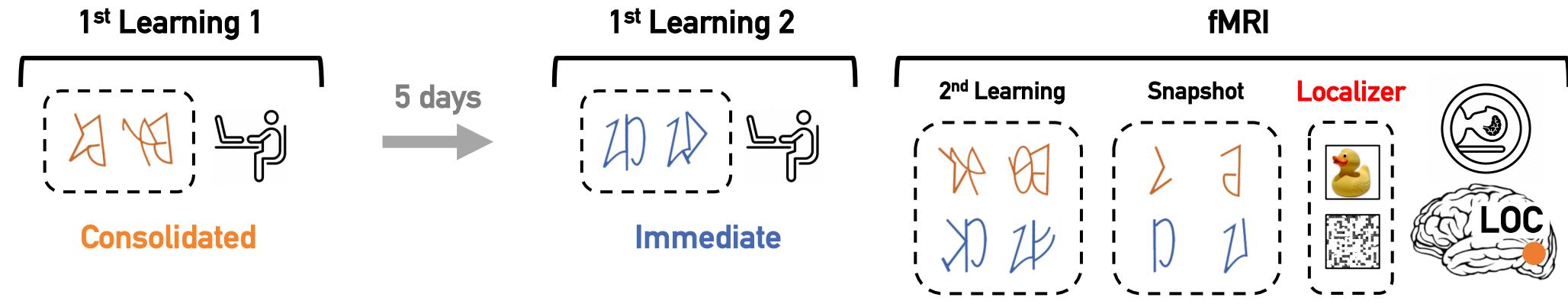
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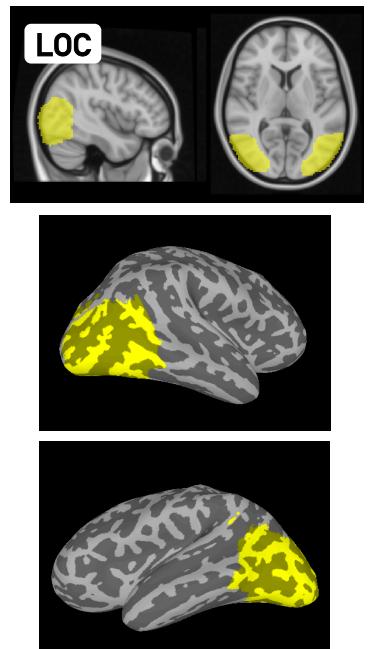
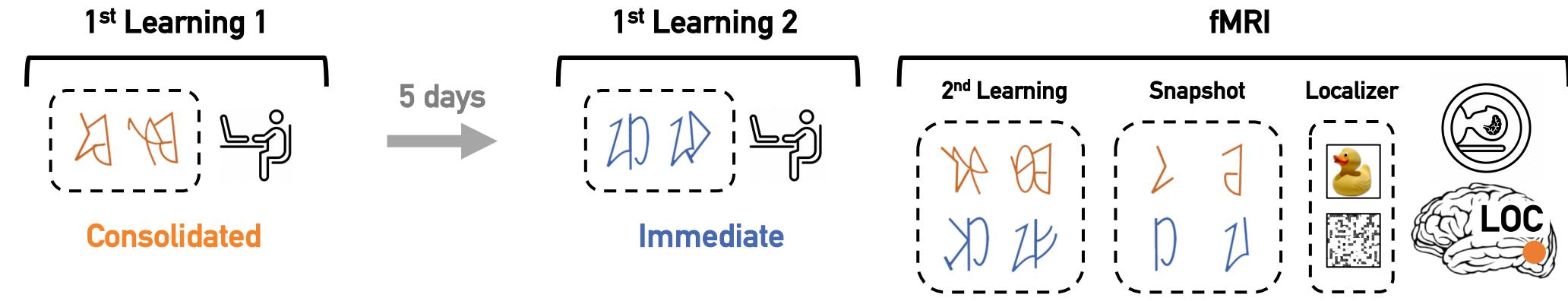
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# Hypothesis & Results

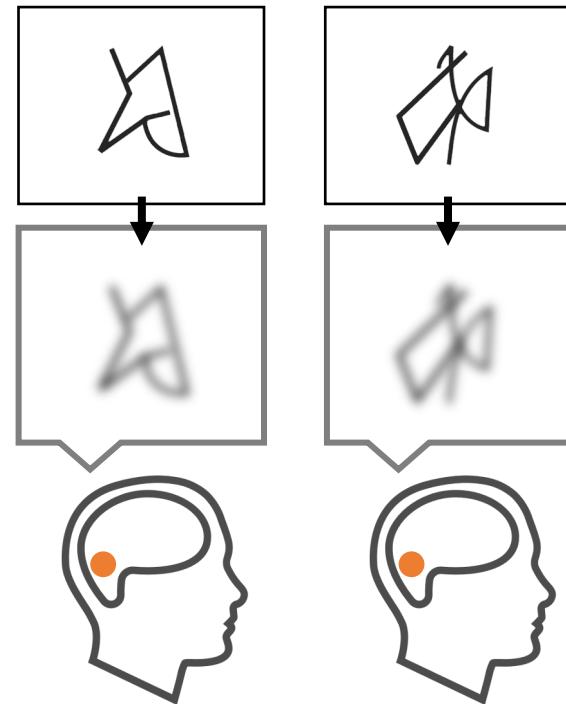
# Hypothesis & Results

Before

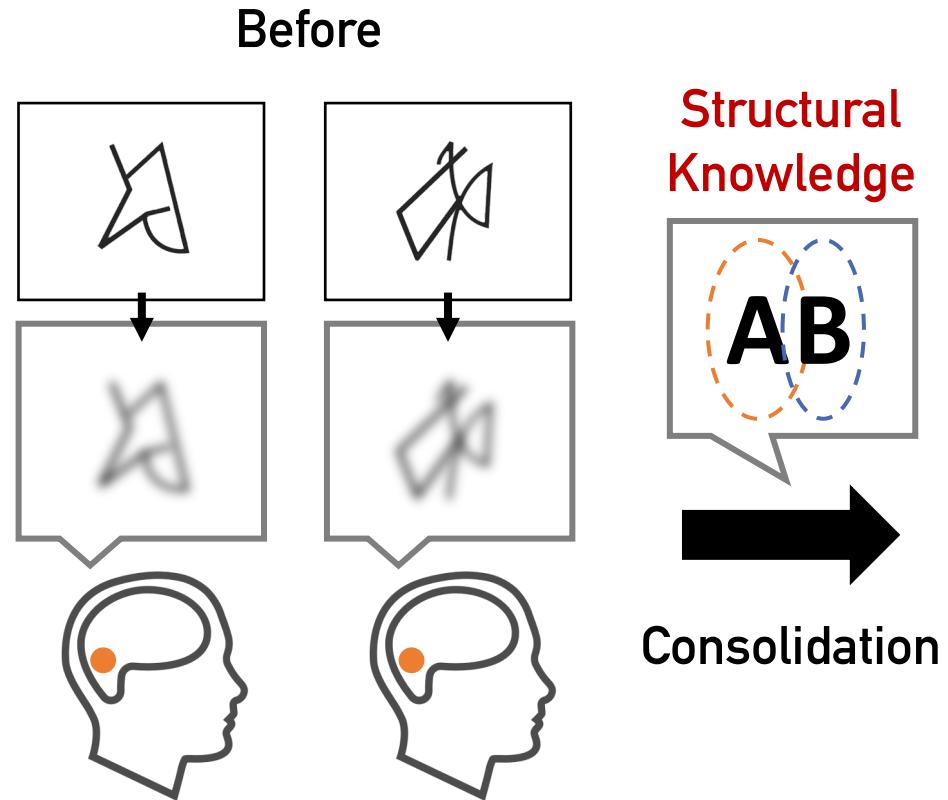


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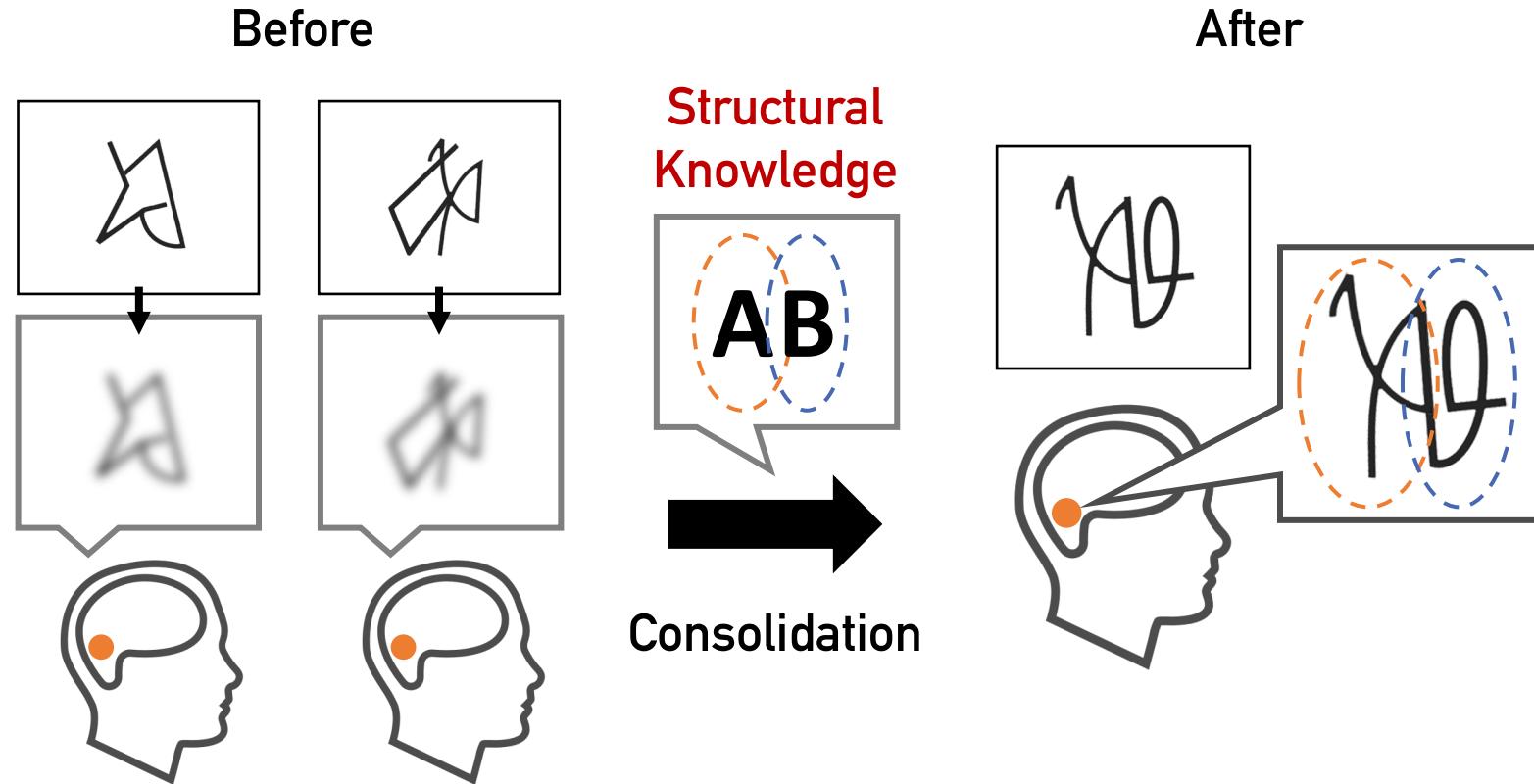
Before



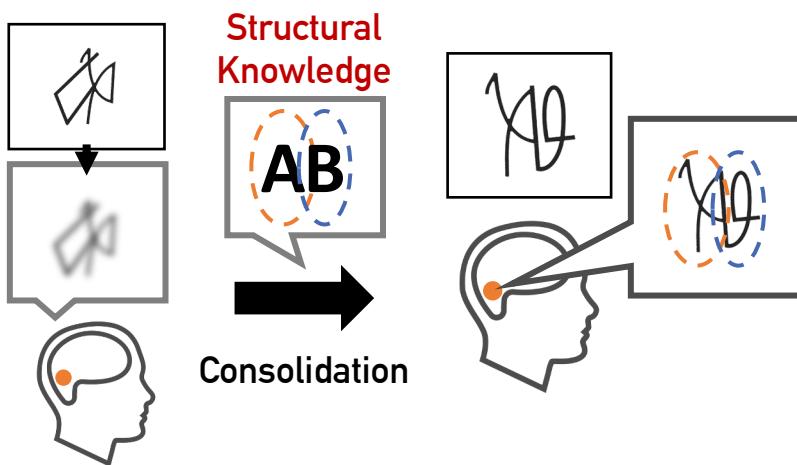
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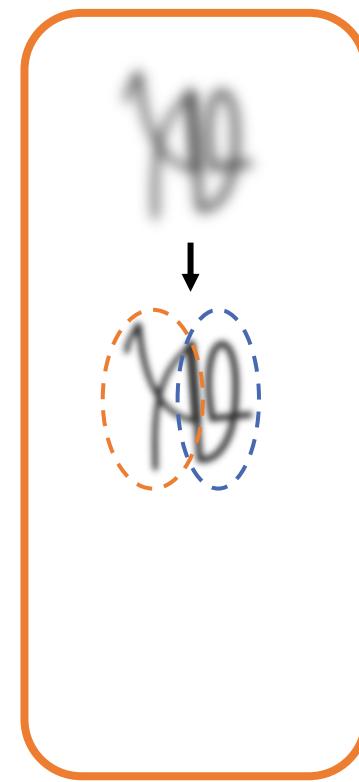
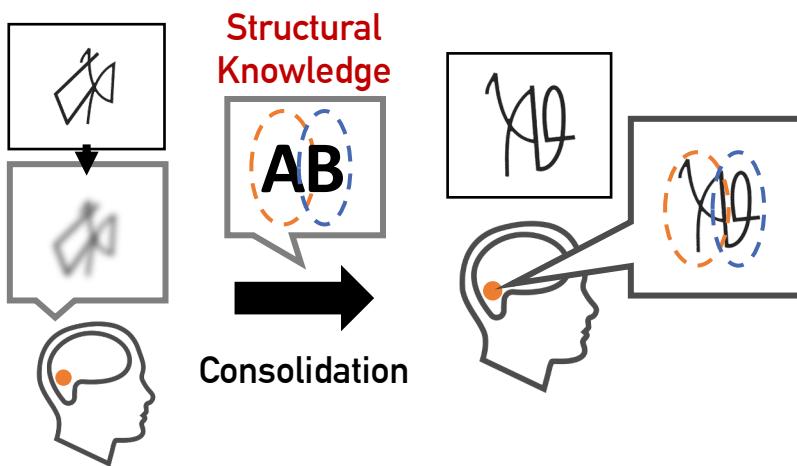
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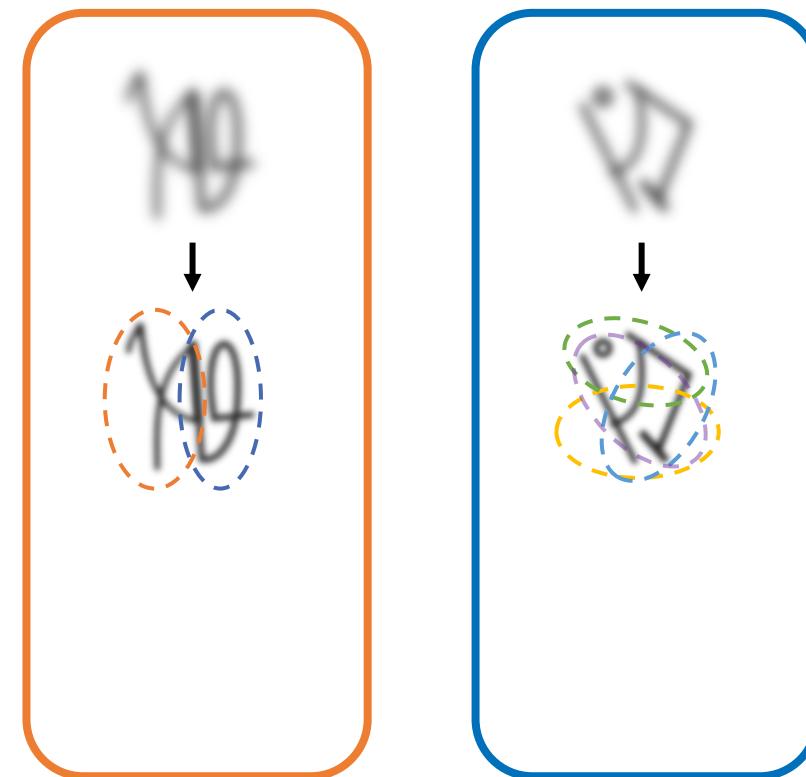
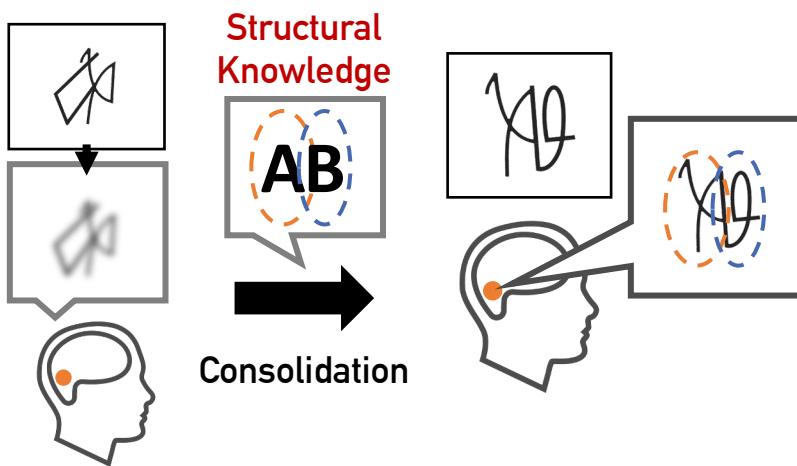
# 1. Object-ness of consolidated objects will be increased



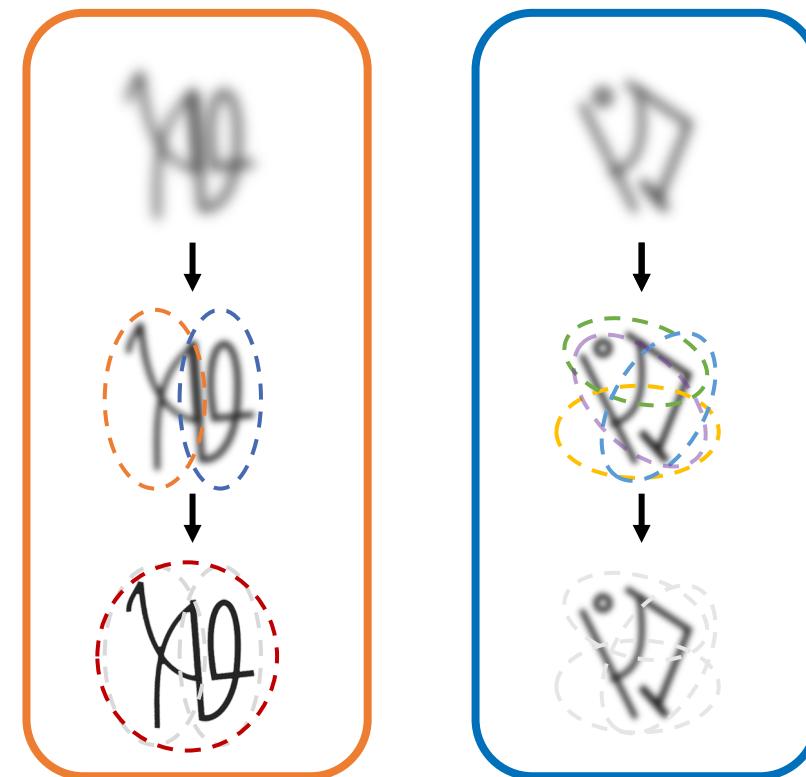
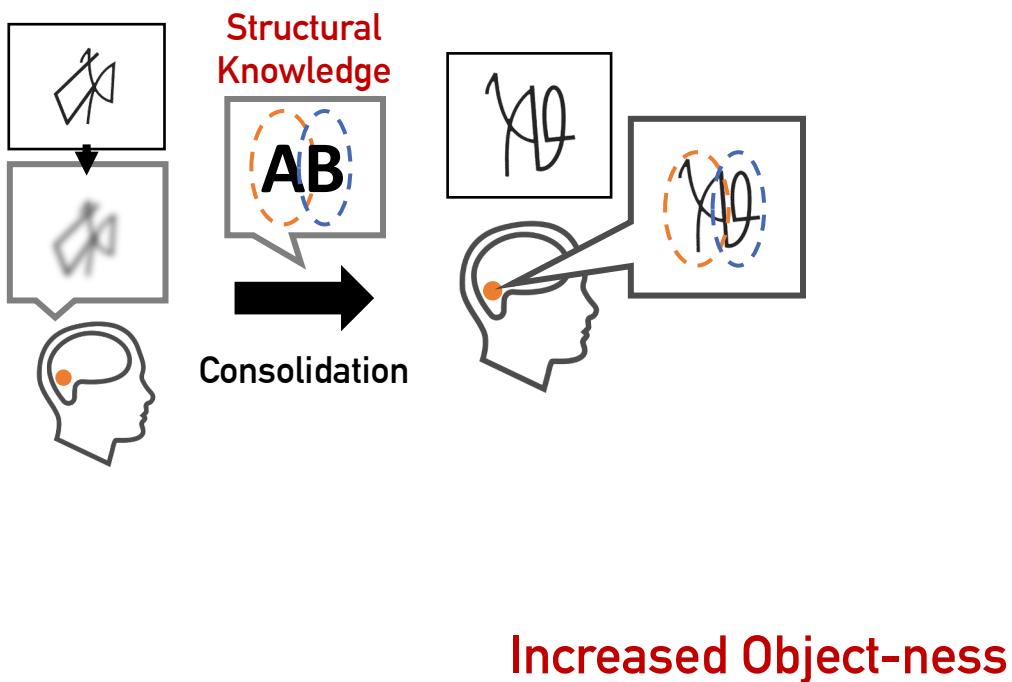
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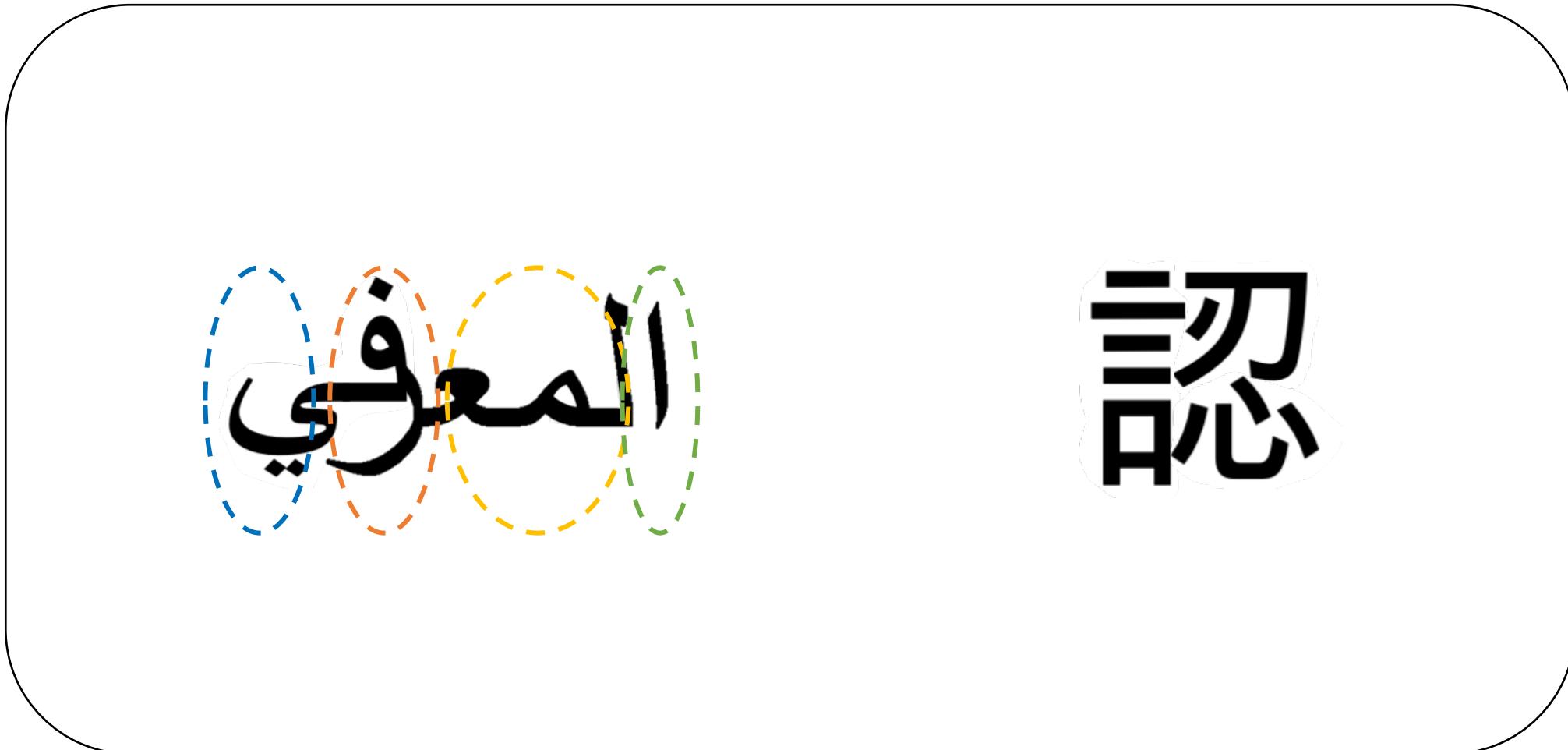


