Title

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Neural Underpinnings of Reasoning: A Closer Look at Parietal Cortex

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Introduction

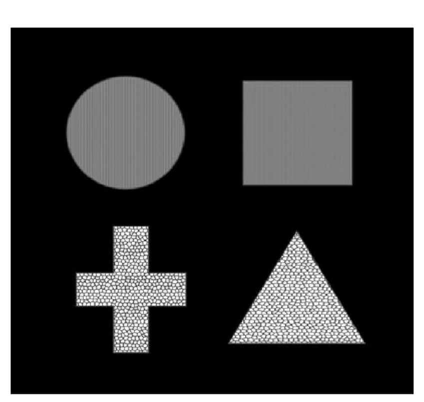
- ***Relational integration*** refers to the ability to jointly consider multiple structured mental representations, or relations, which is central to human cognition
- Literature on relational integration has overwhelmingly focused on the role of lateral prefrontal cortex [1], and particularly **left *rostrolateral prefrontal cortex* (rlPFC)** [2,3]. However, parietal cortex has also been implicated in relational reasoning [3-5].
- Drawing on evidence that individuals with damage to **left *inferior parietal lobule* (IPL)** perform poorly on visuospatial matrix reasoning tasks that require integration [5], the current study posits that the parietal cortex plays a direct and central role in higher-order reasoning.
- The parietal cortex comprises a network of functions and anatomical subdivisions [6].
- Improvements in relational reasoning over development are associated with cortical thinning in IPL, rlPFC, and dorsolateral PFC (dlPFC); furthermore, cortical thinning in IPL predicts age-related functional selectivity for integration in IPL and left rlPFC [7].

Aim: Explore the differential roles of parietal cortex subregions in relational reasoning.

Relational Matching Task

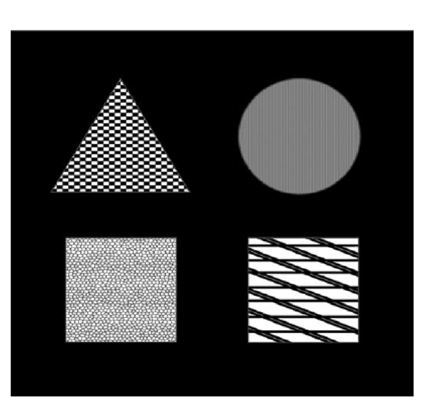
- N = 77 healthy individuals ages 6.5-18.7 years.

Sample stimulus arrays.



Conditions and correct responses.

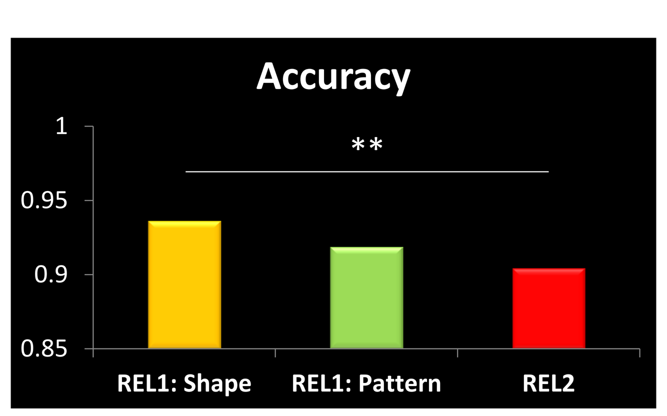
REL1	Top	Bottom
SHAPE	NO	NO
PATTERN	YES	YES
REL2	Top vs. Bottom	
COMPARE	YES	

