



Overlapping neural responses to symbolic math and formal logic in the intra-parietal sulcus



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Background

- Math engages parietal and frontal systems.
- Parietal systems process quantity representations¹.
- However, fronto-parietal circuits also participate in:
 - executive control processes
 - symbolic reasoning
- We compared neural basis of symbolic math to an executive control task (MSIT) and a non-quantitative symbolic reasoning task (formal logic)
- **Do culturally derived symbol systems (math and logic) engage common fronto-parietal mechanisms?**

Methods

Participants:

15 adults (3 females) with at least 3 years of college education.

Experiment:

“Sentence” judgement task:

Language	The monkey that the fox fought stole the food.	○
	The food was stolen by the monkey that the fox fought.	
Same meaning?	The show that the movie copied featured the actor.	X
	The actor was featured by the movie that the show copied.	
Mathematics	X plus thirty-three equals seventy-eight	○
	X plus fourteen equals fifty-nine	
Same X value?	X plus twenty-one equals fifty-eight	X
	X plus twenty-two equals fifty-six	
Formal logic	If not Y then both Z and X	○
	If either not Z or not X then Y	
Consistent?	If not either C or A then B	X
	If B then both C and A	

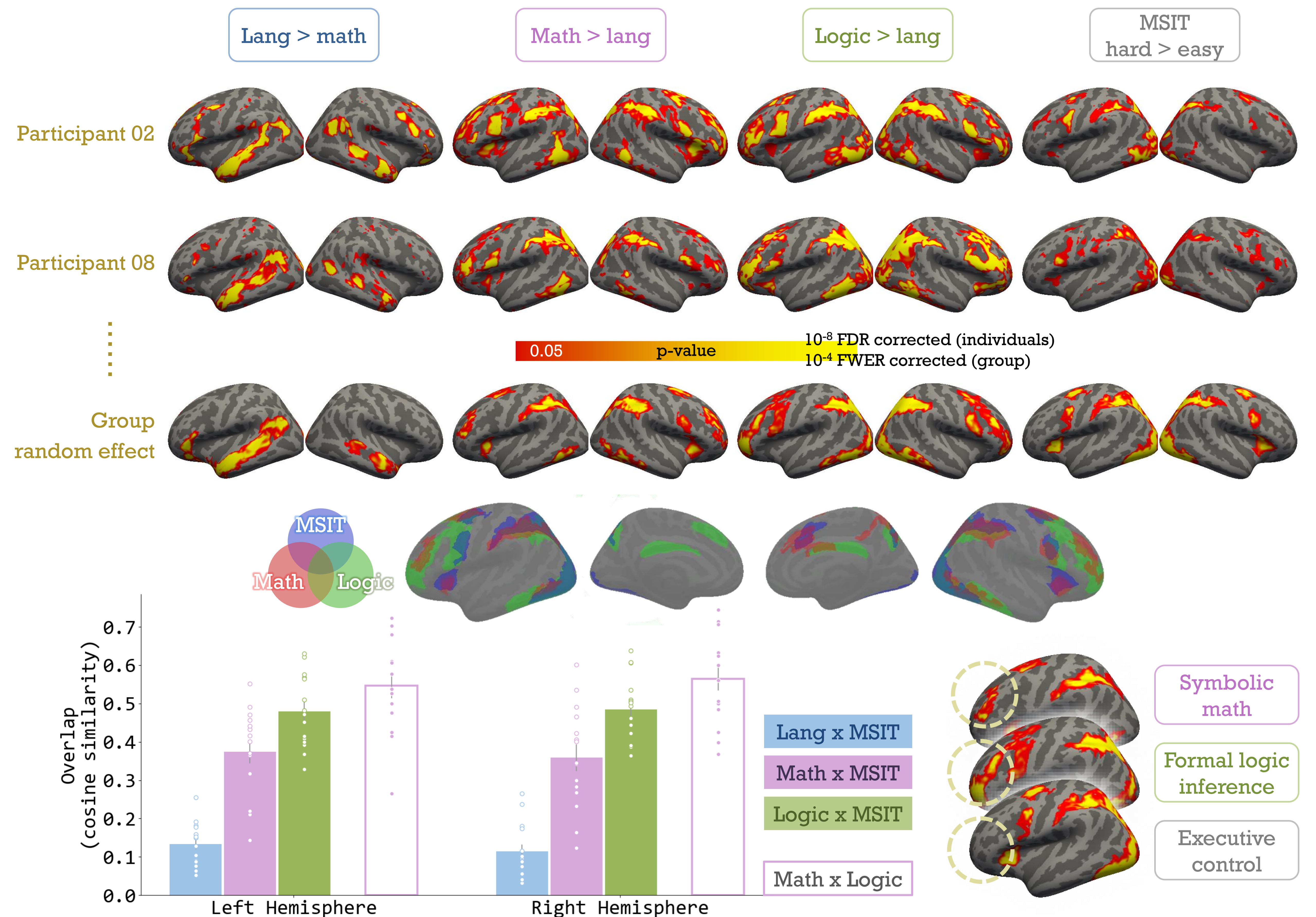
Multi-source interference task:



Quantification of overlap:

Cosine similarity between each pair of whole-brain neural activation patterns.

Results



Conclusion

- Math, logical reasoning and executive control activate common parietal areas.
 - Math overlaps with executive control in posterior frontal cortices (insula and precentral gyrus)
 - Math overlaps with logical reasoning in anterior PFC (including BA46/10/9).
 - Although formal logical inference doesn't involve numerical operation, its neural resources are highly similar to symbolic math.
- Math shares fronto-parietal neural resources with other culturally derived symbol systems. Even systems that do not involve quantity.**

References

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