المعرفة

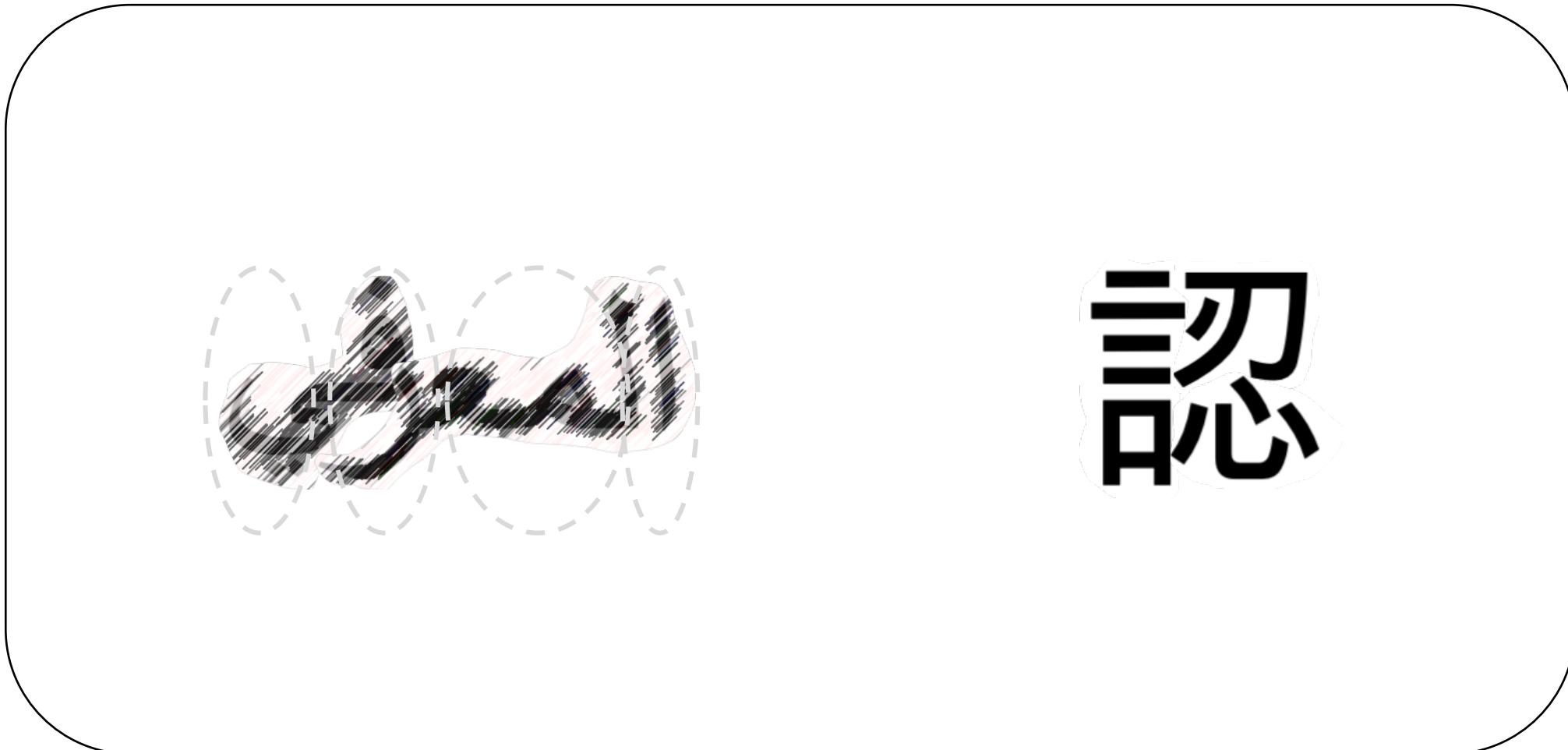


認心

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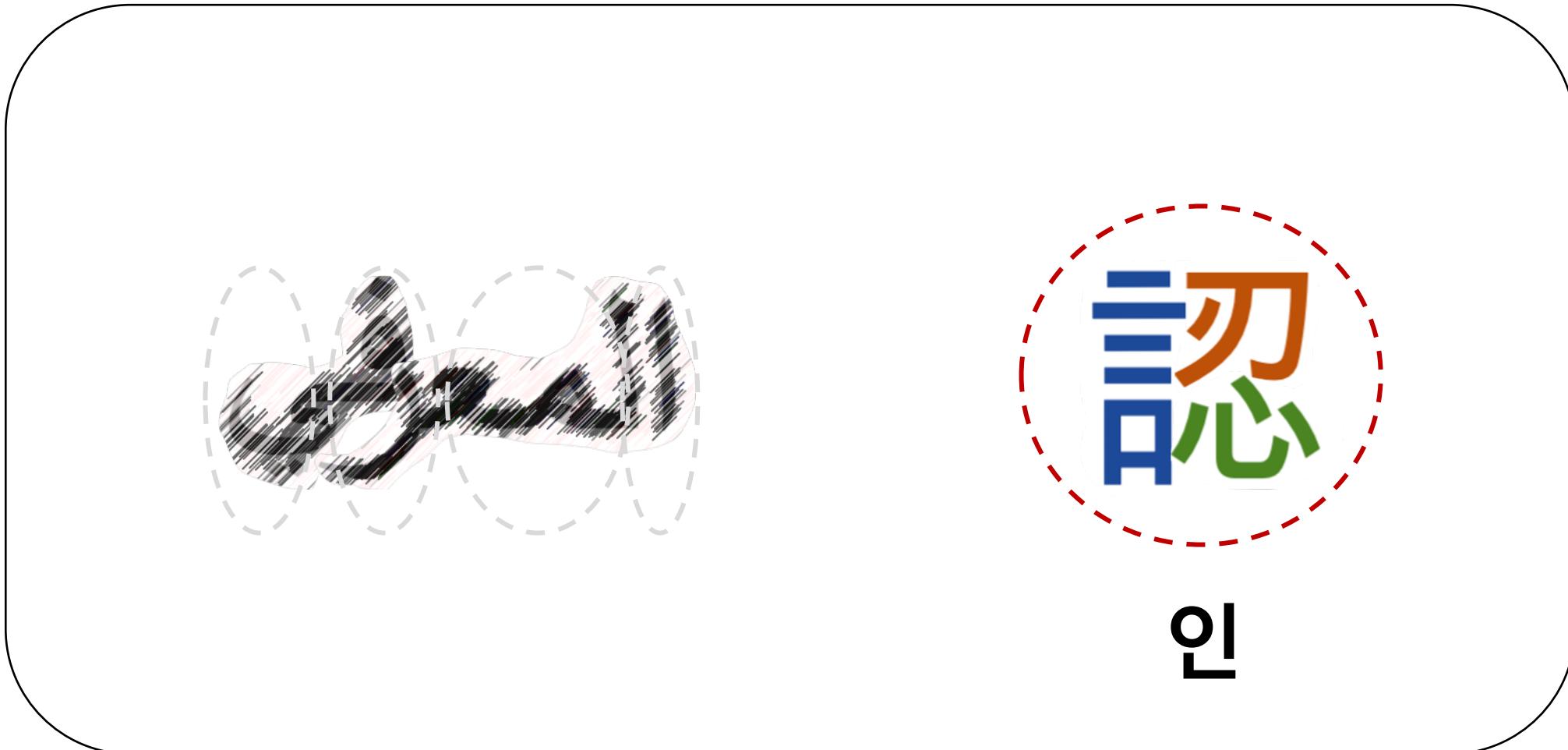
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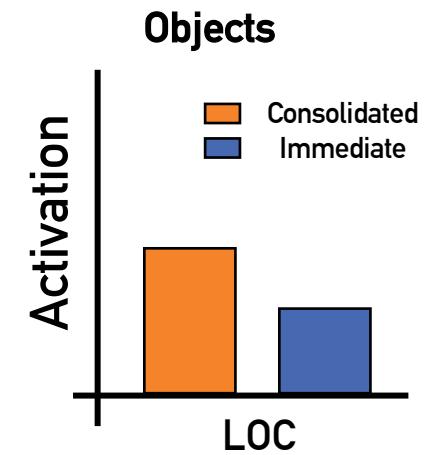
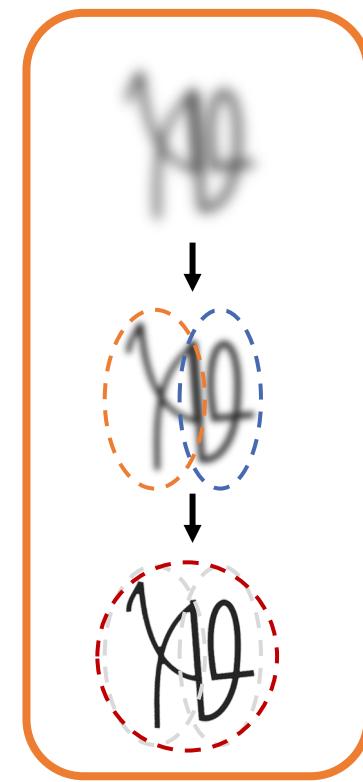
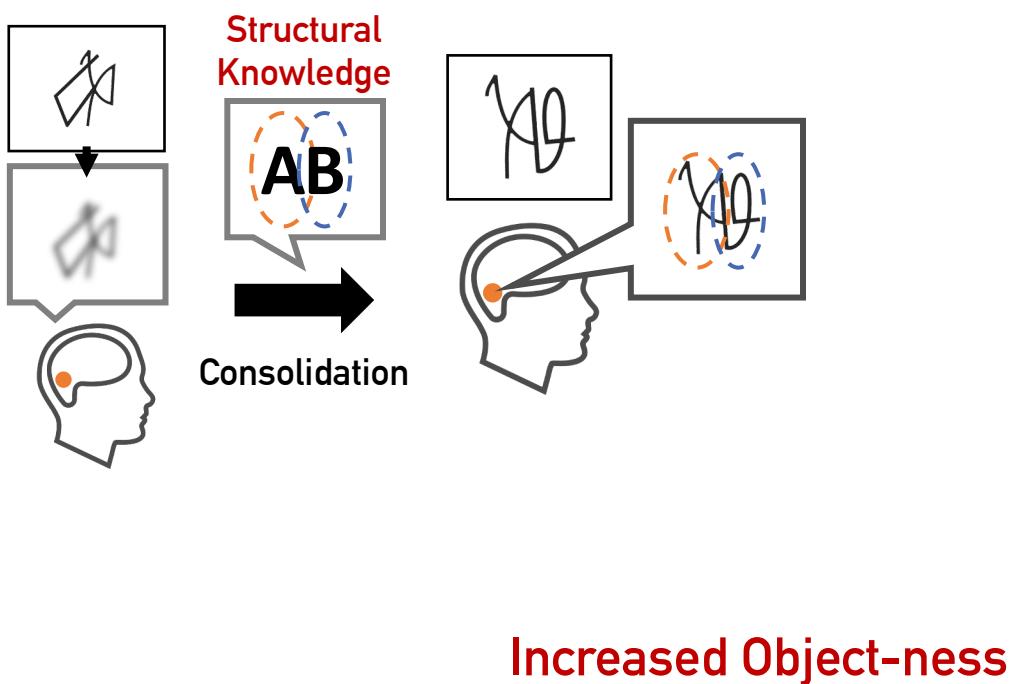
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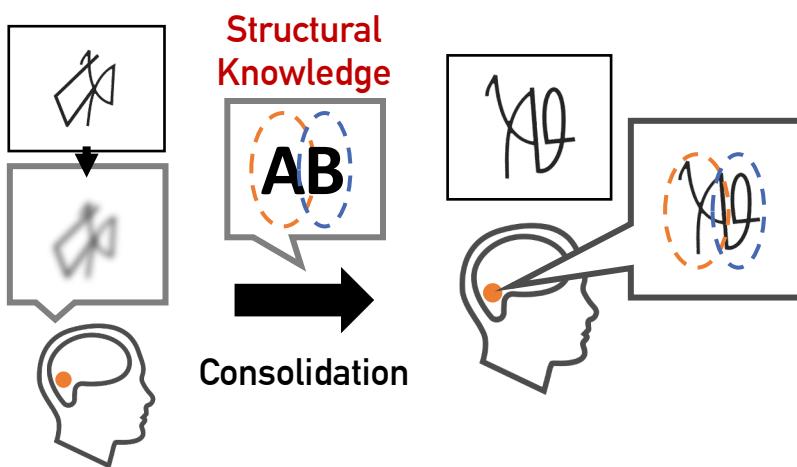
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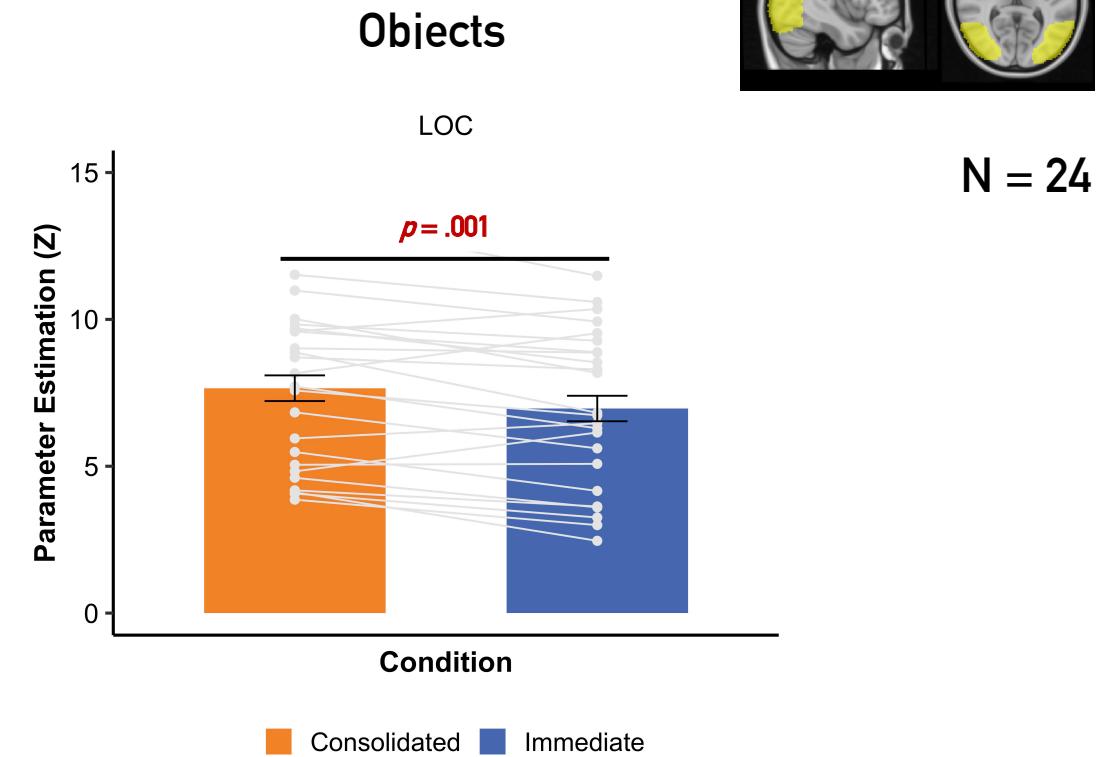
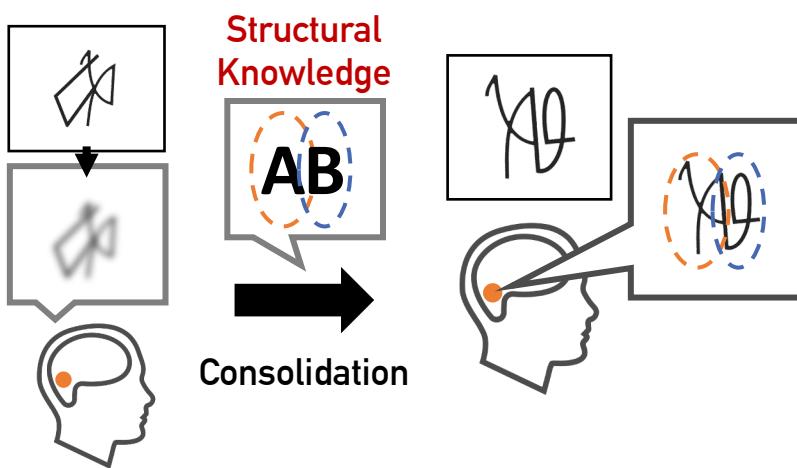


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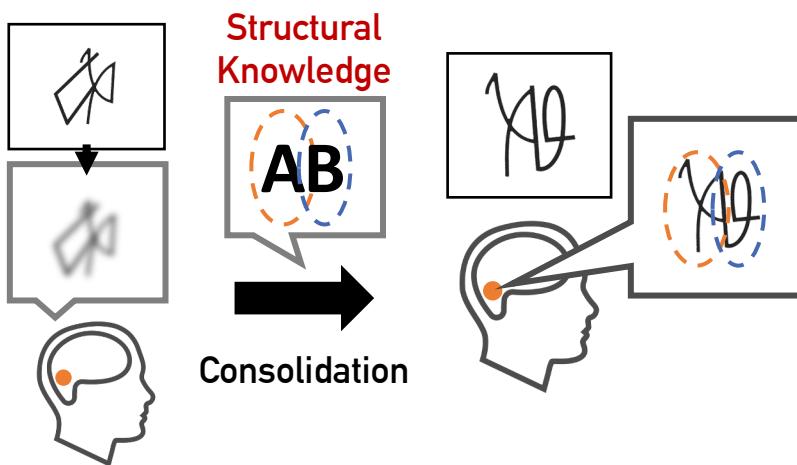