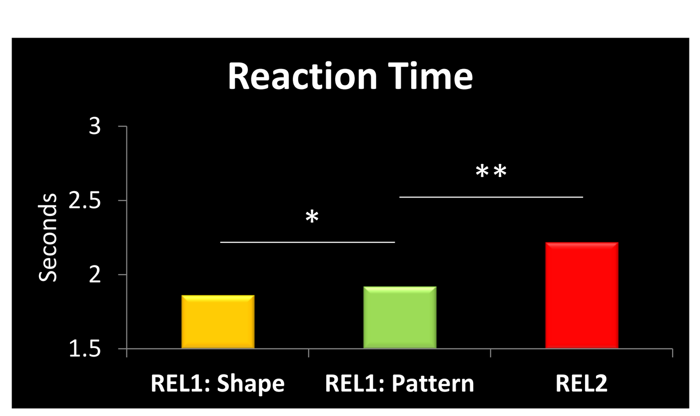


REL1	Top	Bottom
SHAPE	NO	YES
PATTERN	NO	NO
REL2	Top vs. Bottom	
COMPARE	NO	

- Participants judged whether pairs of stimuli match along a specific stimulus dimension: Shape or Pattern [2,7].
- **Shape** trials and **Pattern** trials require ***one 1st-order relational judgment*** **(REL1)**.
- **Compare** trials require ***one 2nd-order relational judgment*** **(REL2)**—i.e., whether the bottom pair matches along the *same stimulus dimension* (Shape or Pattern) as the top pair.

Behavioral Results (N = 77)





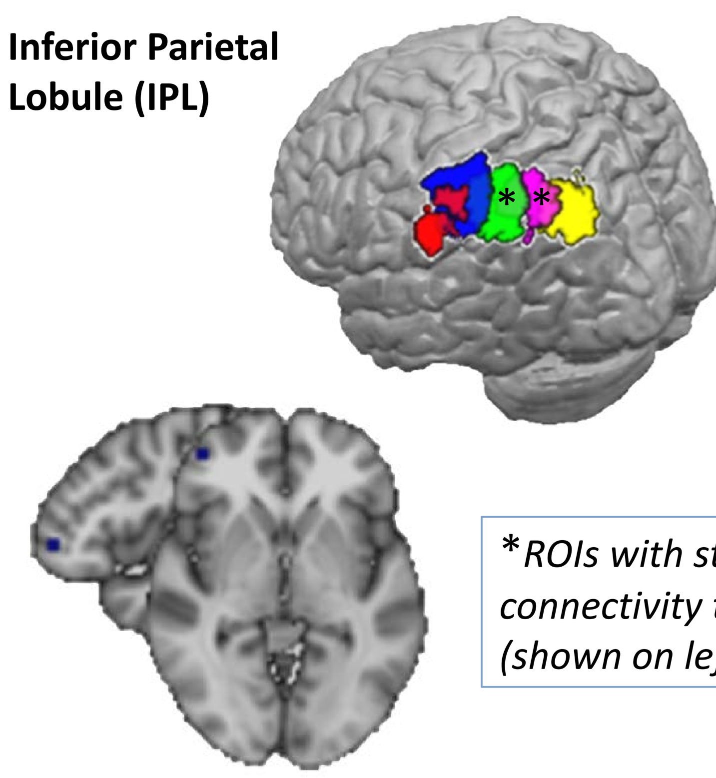
- Participants were fastest and most accurate for Shape (REL1) judgments, and slowest and least accurate for Compare (REL2) judgments ($p < .02$).

FMRI Analyses

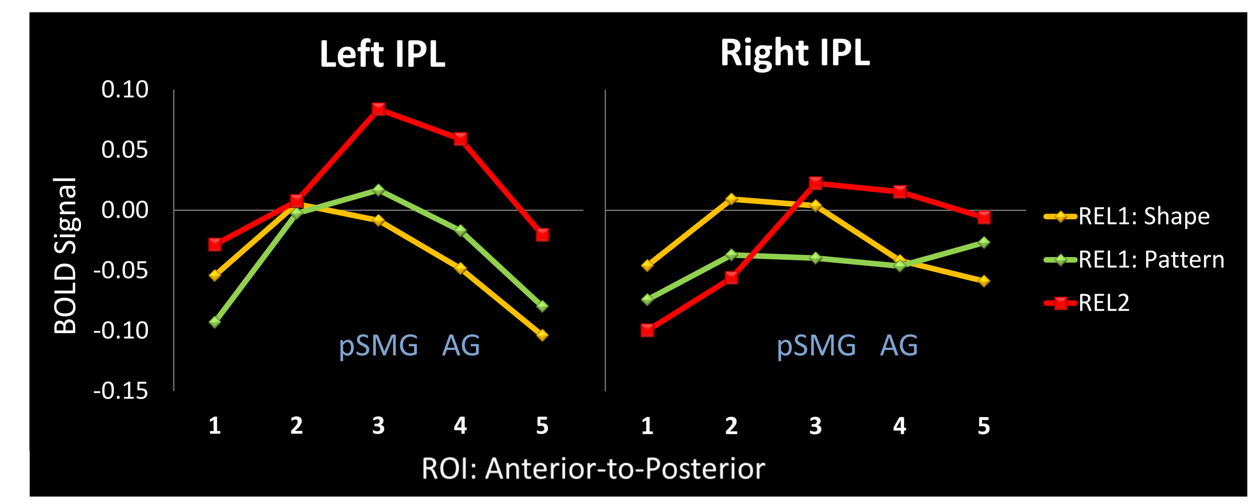
Tractography-based parcellation results [6].

Regions of interest (ROIs): 1 2 3 4 5

Inferior Parietal Lobule (IPL)



*ROIs with strong connectivity to rlPFC (shown on left)



Mean activation as a function of REL condition, by ROI.

Left *posterior supramarginal gyrus* (pSMG) and left *angular gyrus* (AG) are most selective for REL2.

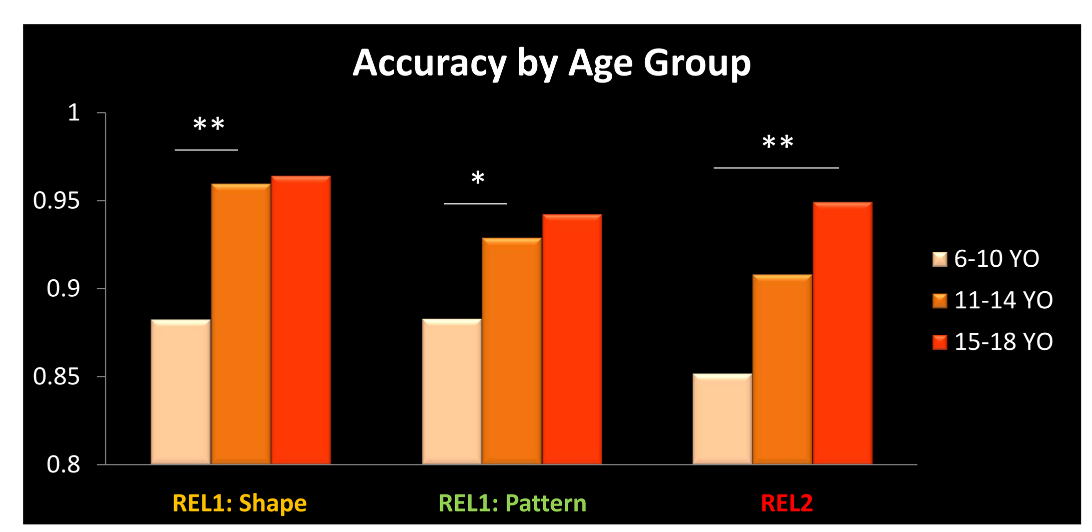
- ROI × Hemisphere × REL, $F_{4,288} = 2.551$, $p = .039$.
- **Left pSMG and left AG are the regions identified by Mars et al. as most tightly connected to left rlPFC [6].**