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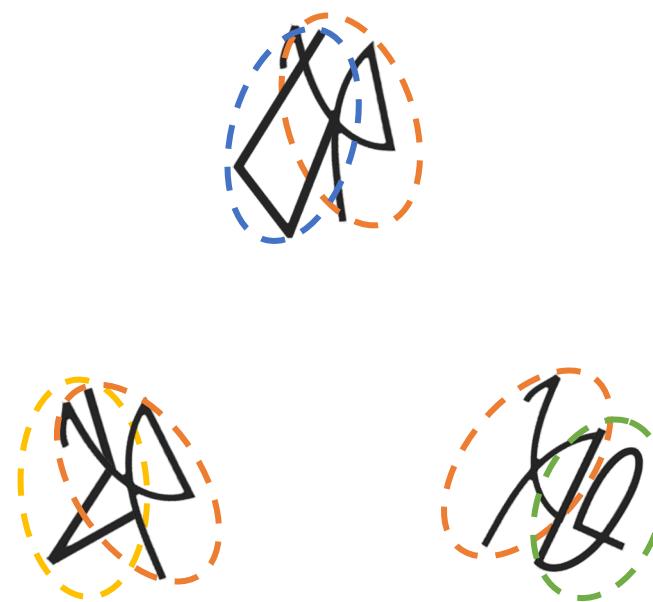
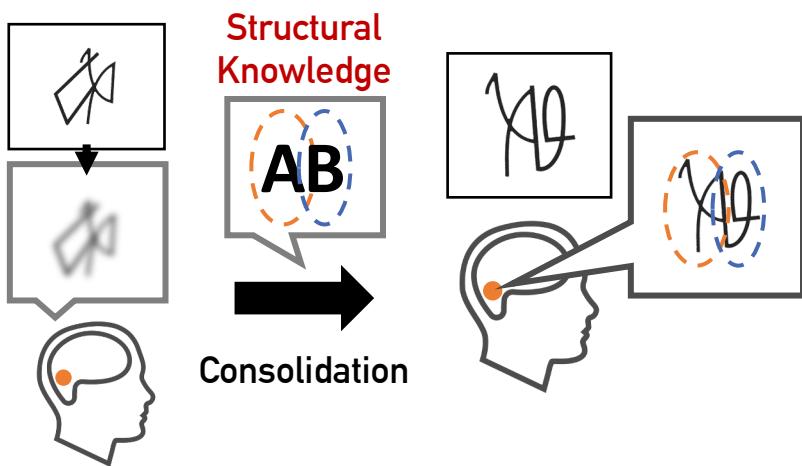
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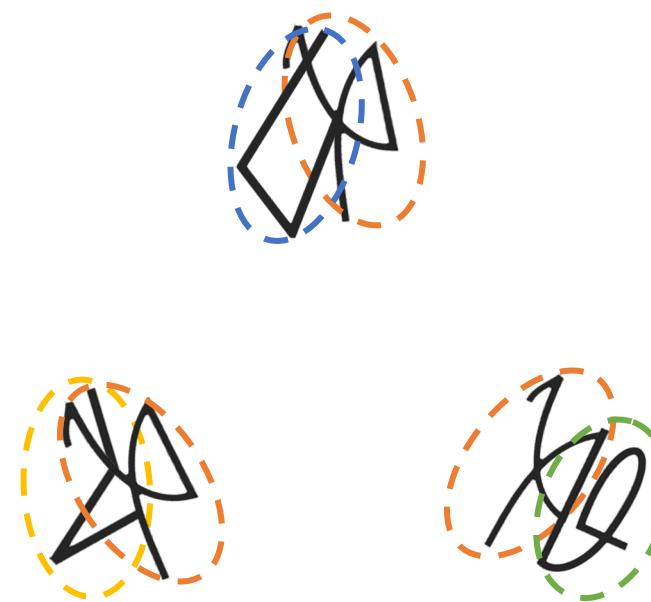
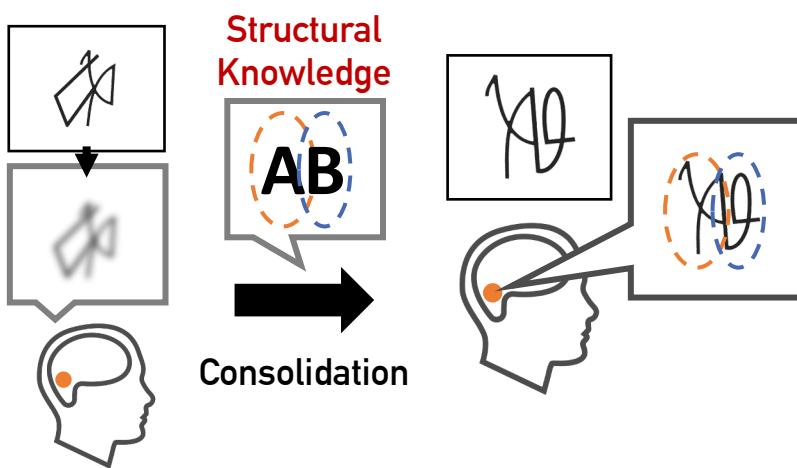
## 2. Representational similarity between objects will be increased



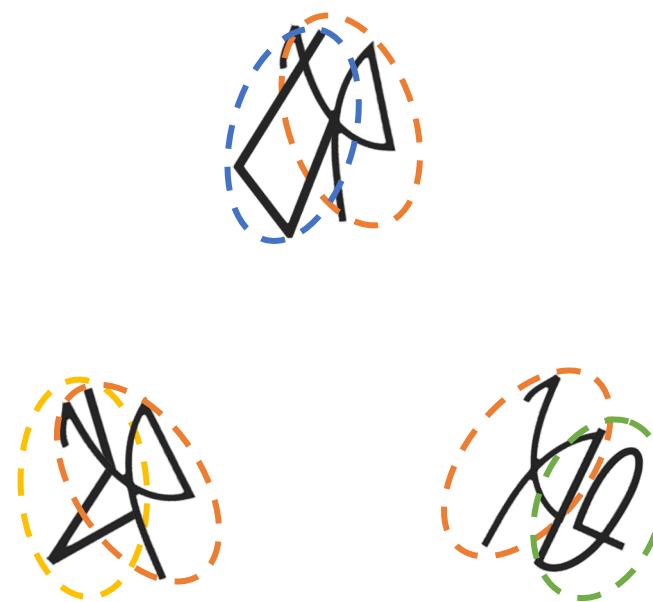
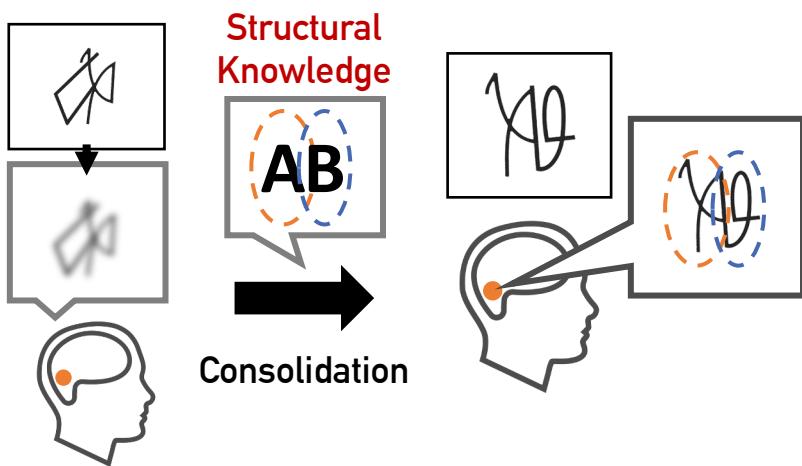
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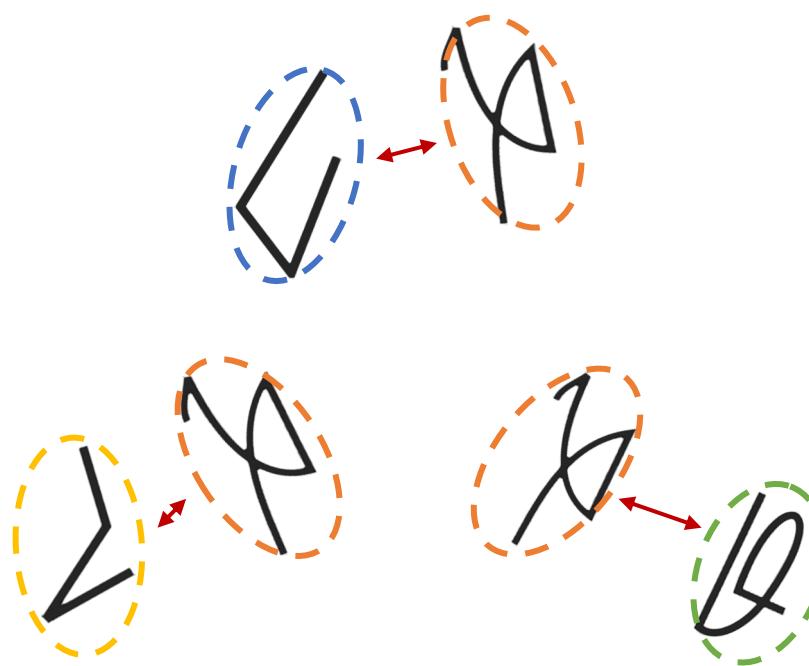
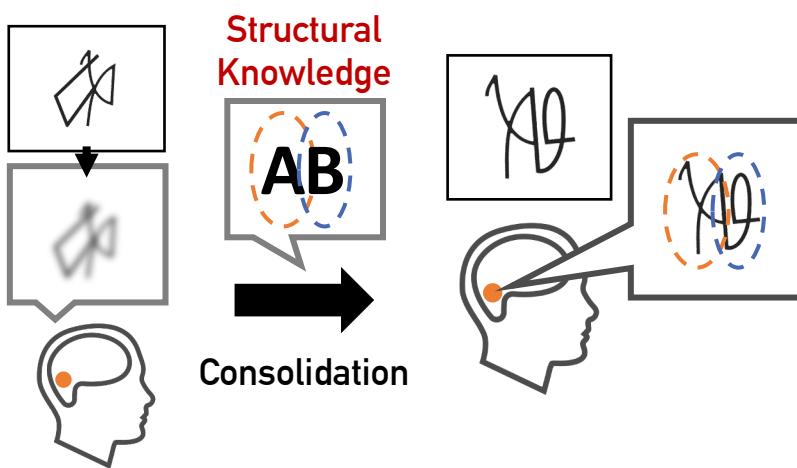
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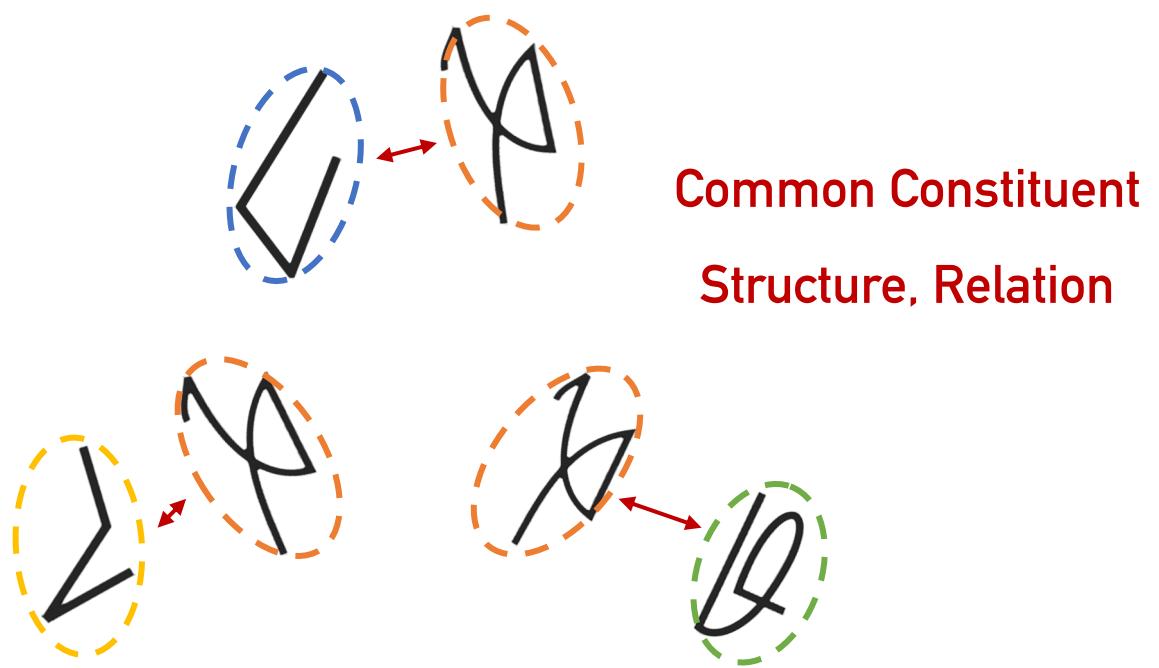
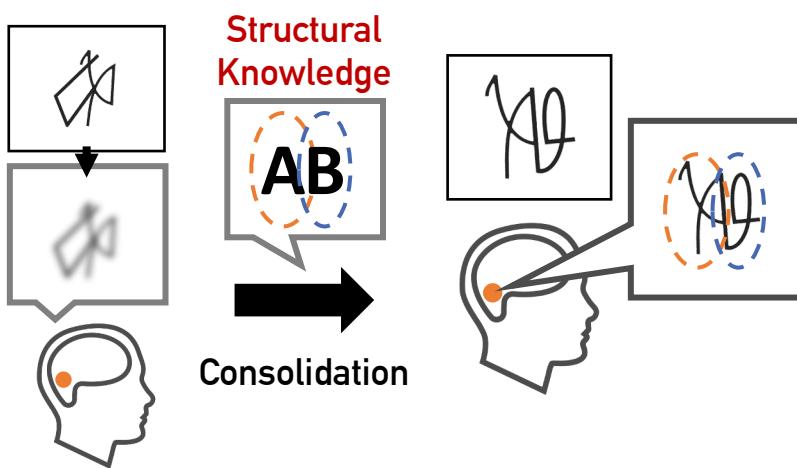
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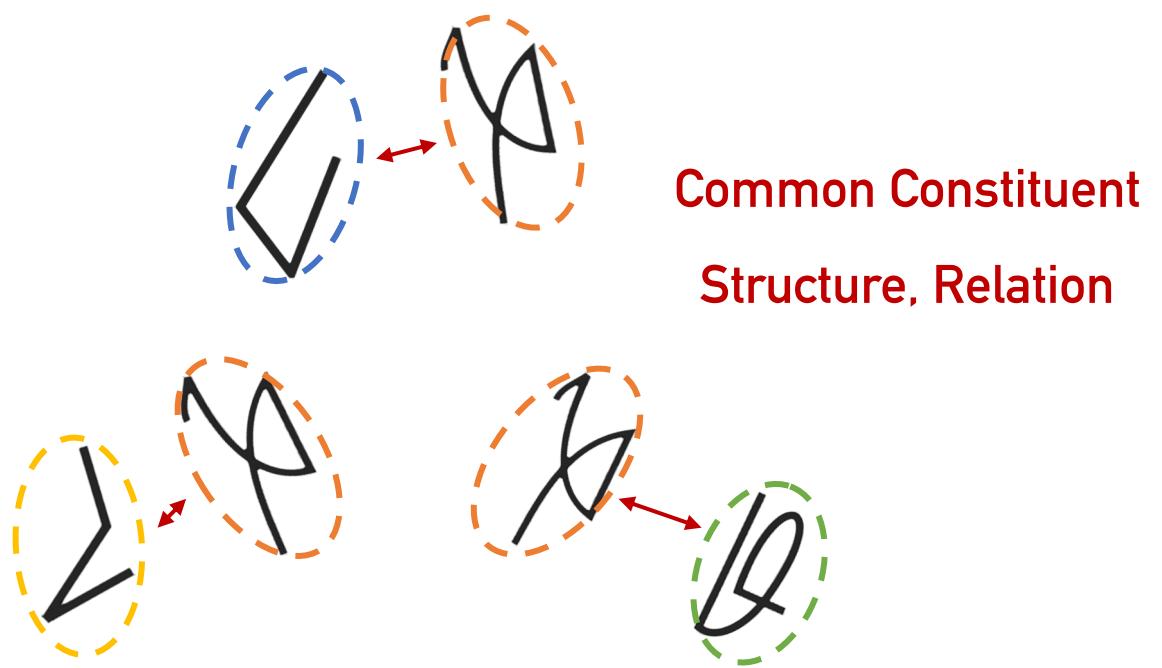
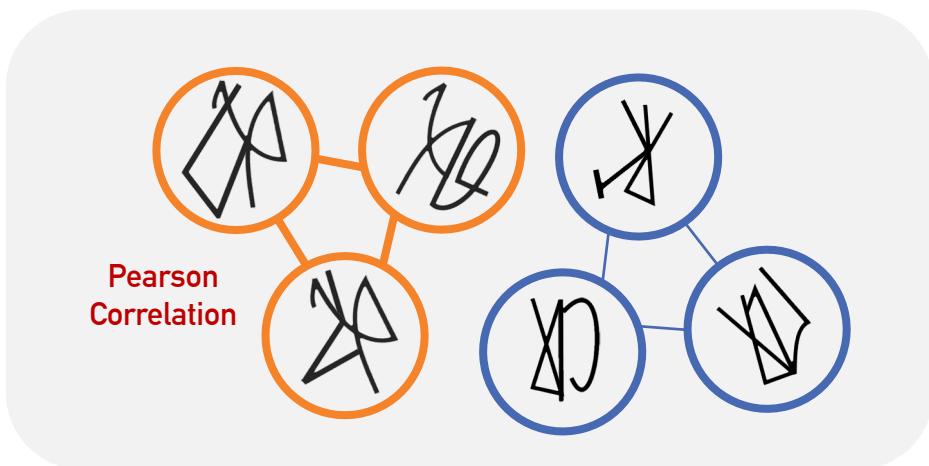
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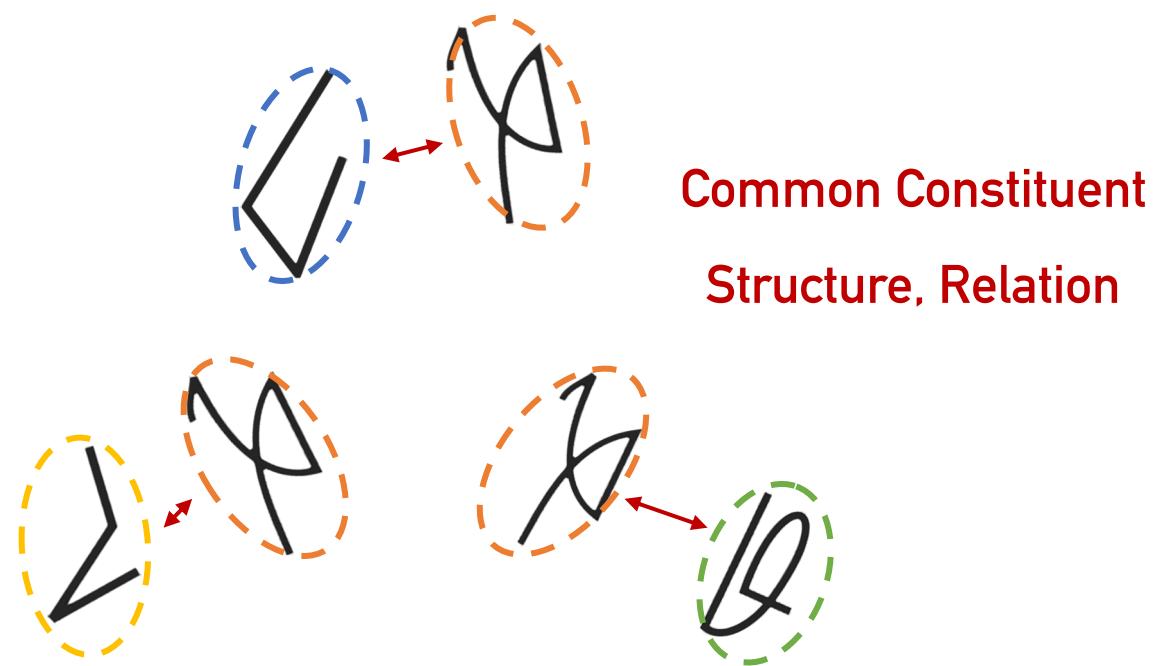
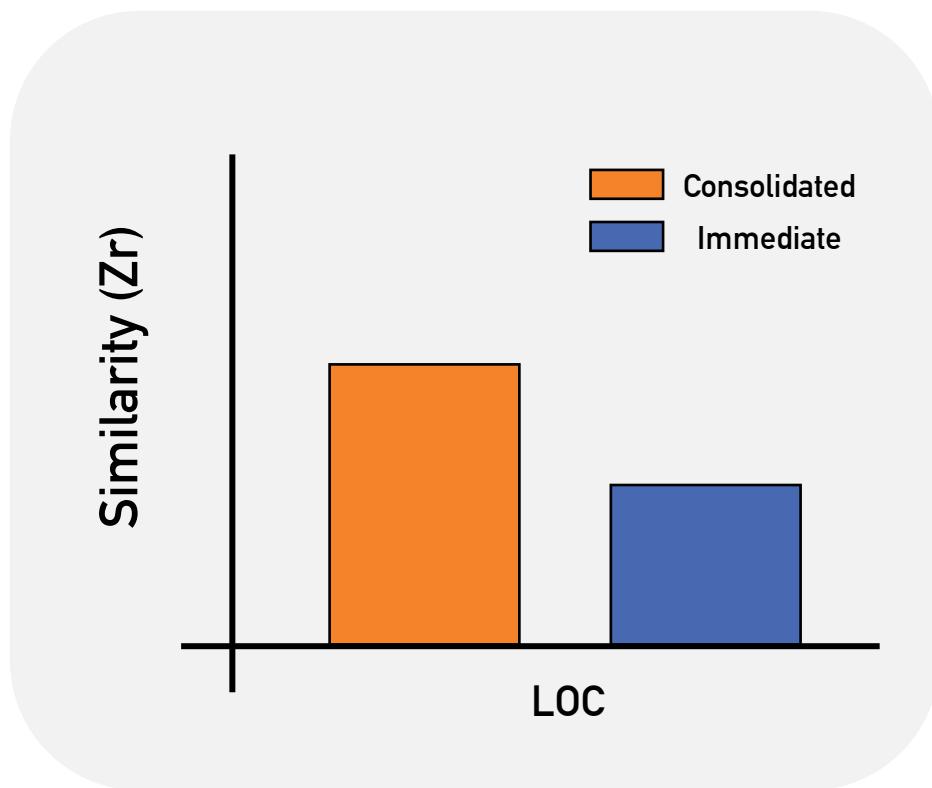
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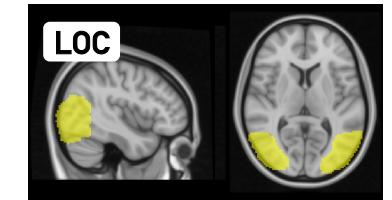
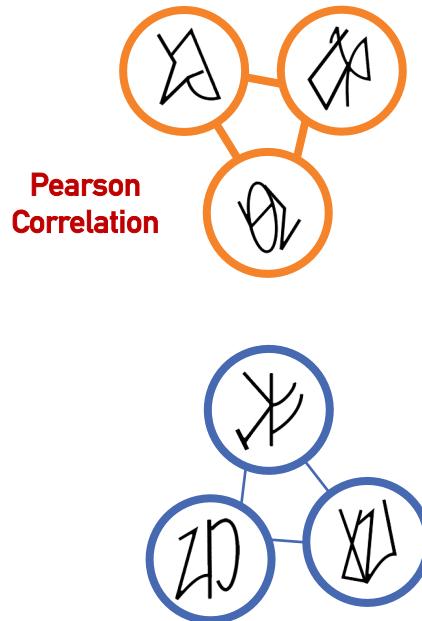
Increased Representational Similarity

Common Constituent  
Structure, Relation

## 2. Representational similarity between objects will be increased

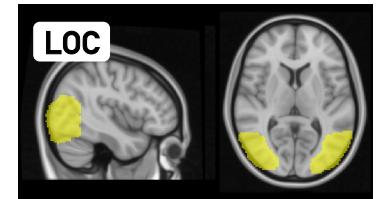
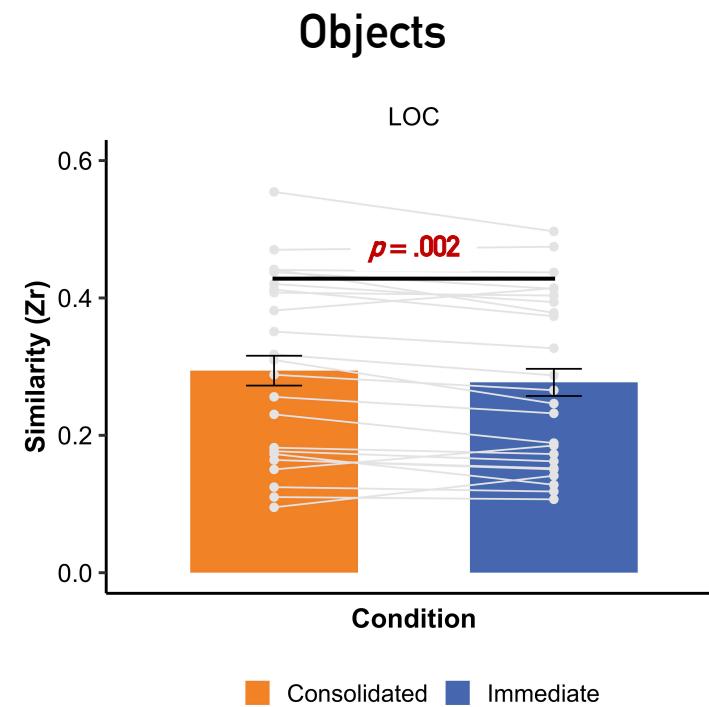
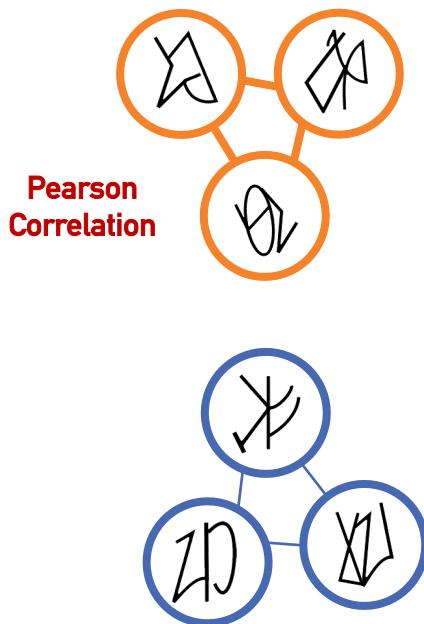


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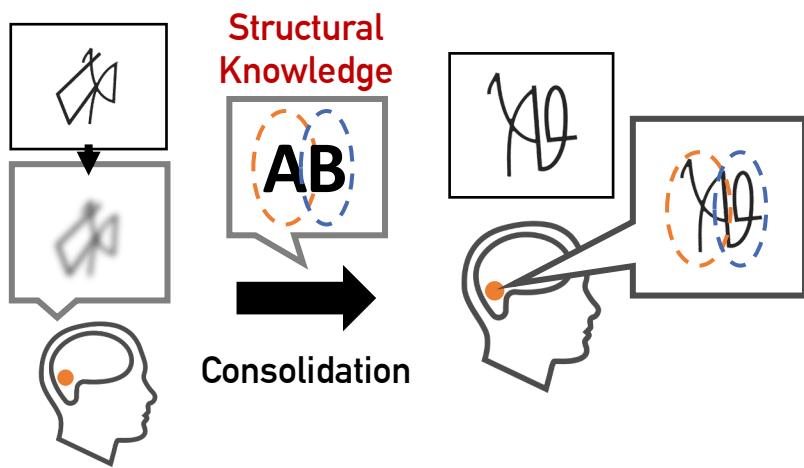
N = 24

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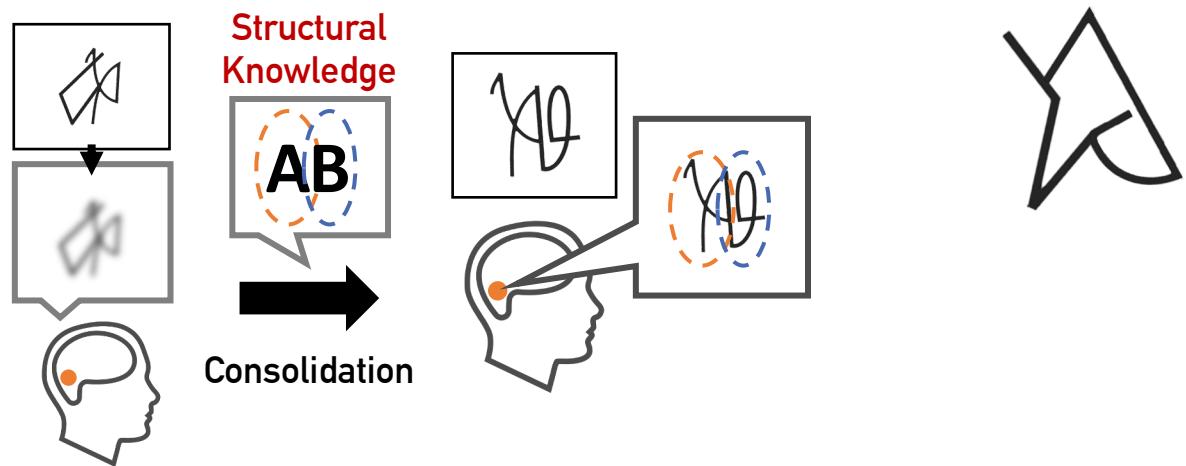


N = 24

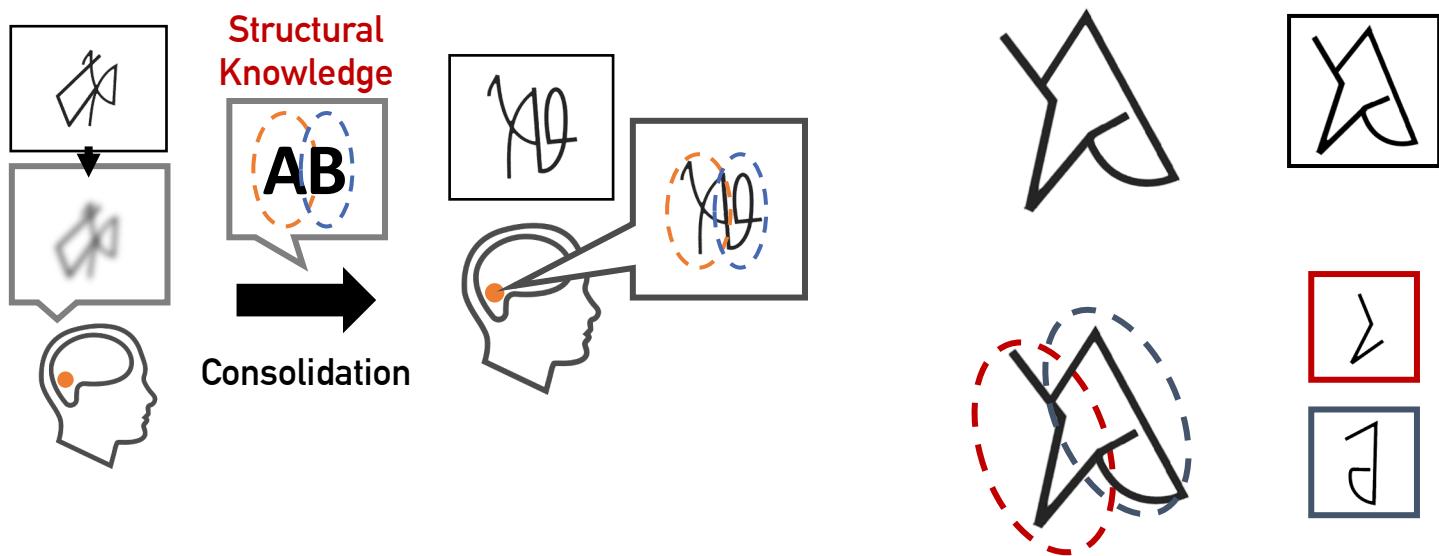
### 3. Object representations will be well explained by their constituent representations.



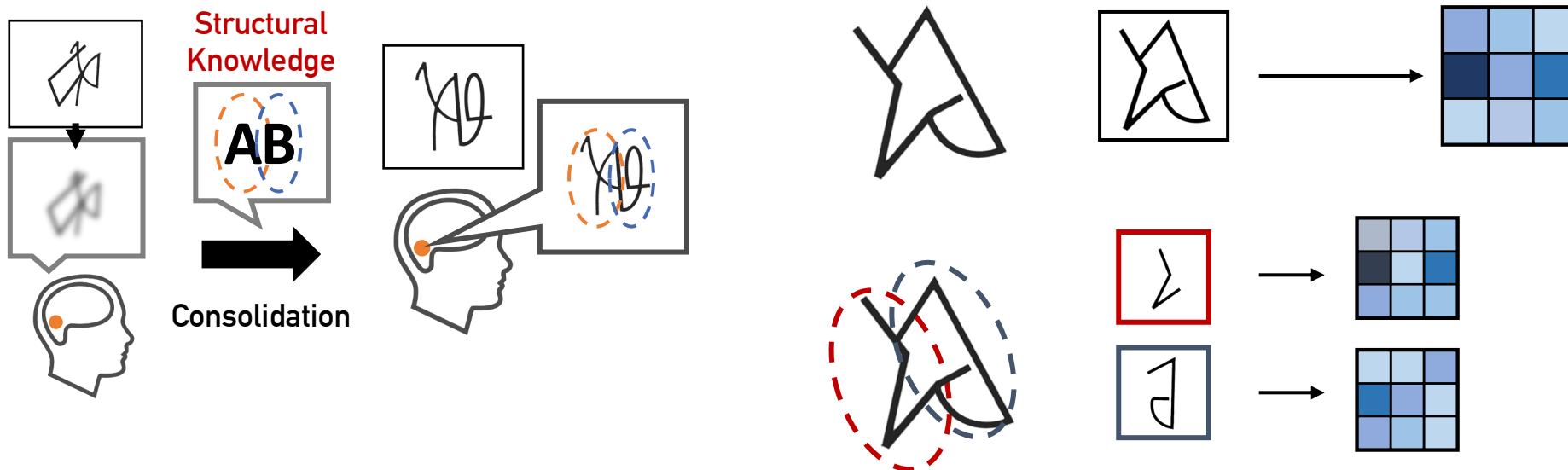
### 3. Object representations will be well explained by their constituent representations.



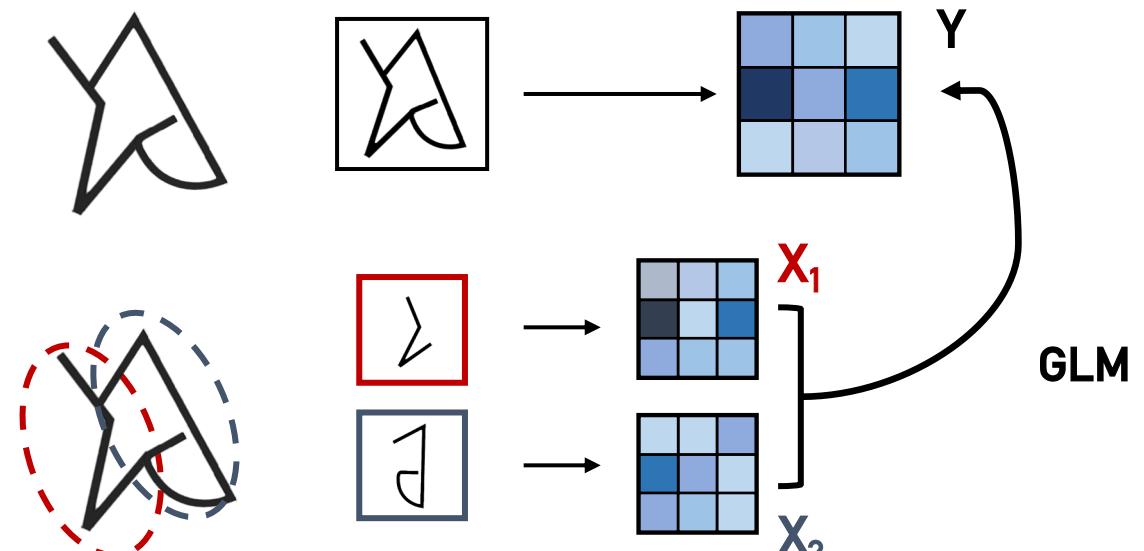
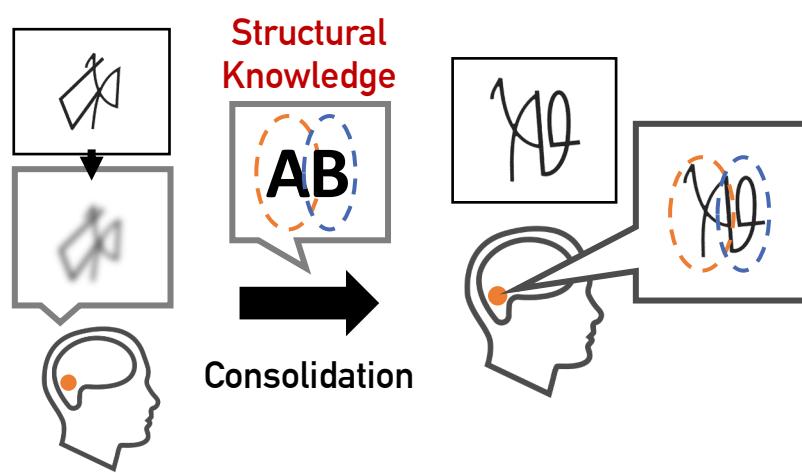
### 3. Object representations will be well explained by their constituent representations.



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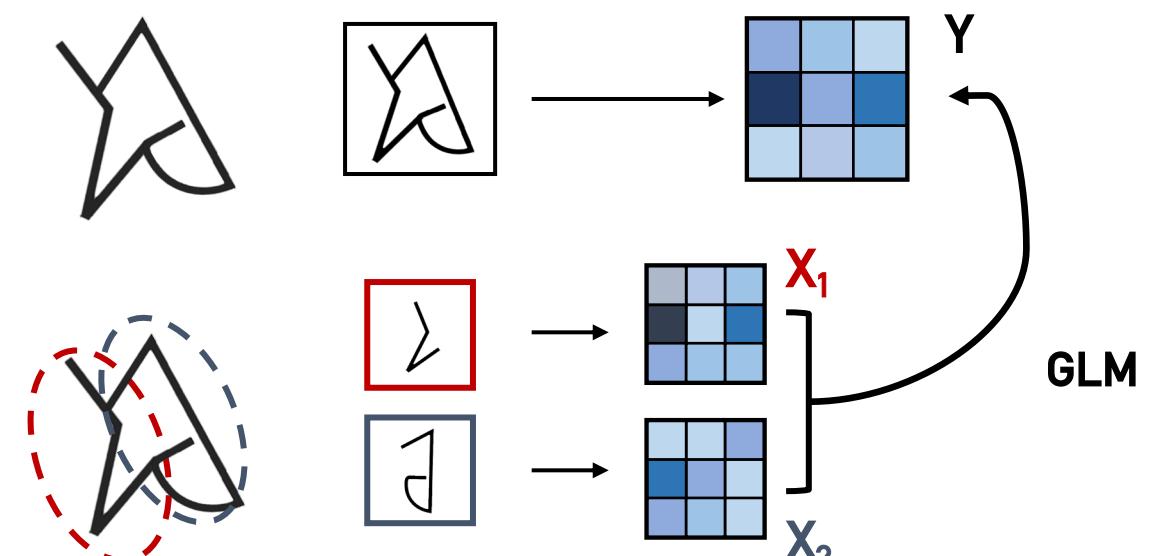
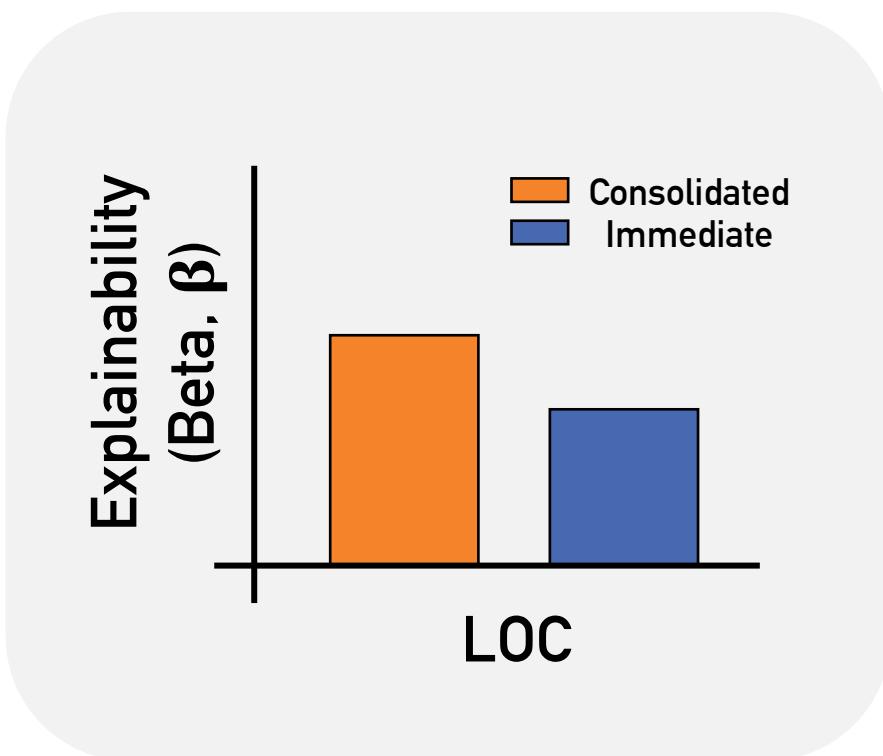


### 3. Object representations will be well explained by their constituent representations.

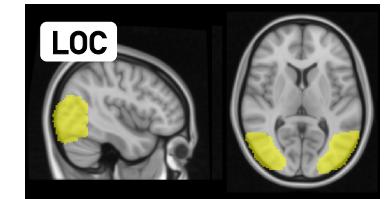
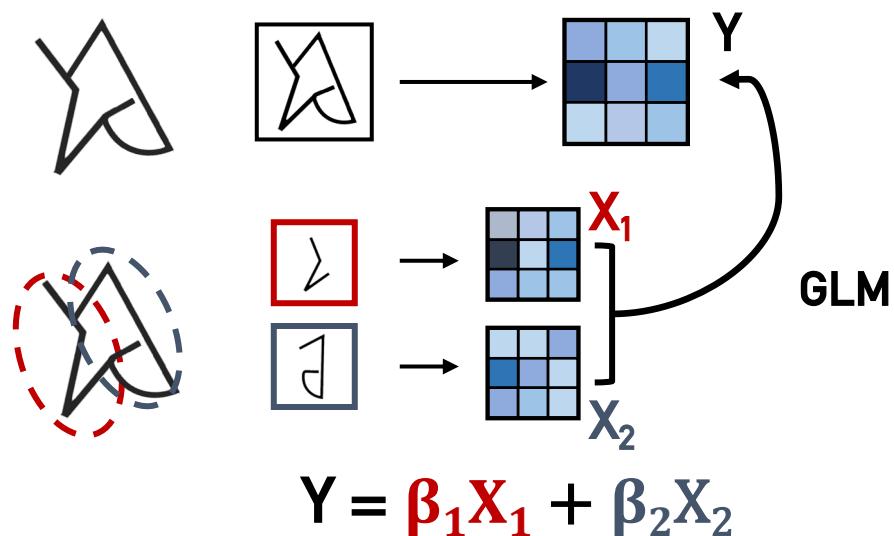


$$Y = \beta_1 X_1 + \beta_2 X_2$$

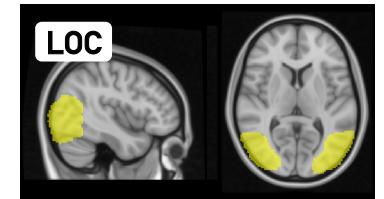
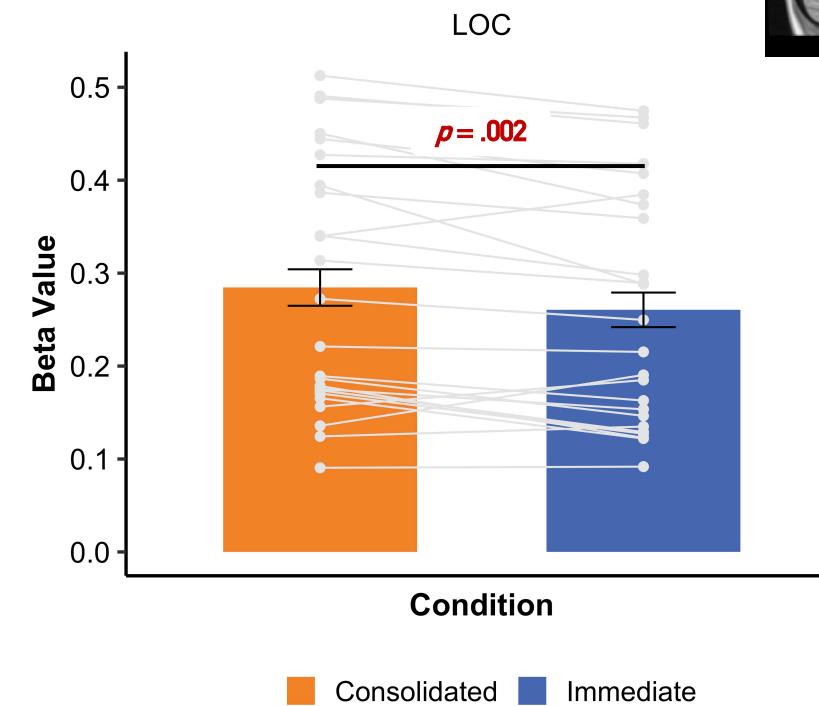
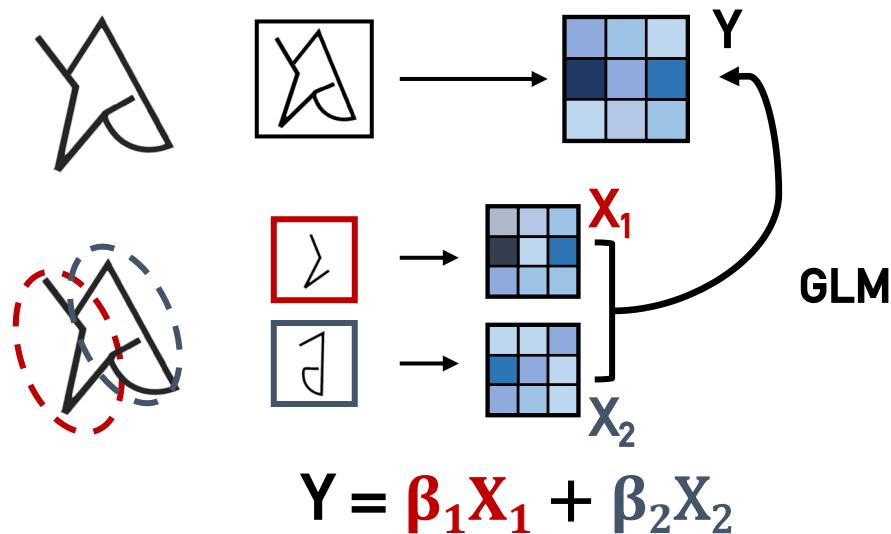
### 3. Object representations will be well explained by their constituent representations.