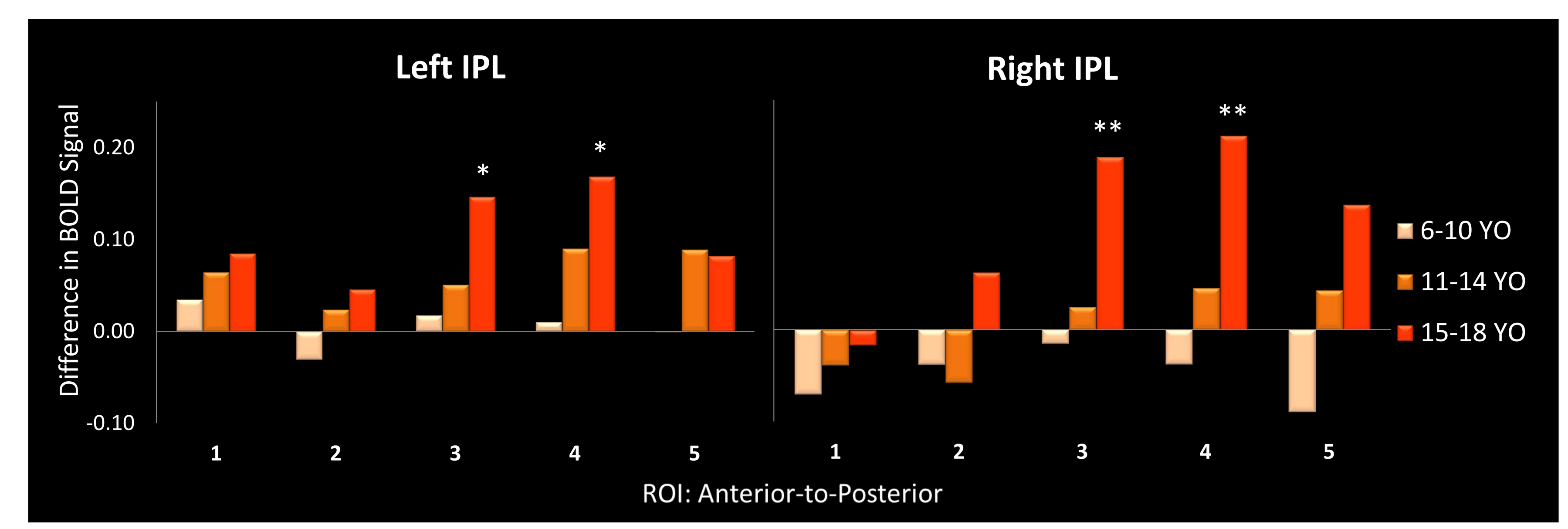
Differential BOLD activation in IPL for REL1 versus REL2 emerges over adolescence.

- ROI × REL × Age, $F_{8,288} = 2.145$, $p = .032$.
- **Specialization for REL2 is observed in bilateral pSMG and AG in late adolescence.**

REL1 accuracy is high by early adolescence.

REL2 accuracy continues to improve through adolescence.





Mean difference in activation as a function of age group: REL2-REL1 (Pattern), by ROI.

** $p < .01$, * $p < .05$

Conclusions

- Developmental gains in higher-order relational processing were observed over a prolonged trajectory, consistent with age-related cortical thinning in IPL, and functional selectivity in IPL and left rlPFC [7].
- By late adolescence, pSMG and AG are differentially engaged by REL1 (Pattern) vs. REL2 trials, despite minimal differences in task difficulty between these two conditions.
- Functional selectivity in left IPL showed that relational integration is supported by regions associated with complex attention processes [6].
- Left pSMG and left AG—the ROIs identified as most tightly connected to left rlPFC [6]—were most selective for relational integration, and were the only regions active during integration but not lower-level processing, corroborating evidence that these regions work in tandem with left rlPFC to support higher-order reasoning [2,3,7].
- Results may extend a model of AG as a site where multisensory inputs are combined to support complex cognition [8] to include a uniquely human [6], long-range AG-rlPFC connection associated with higher-order reasoning [9].

Acknowledgements

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