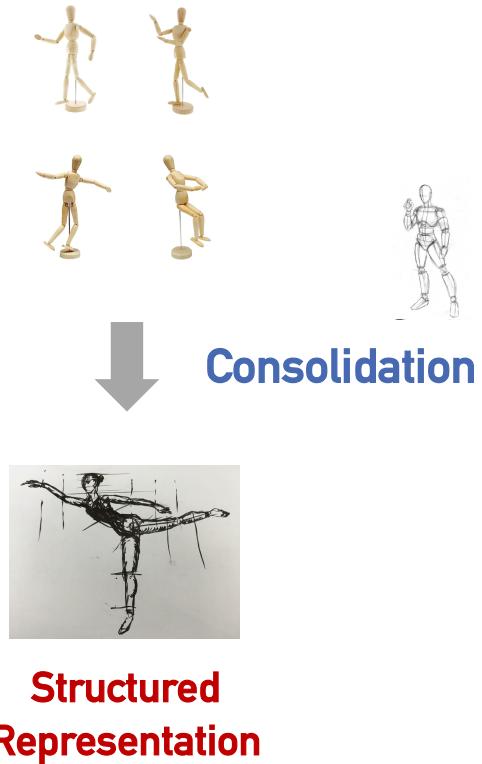
### 3. Object representations will be well explained by their constituent representations.



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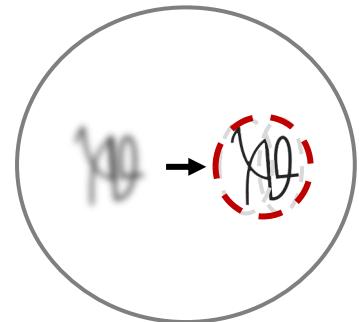


# Summary

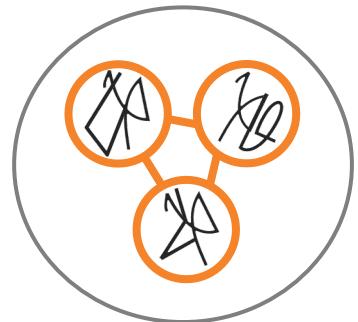


## Structured Representation

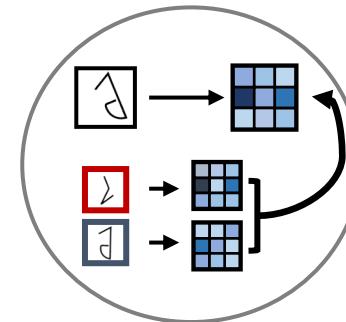
Object-ness (Activation)



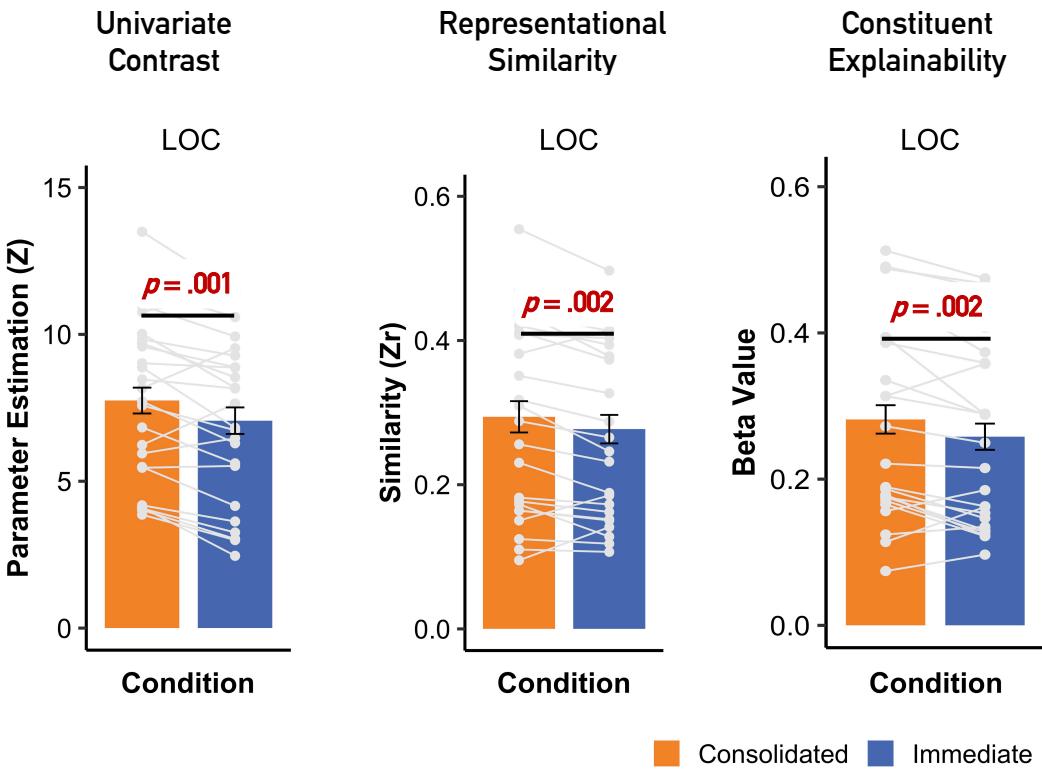
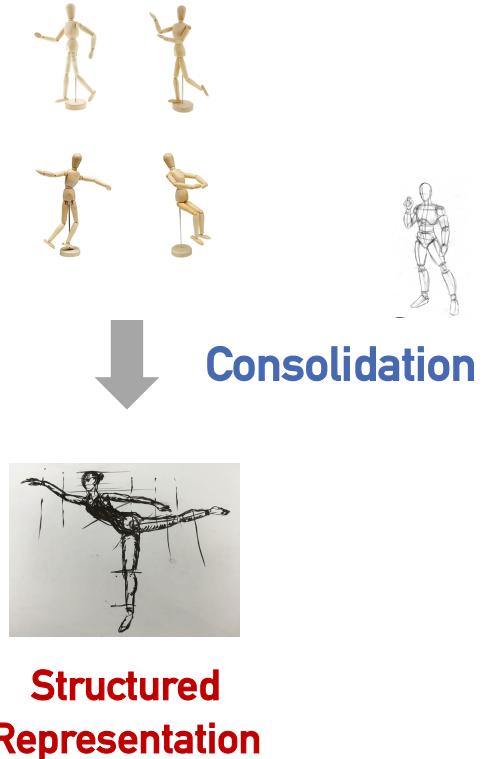
Similarity



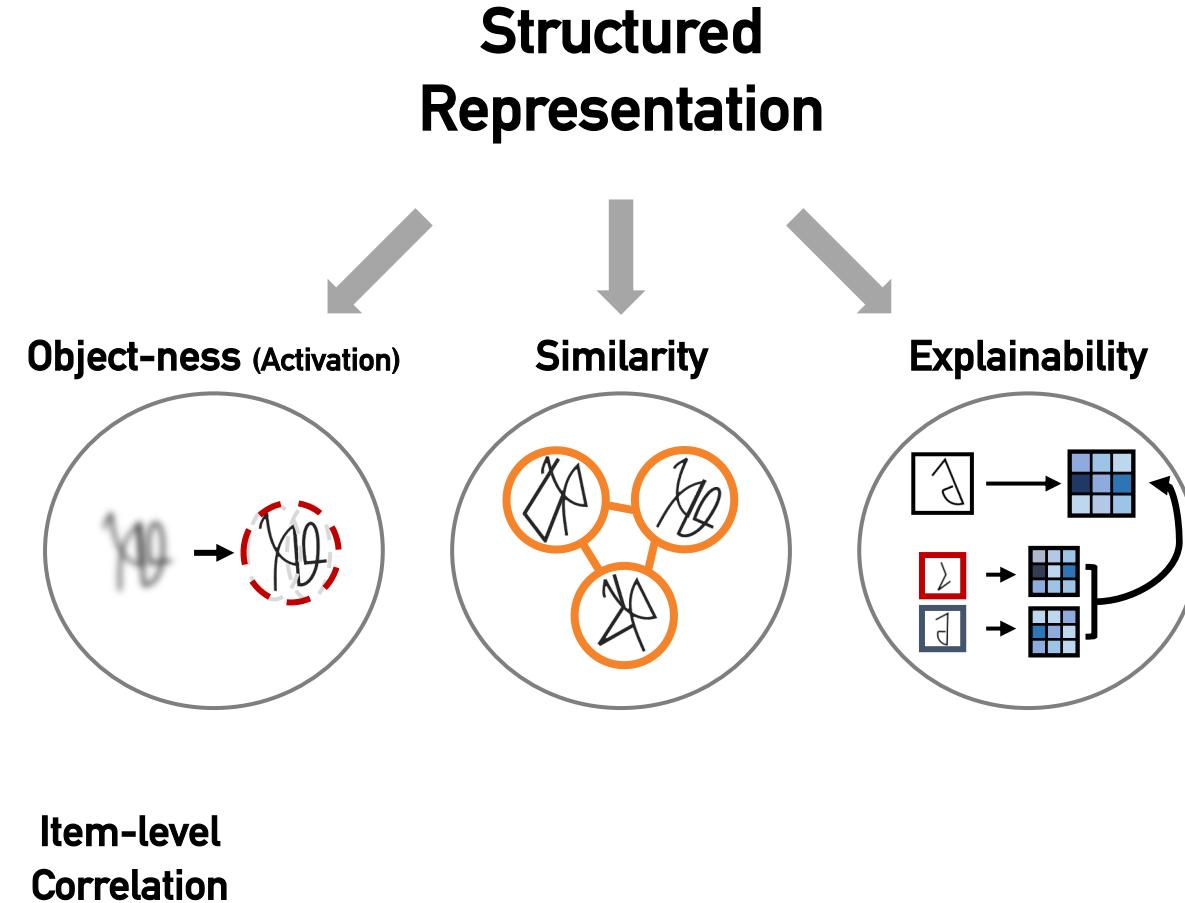
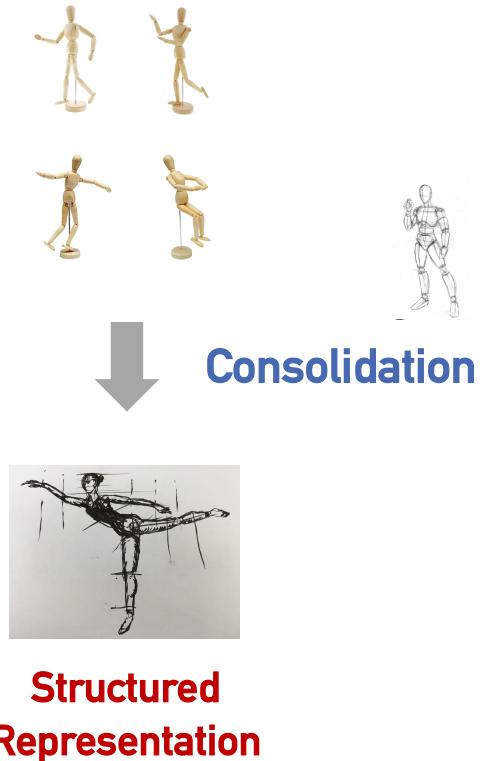
Explainability



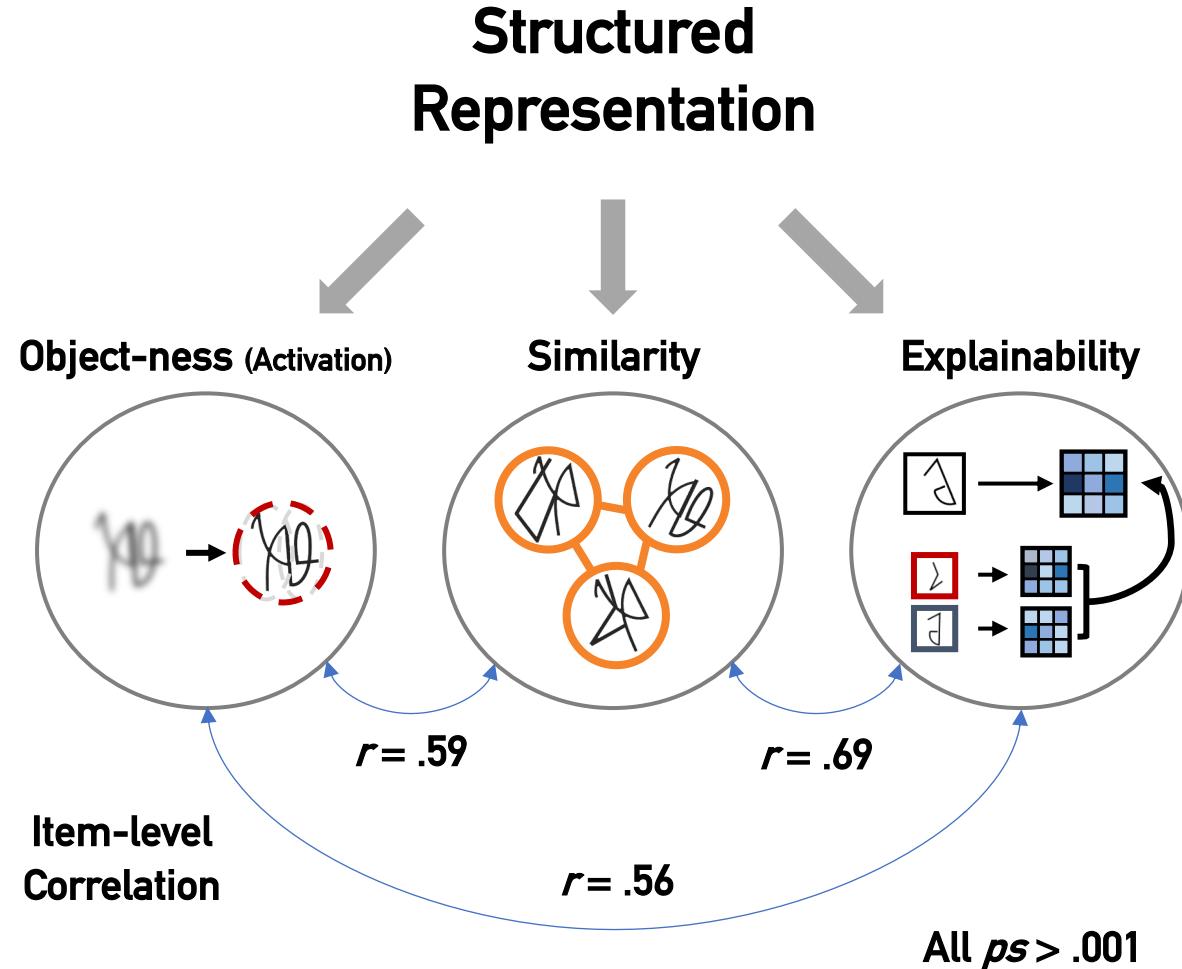
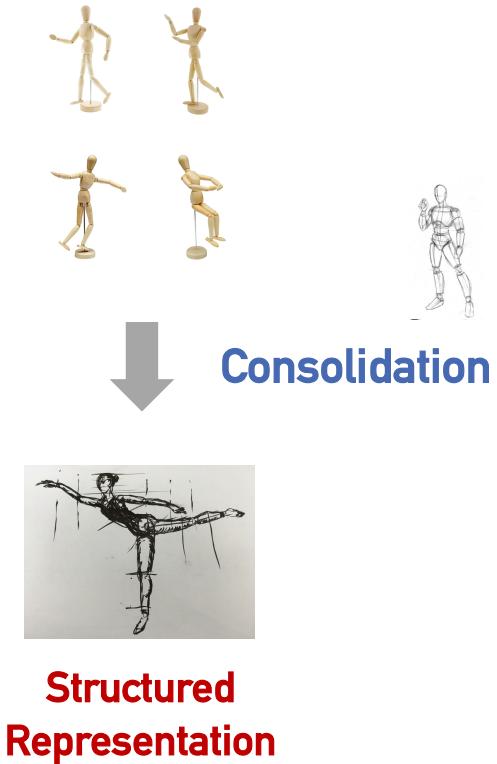
# Summary



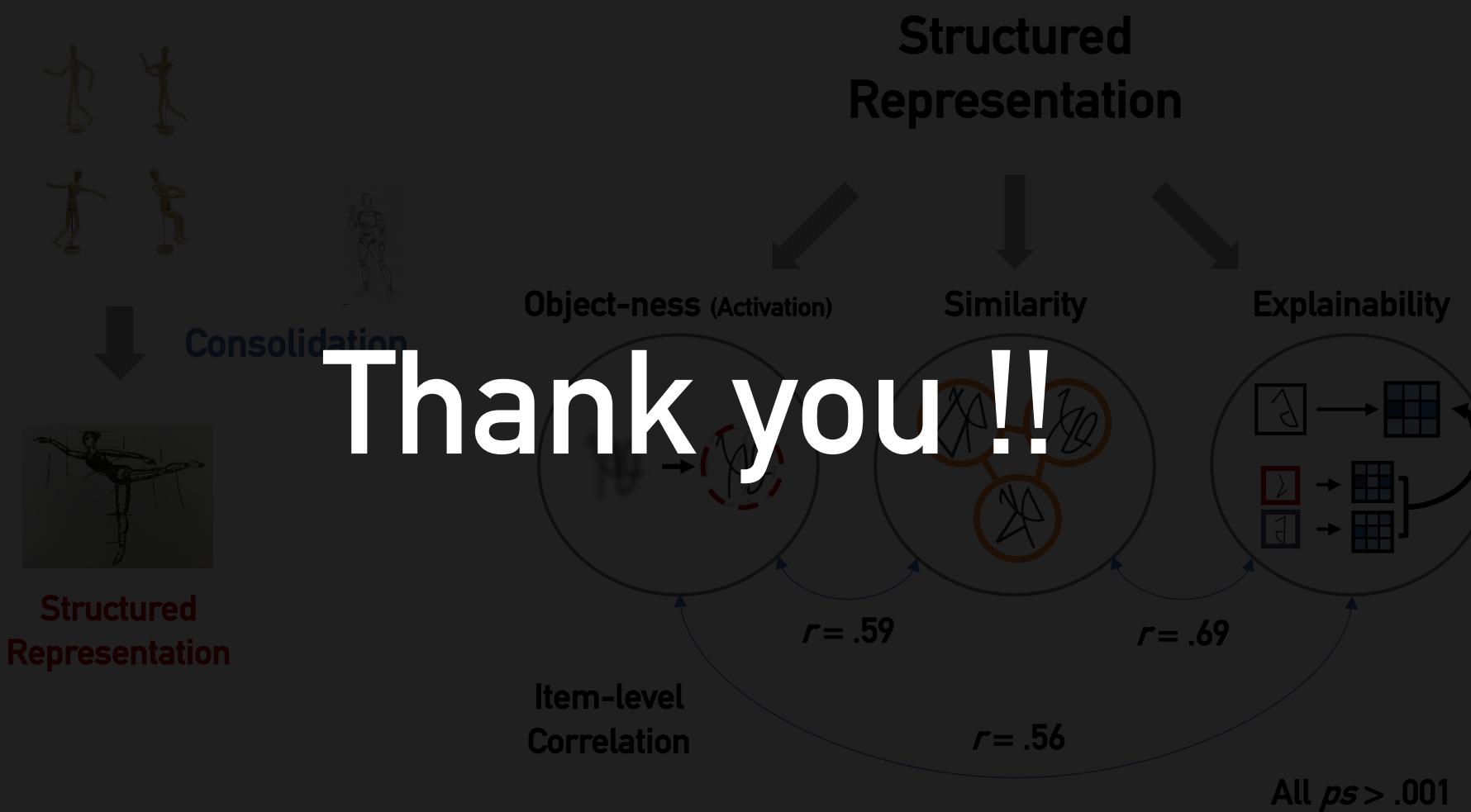
# Summary



# Summary



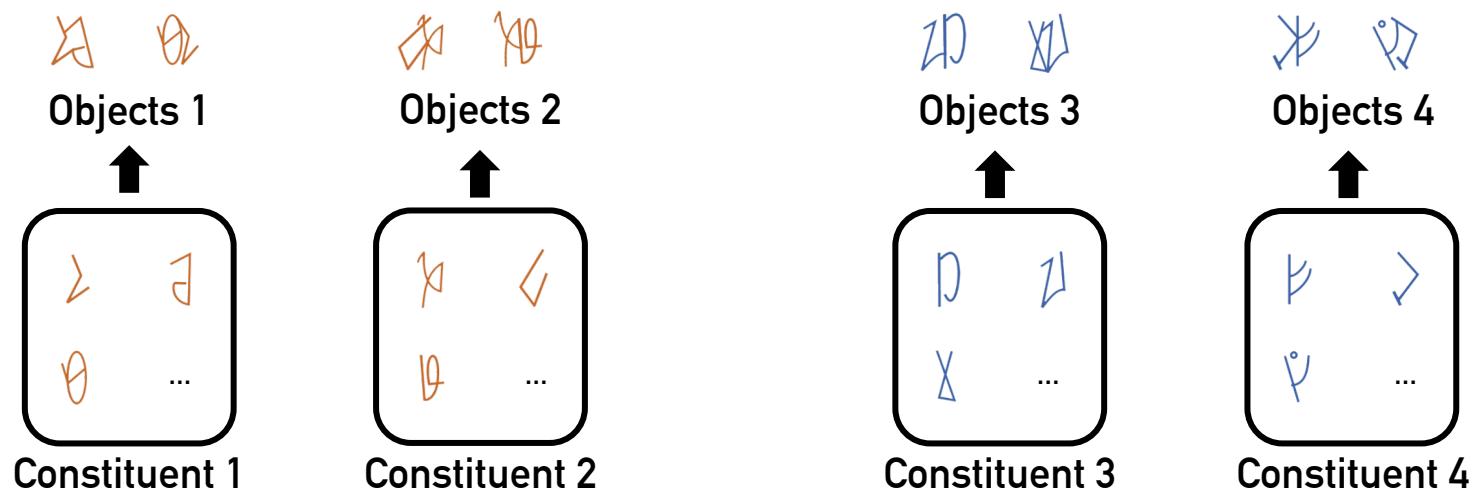
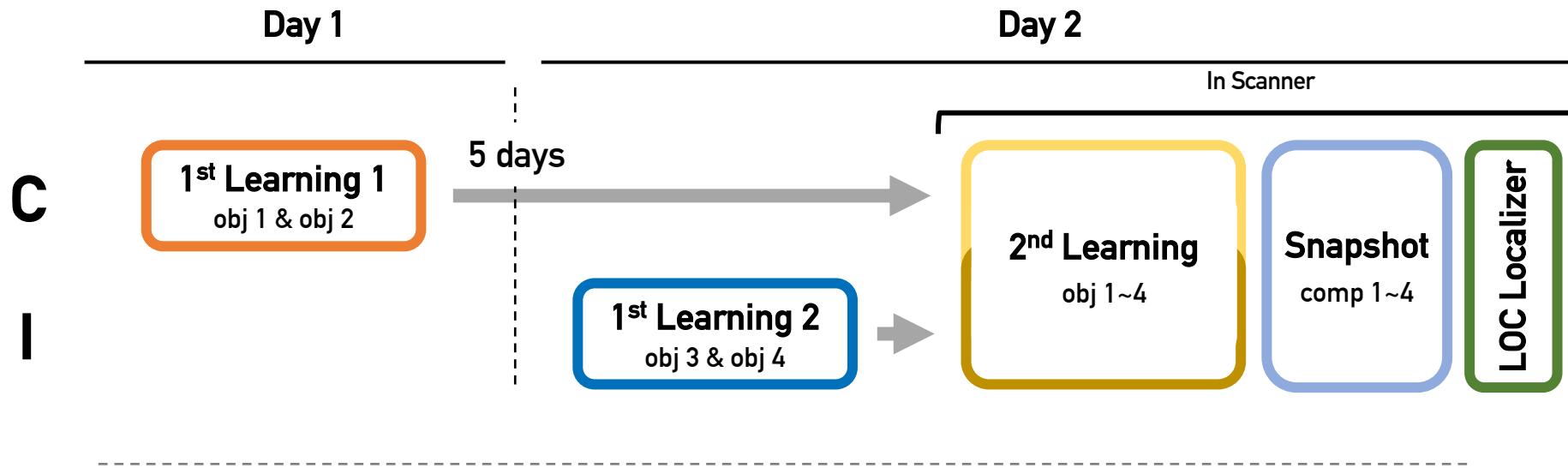
# Summary





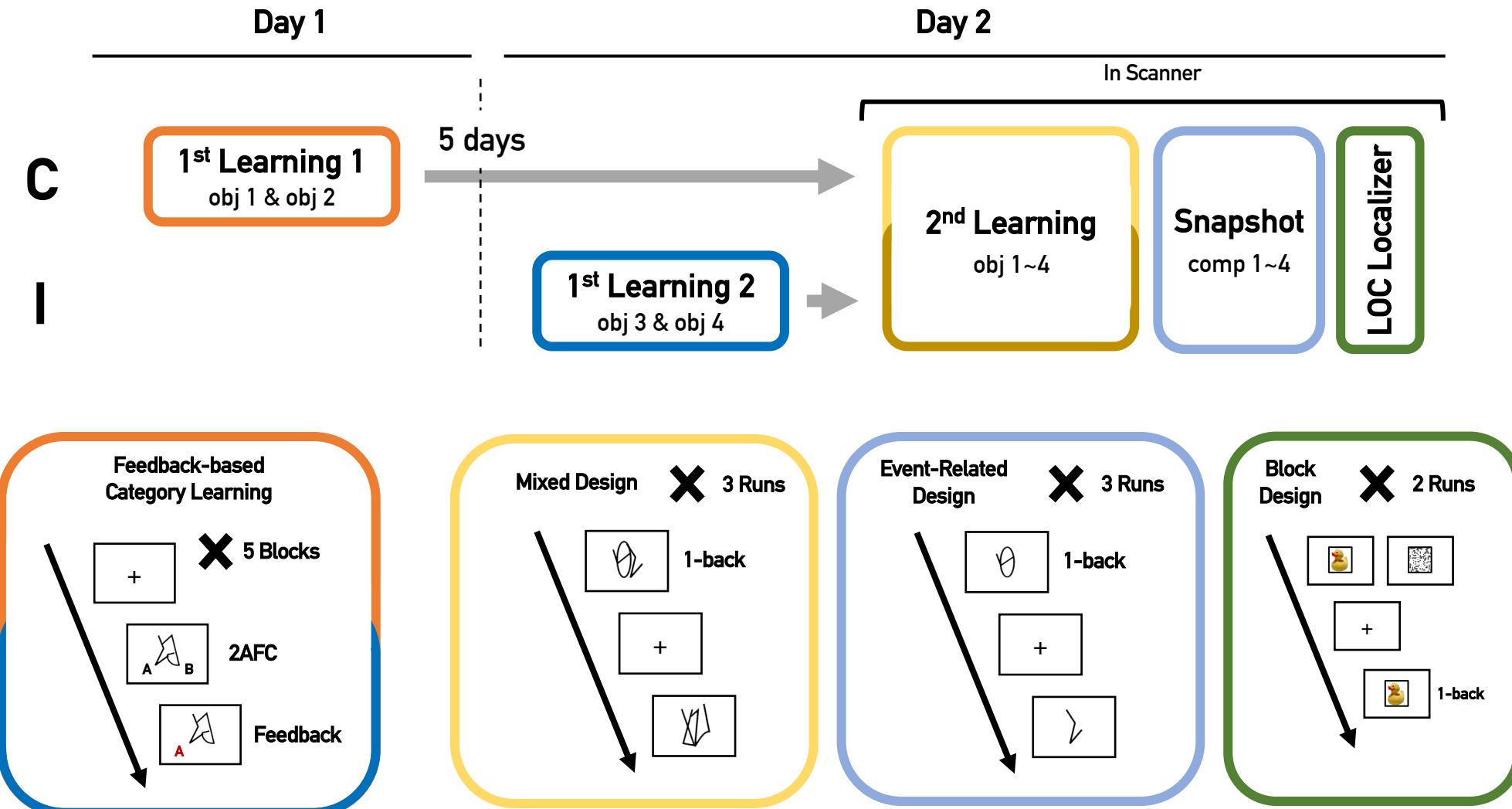
# Method

Within-Subjects Design

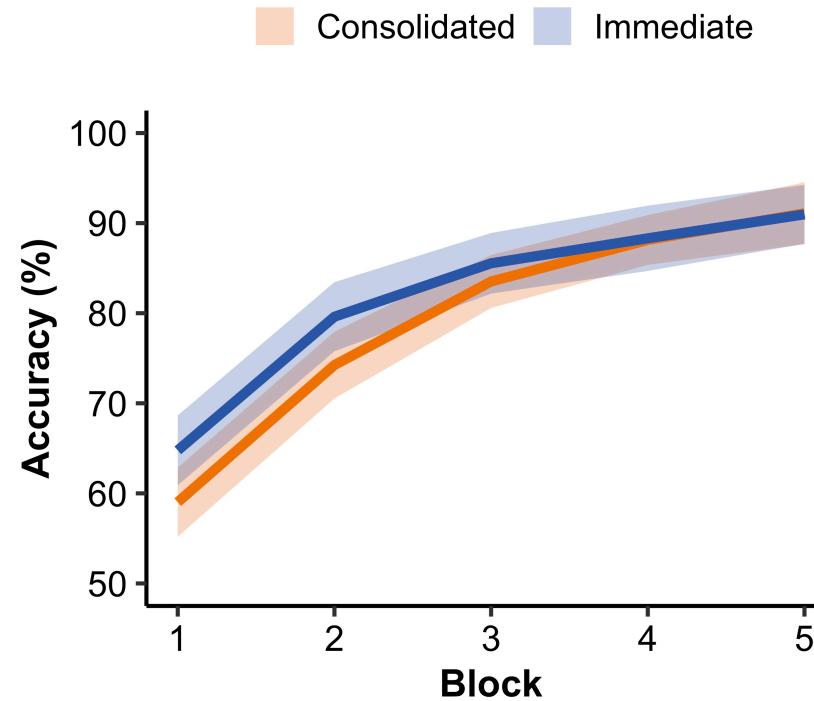
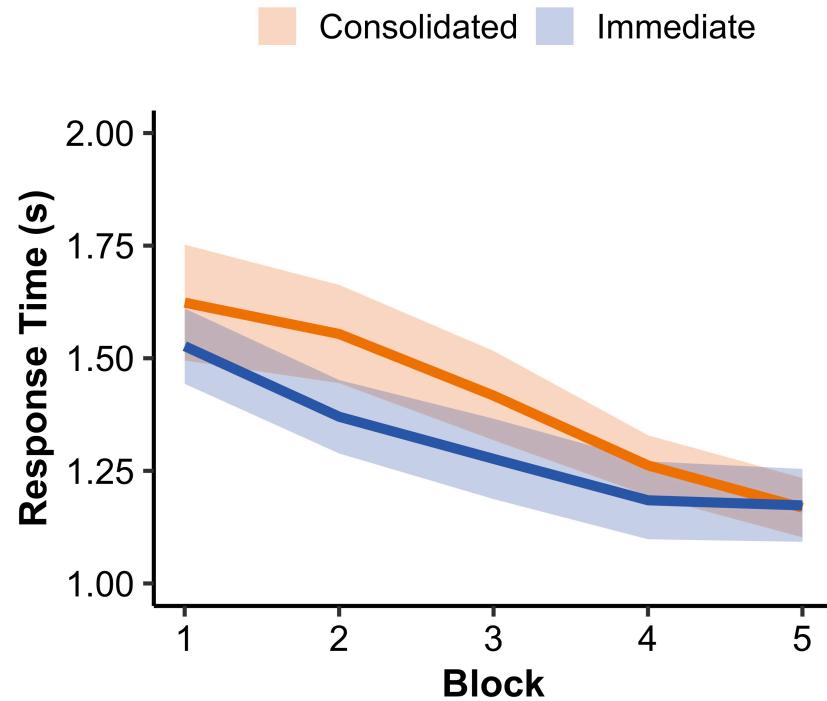


# Method

Within-Subjects Design

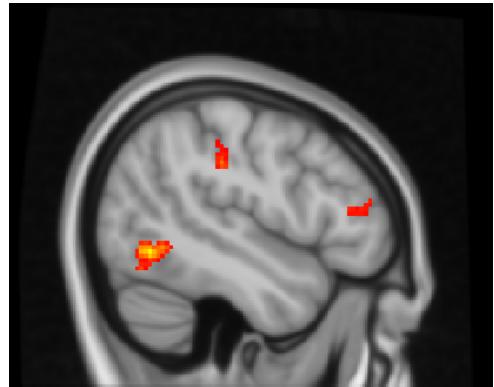


# Learning Performance



N = 24

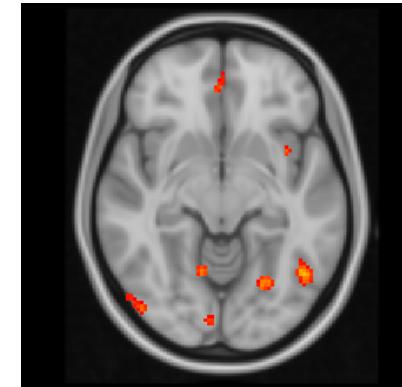
# Whole Brain



Left, X = -47



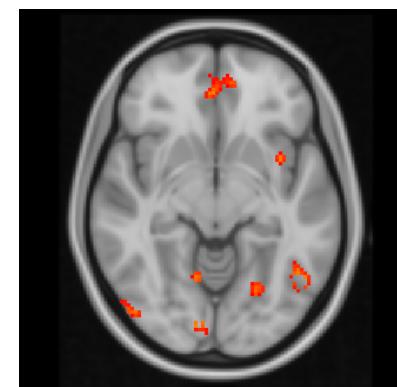
Right, X = 46



Axial, Z = -9



Medial, X = 2

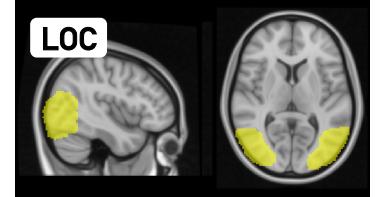


Axial, Z = -8

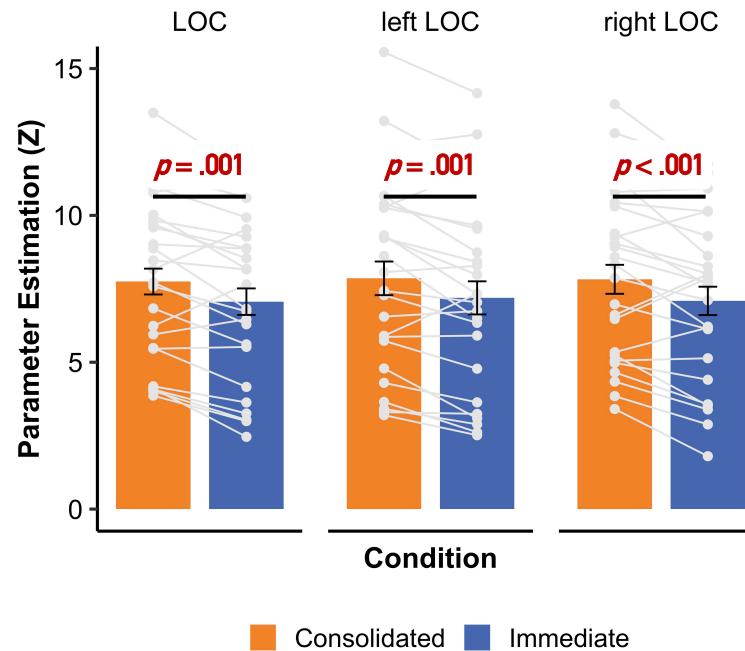
**Consolidated - Immediate**

**Uncorrected  $p < .001$**

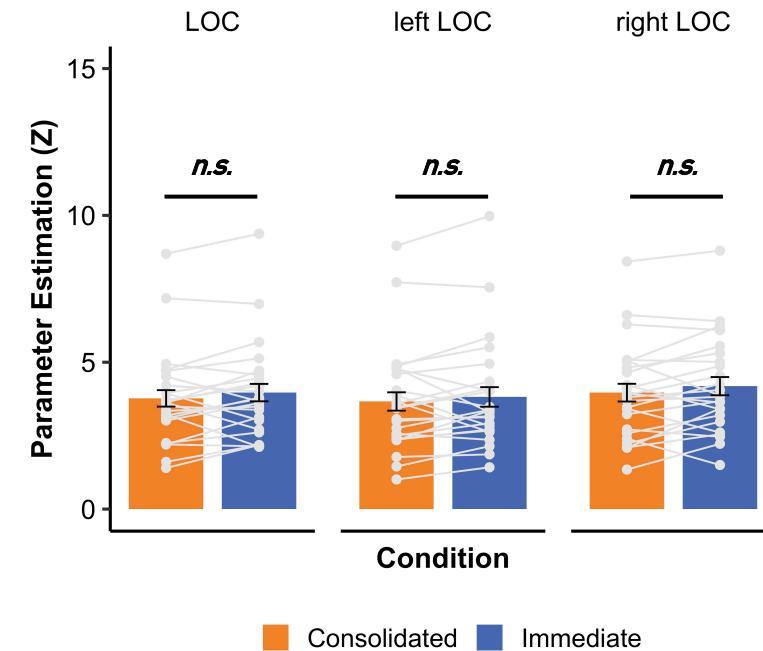
# SP 1. Univariate Contrast



Objects

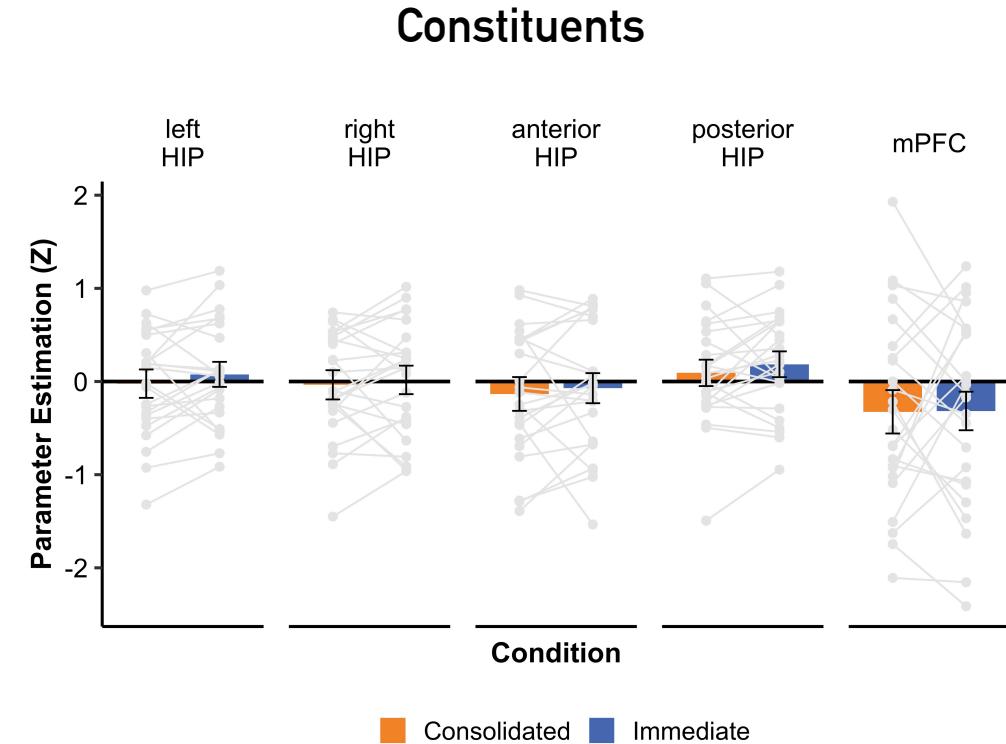
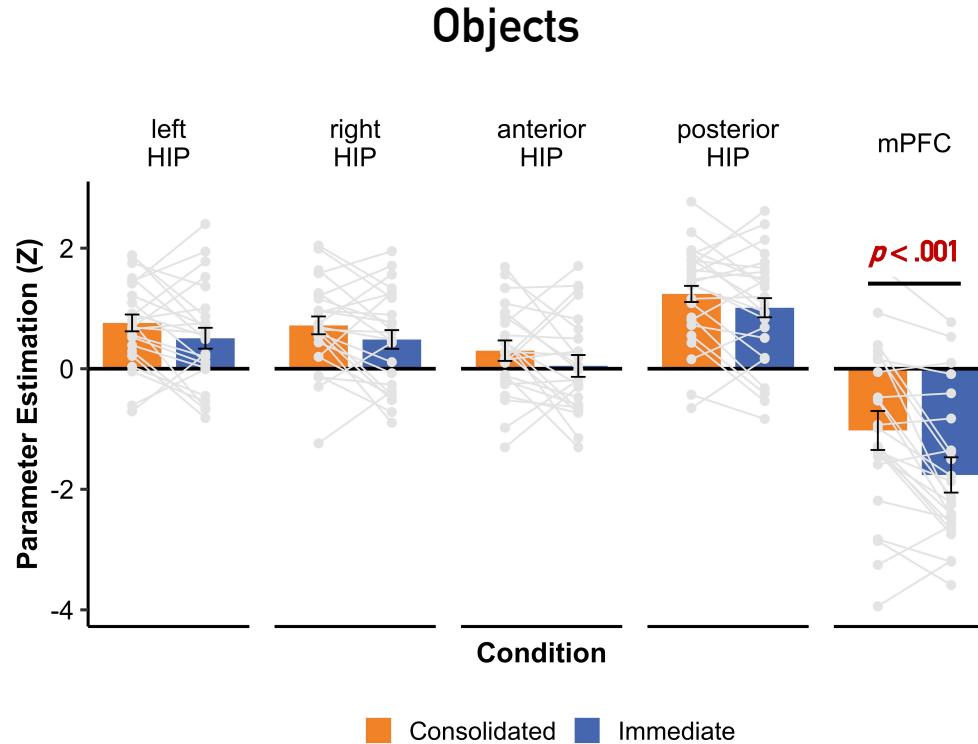


Constituents



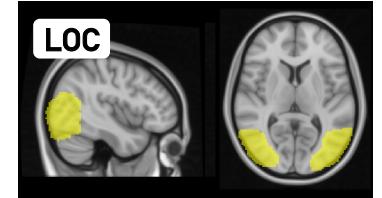
N = 24

# SP 1. Univariate Contrast

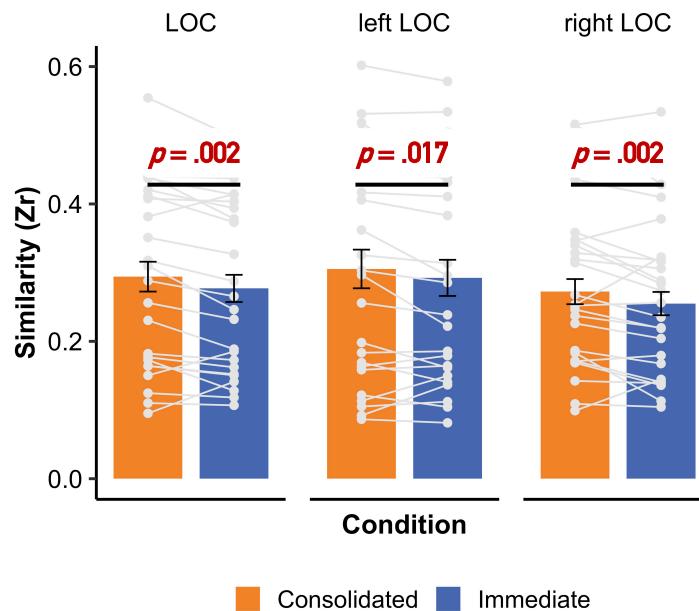


N = 24

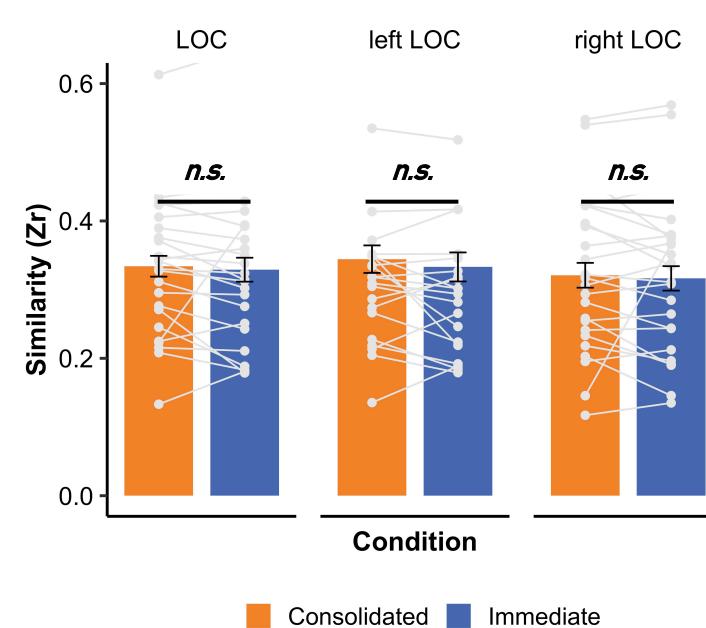
# SP 2. Representational Similarity



Objects

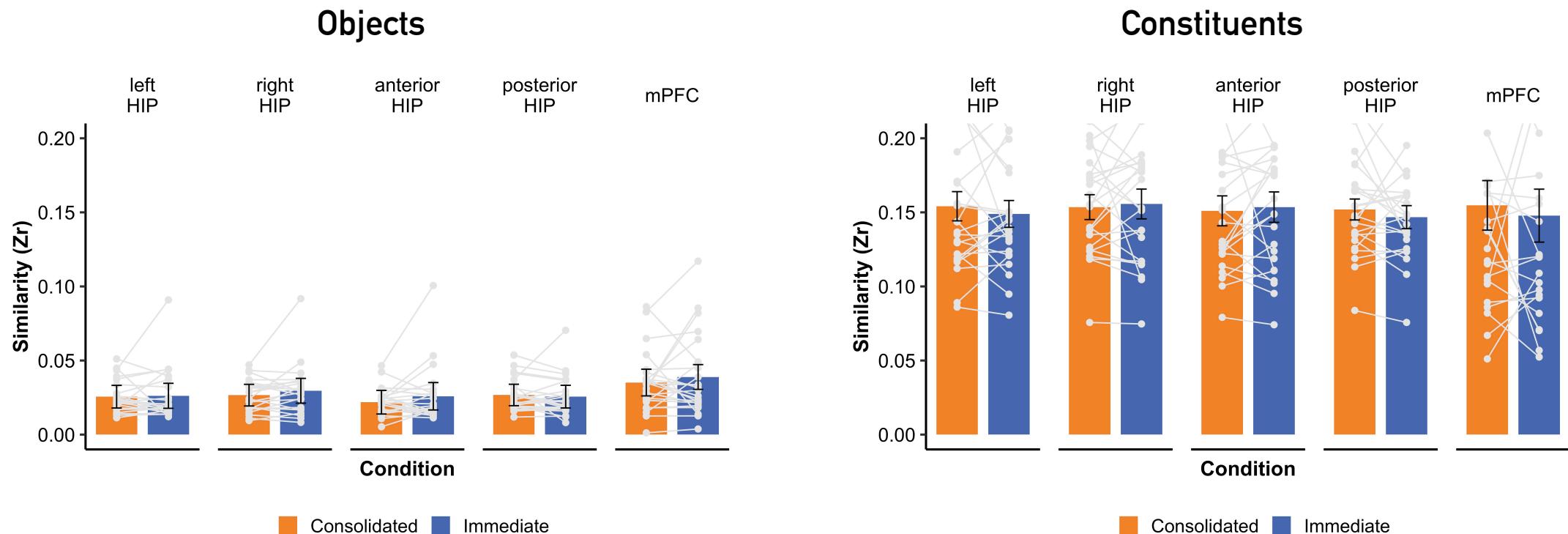


Constituents



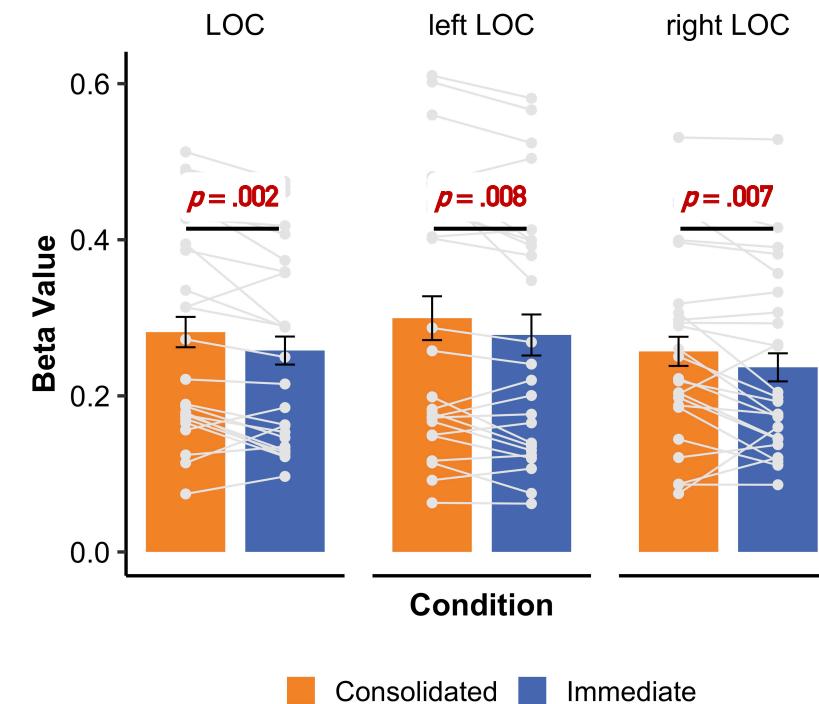
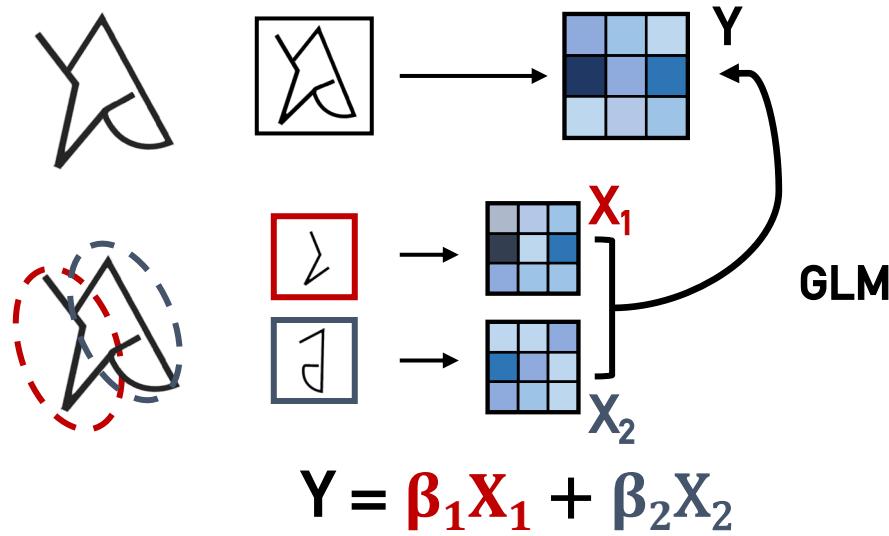
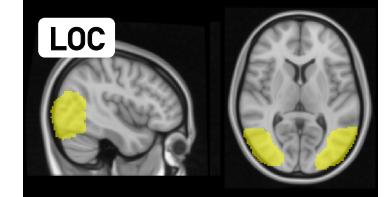
N = 24

# SP 2. Representational Similarity



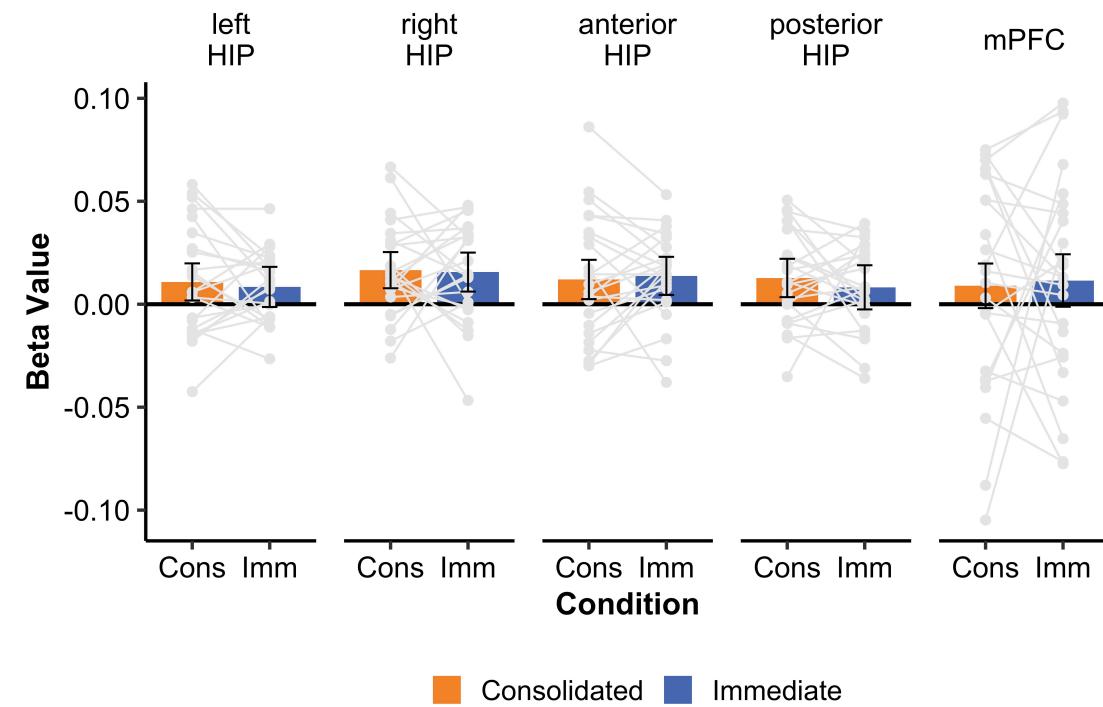
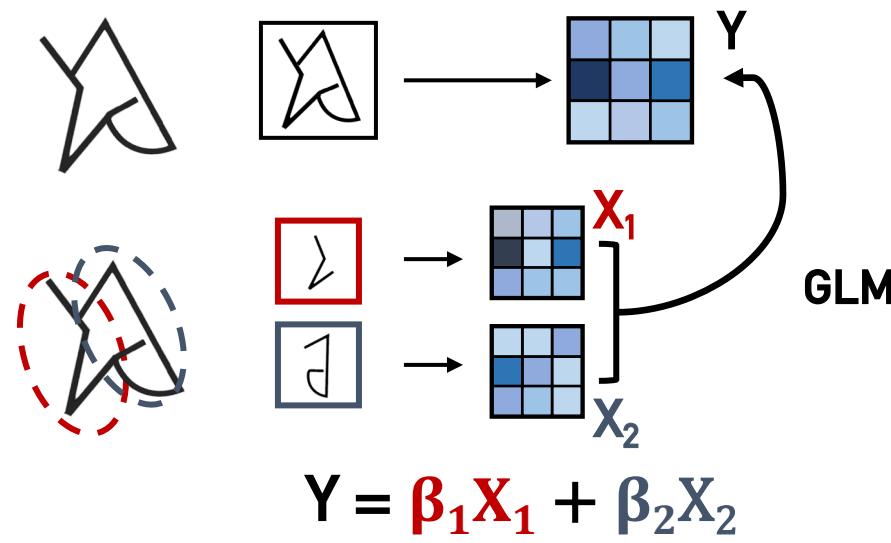
$N = 24$

# SP 3. Explainability



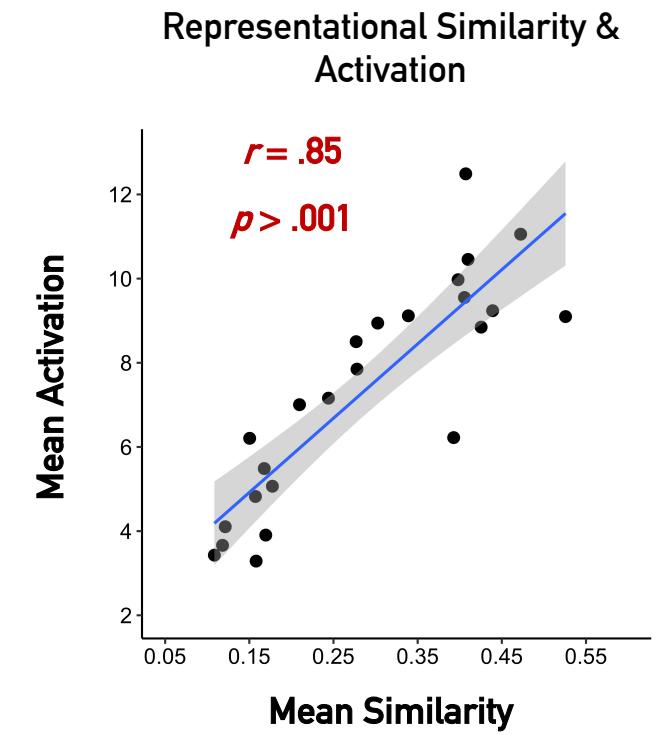
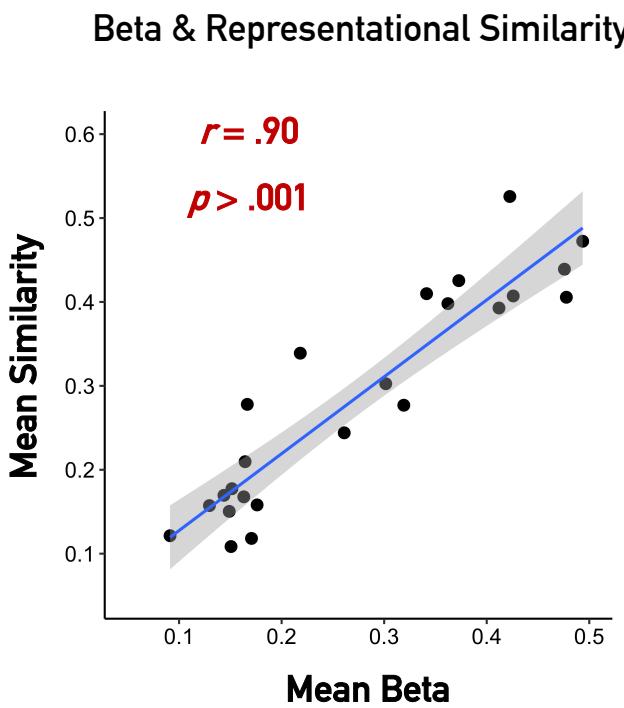
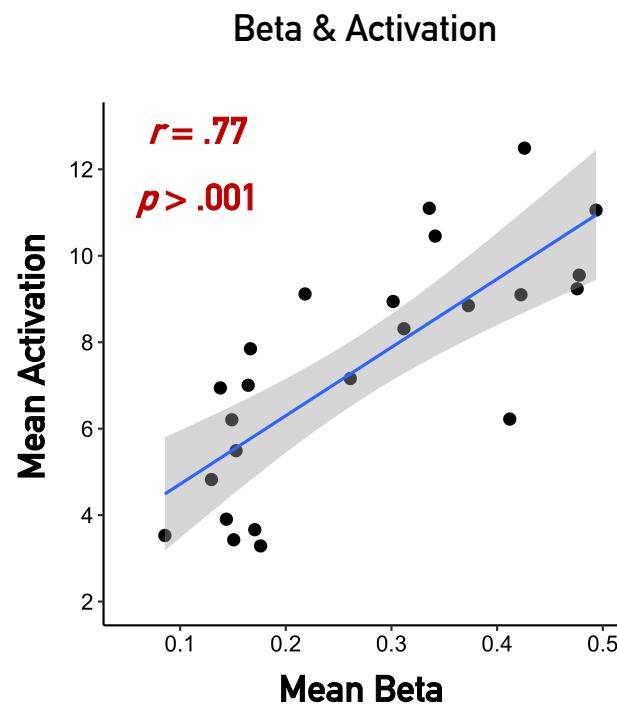
N = 24

# SP 3. Explainability

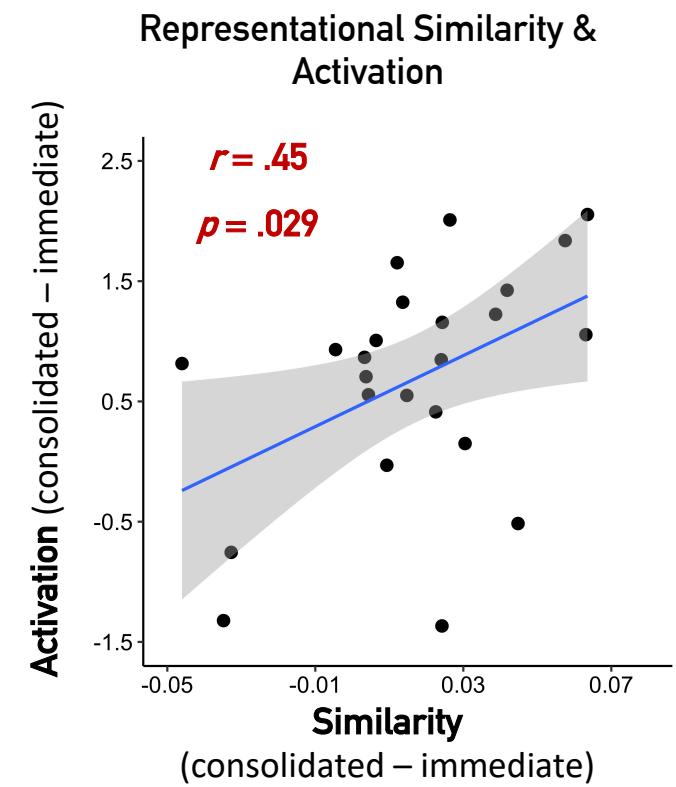
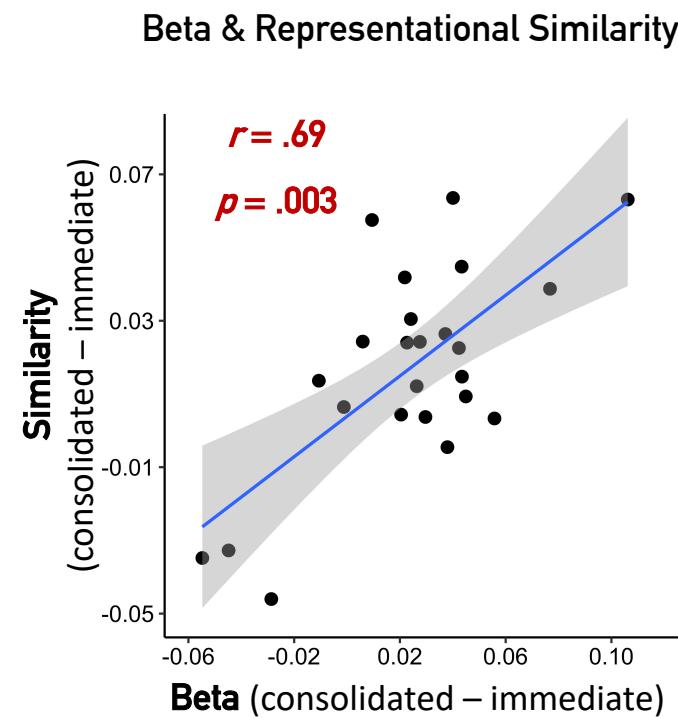
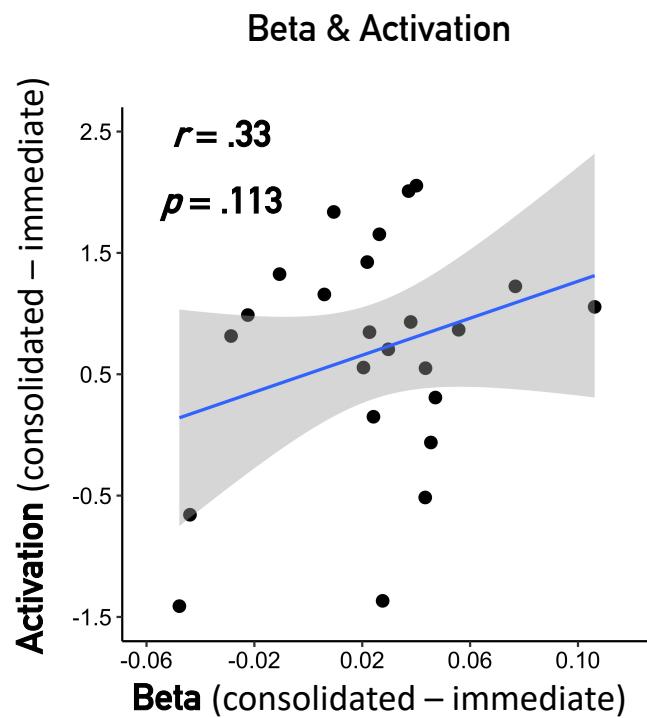


$N = 24$

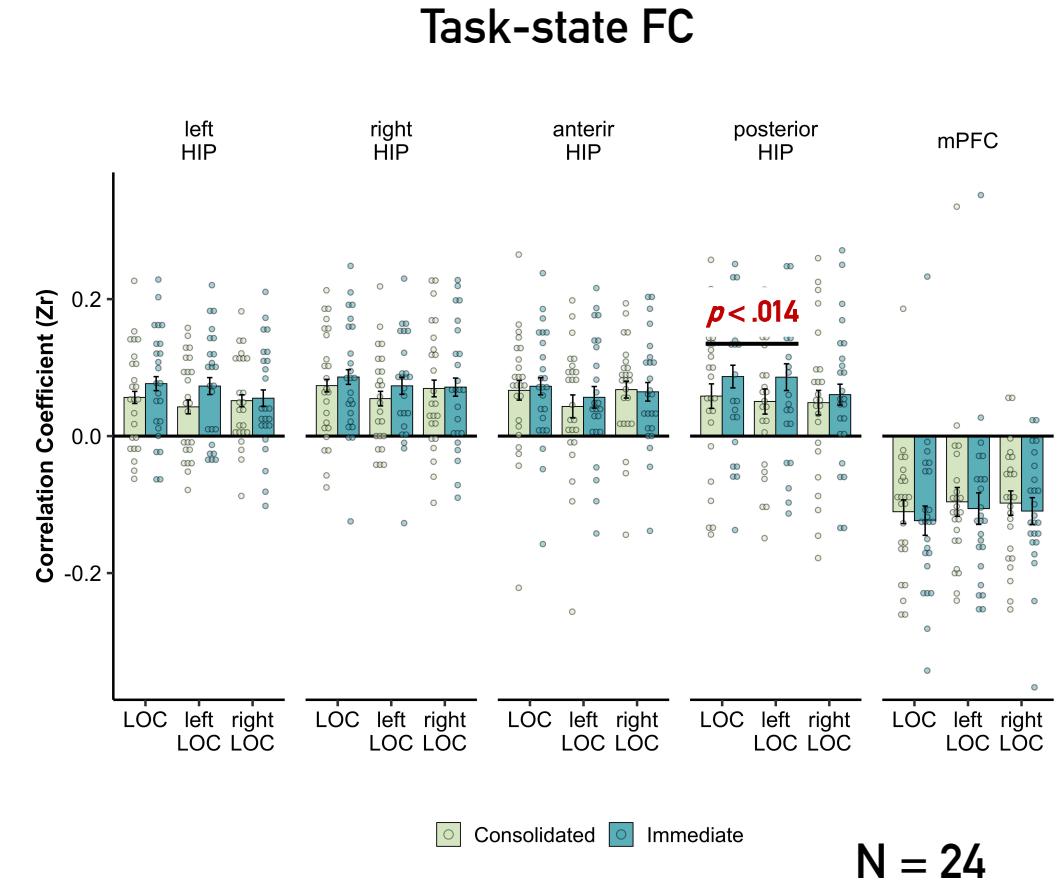
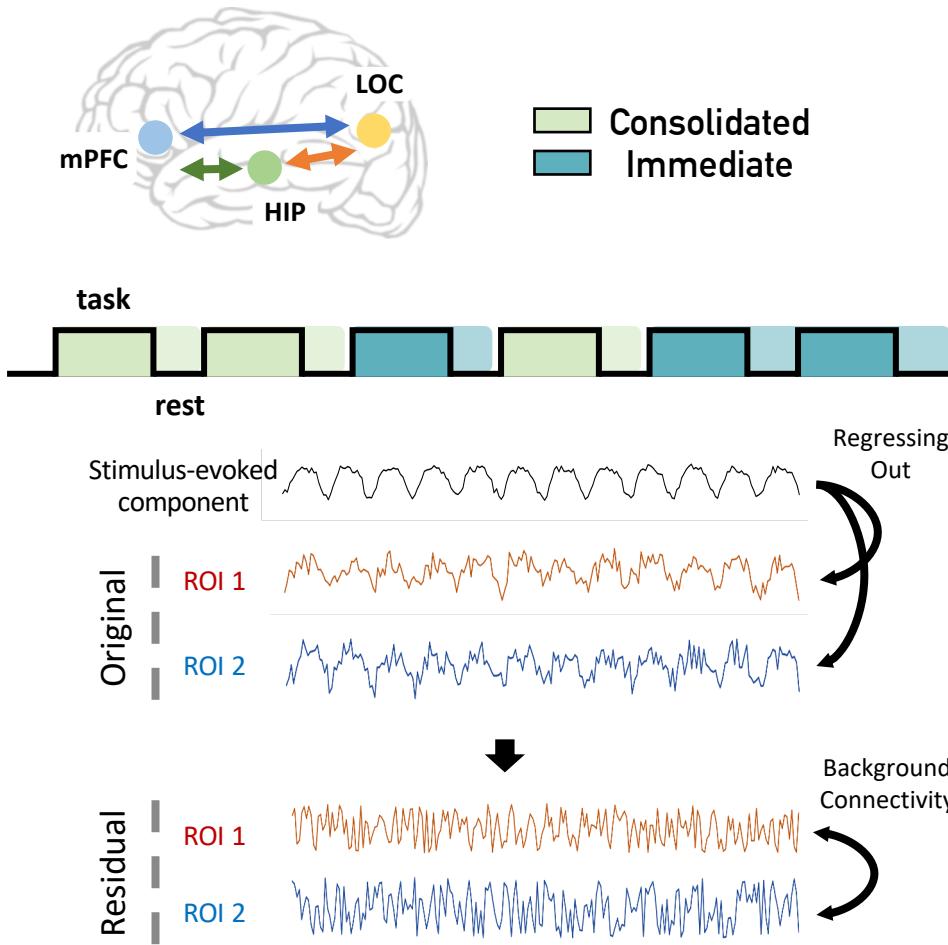
# SP 4. Correlation



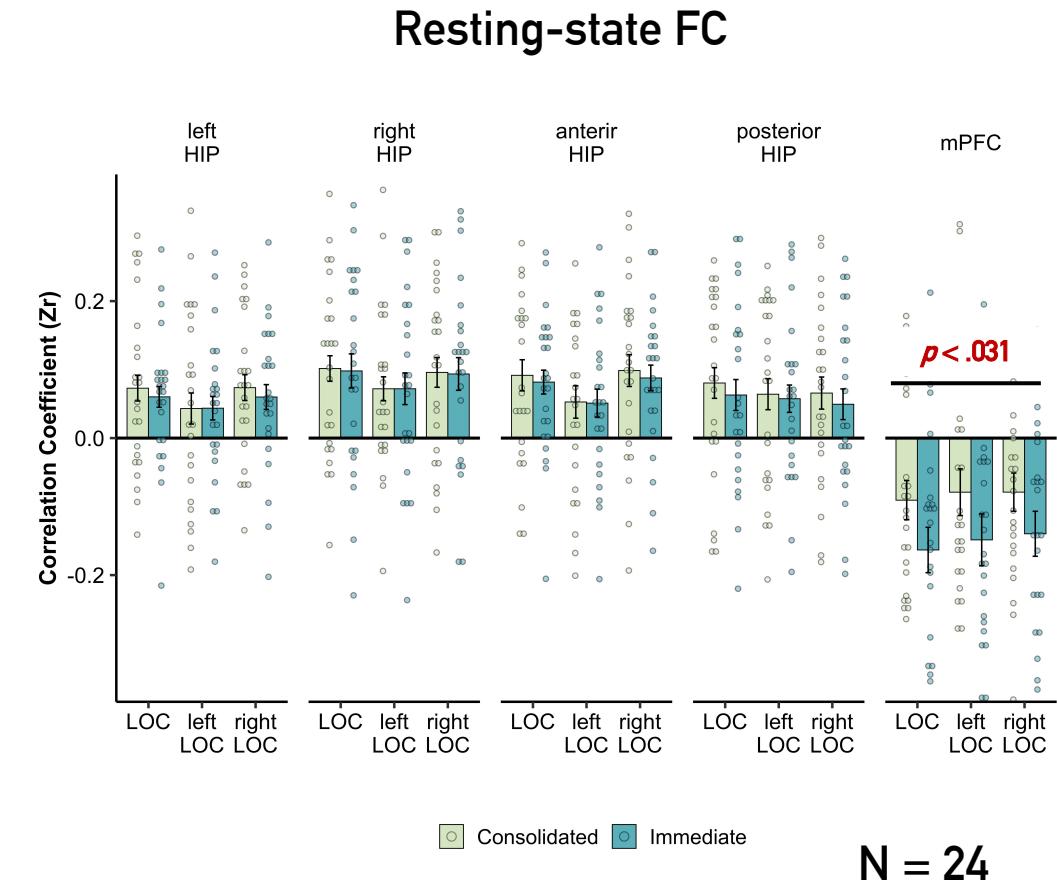
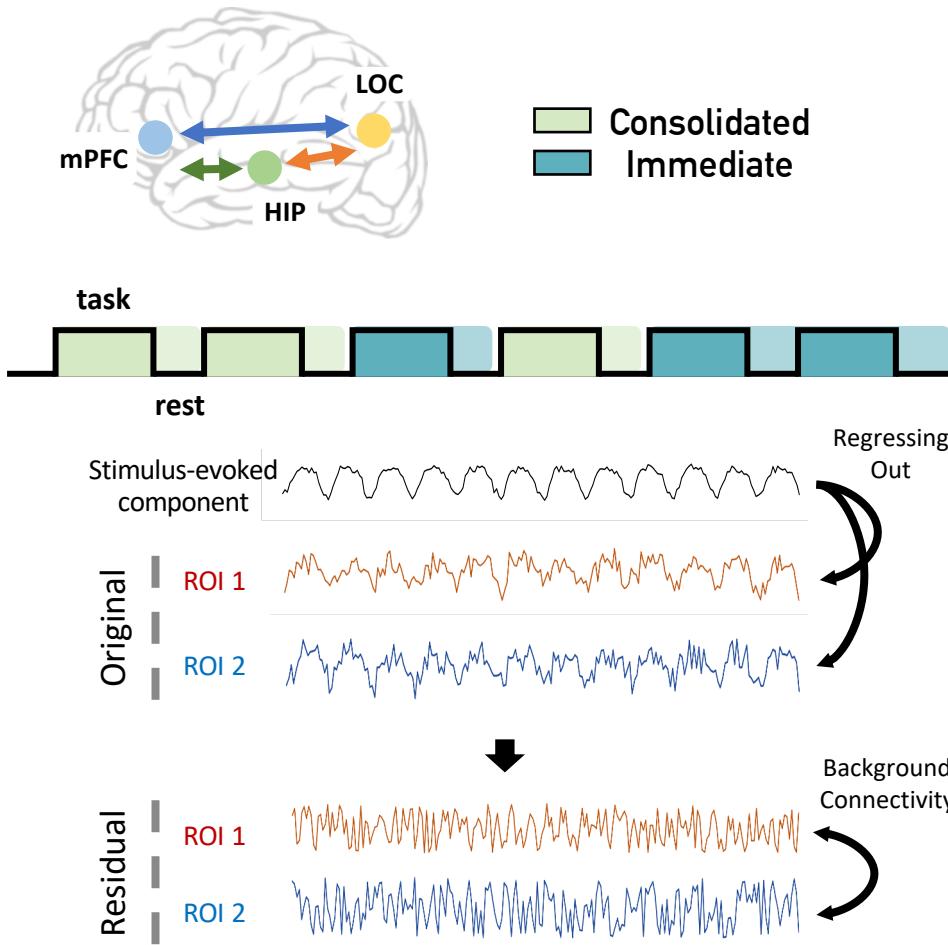
# SP 4. Correlation



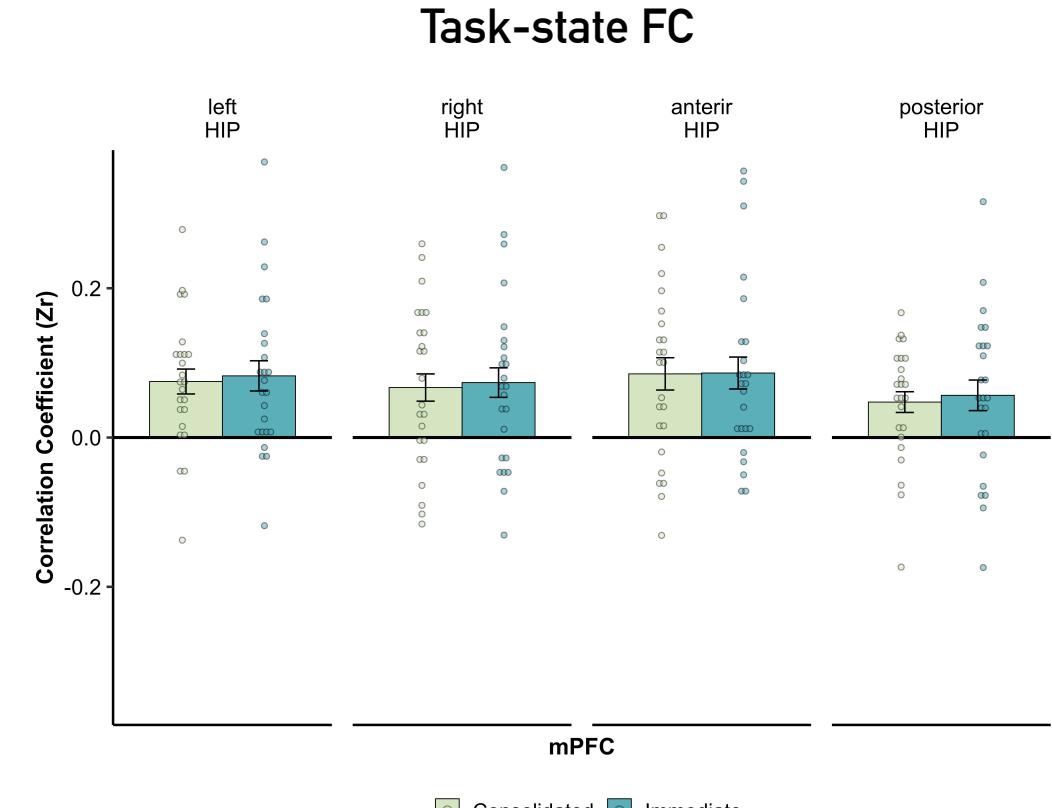
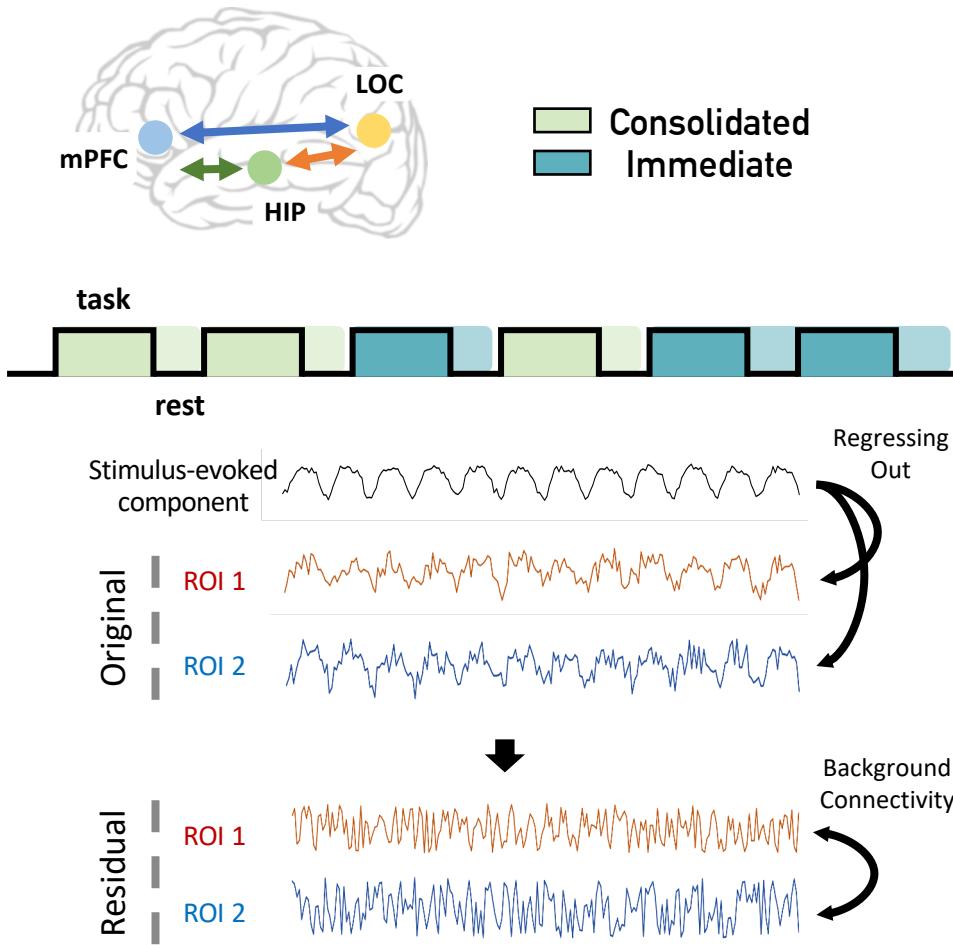
# SP 5. Functional Connectivity



# SP 5. Functional Connectivity

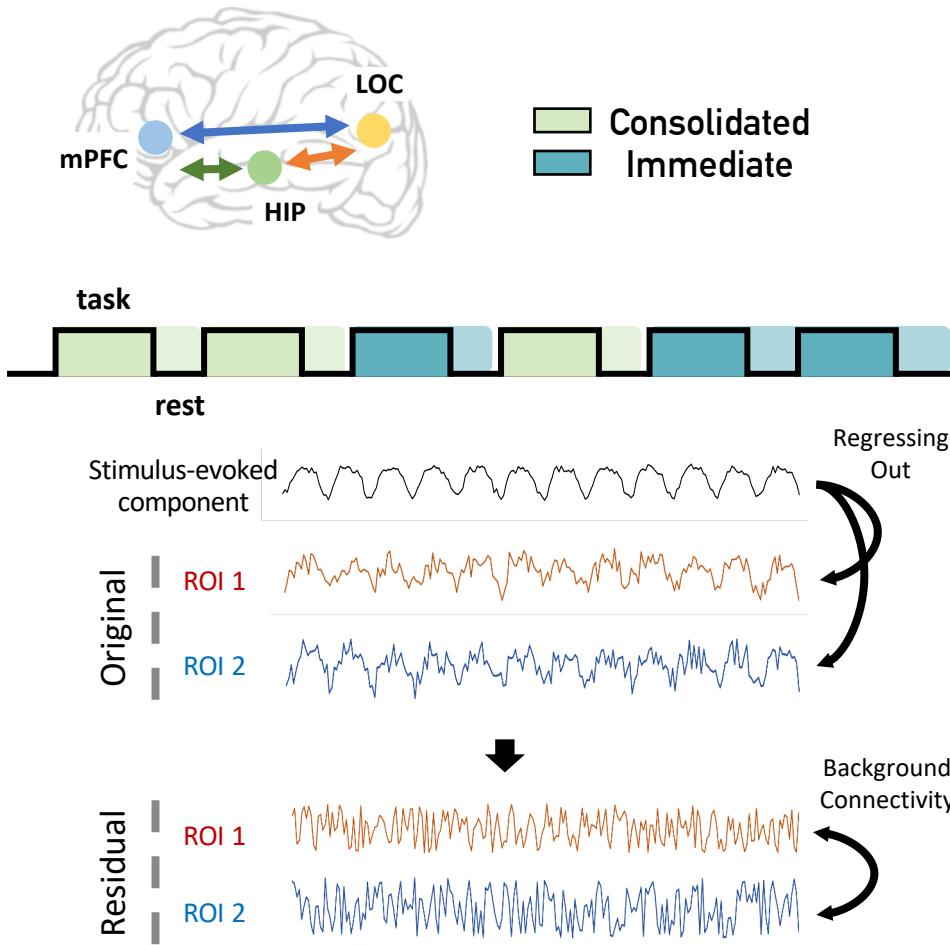


# SP 5. Functional Connectivity

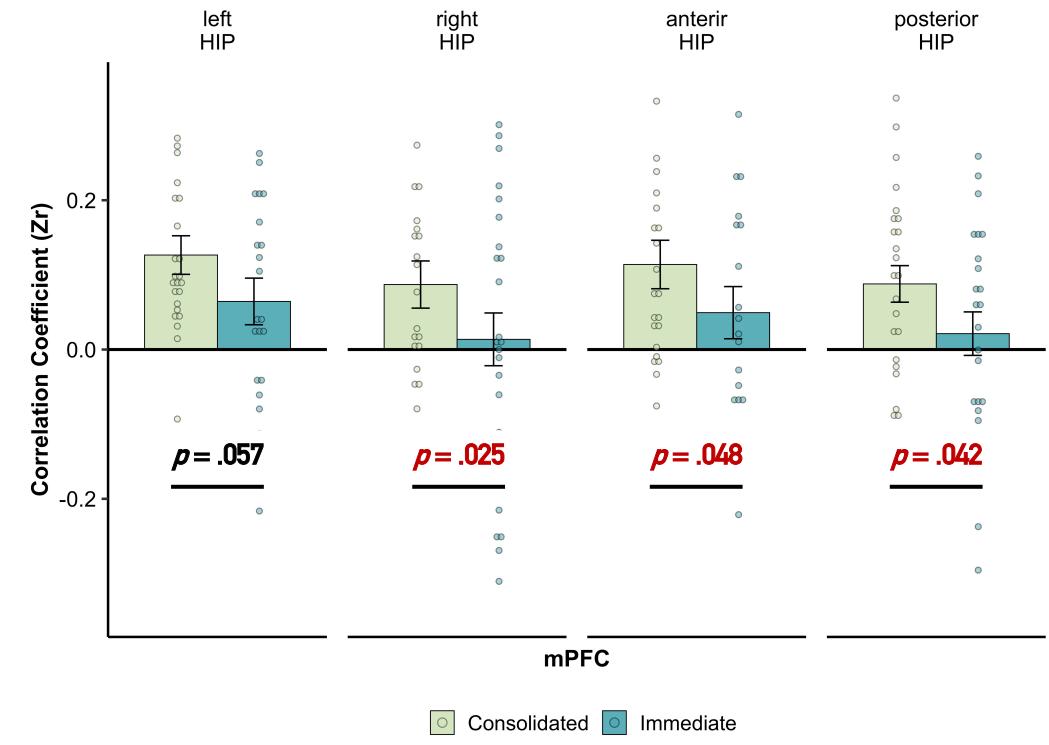


N = 24

# SP 5. Functional Connectivity



Resting-state FC



N = 24

# Reference

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