Interoceptive Awareness and Affective Empathy Share Intrinsic Spatial Connectivity and Temporal Variability

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INTRODUCTION

- Human empathy is the ability to understand and identify with the feelings and emotional state of others (Cuff et al., 2016)
- It is comprised of affective (sharing emotional experiences) and cognitive components (understand and make inferences about mental and/or emotional state) (Mackes et al., 2018)
- Awareness of internal bodily sensations (interoception, IA) and its connection to empathy have been postulated, yet its neural basis remains poorly understood
- The present study used a data-driven approach during naturalistic resting state to investigate what spatial and temporal brain network dynamics empathy and interoceptive awareness share

MATERIALS

Sample: 26 healthy participants (16 females, mean age = 21.8) underwent a resting state fMRI task using naturalistic stimuli.

Independent Component Analysis (ICA) was conducted in the Functional Connectivity (CONN) Toolbox of SPM12

- The resultant components were correlated with an affective and cognitive empathy questionnaire (IRI), and an interoceptive questionnaire (MAIA)

Task: The participants watched a 7 min abstract, nonsocial movie titled *Inscapes* **(Figure 1)** previously demonstrated to evoke strong connectivity in intrinsic connectivity networks that are more similar to rest than those during conventional movies (Vanderwal et al., 2015). The movie features a series of technological-looking abstract shapes. Participants were told to keep their eyes open and relax while watching and listening to the movie.

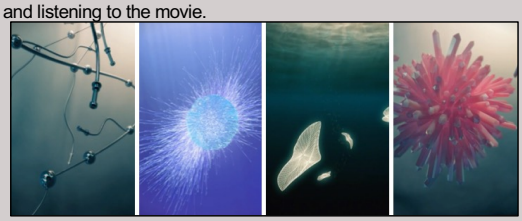

Figure 1: Still-shots from *Inscapes* Movie

METHODS

Data Acquisition: Images were acquired using a Siemens Skyra 3T scanner with a 20 channel head coil. Standard 2mm^3 MPRAGE scans provide structural data, while whole brain 2mm^3 GE-EPI slice acceleration factor 3 (78 slices, TR=2s) provided functional data.

Spatial Connectivity: Group-level independent component analysis (ICA) using the CONN toolbox was conducted to identify networks of functionally connected during resting state (rsFC) brain regions that may be associated with IRI and MAIA scores. This involved the application of the fastICA algorithm to dynamic volumes concatenated across subject and resting state condition in order to identify independent spatial components and back-projection of these components to individual subjects, resulting in maps of regression coefficients representing FC between the network and every voxel in the brain For each network, the resulting statistical maps were cluster thresholded at $p \leq 0.05$, voxel thresholded at $p < 0.001$ (FDR-corrected) using Gaussian Random Field Theory and corrected for age and gender.

Temporal Variability: In order to assess efficient network communication, and its relationship to empathy and IA, we also assessed temporal variability of each IC and regressed it with IRI and MAIA questionnaires. Although rarely utilized as an individual difference measure (Samanez-Larkin et al., 2010), we were interested in whether empathy or IA shared temporal variability in BOLD signal (measured as SD BOLD). Temporal variability is defined as a fluctuation of neural activity over time, and has been described as beneficial for the neural system's adaptability, efficiency and cognitive performance (Dai et al., 2016).

BEHAVIORAL RESULTS

Intercorrelations between IRI and MAIA Questionnaires and Descriptive Statistics

	1	2	3	4	5	6	7	8	9	10	11	12	Mean	STD
IRI Total (1)	--												75.79	11.12
IRI Affective Empathy (2)	0.60	--											31.84	6.3
IRI Personal Distress (3)	0.11	0.79	--										10.24	5.61
IRI Empathic Concern (4)	0.80	0.48	-0.17	--									21.6	3.85
IRI Cognitive Empathy (5)	0.83	0.05	-0.41	0.67	--								44	8.52
IRI Perspective Taking (6)	0.58	-0.15	-0.52	0.50	0.83	--							21.64	4.97
IRI Fantasy (7)	0.80	0.22	-0.18	0.61	0.84	0.39	--						22.36	5.25
MAIA Total (8)	-0.23	-0.64*	-0.66*	-0.08	0.16	0.31	-0.04	--					23.28	4.36
MAIA Awareness of Body Sensations (9)	-0.30	-0.36	-0.19	-0.29	-0.12	-0.17	-0.03	0.54	--				2.98	0.81
MAIA Emotional Reaction (10)	-0.33	-0.23	-0.21	-0.08	-0.25	-0.11	-0.31	0.37	-0.03	--			5.65	1.26
MAIA Capacity to Regulate Attention (11)	-0.33	-0.83*	-0.74*	-0.27	0.17	0.32	-0.03	0.79	0.48	0.24	--		3.05	0.94
MAIA Awareness of Mind Body Integration (12)	0.09	-0.34	-0.49*	0.16	0.35	0.41*	0.18	0.82	0.37	-0.05	0.50	--	8.12	2.46
MAIA Trusting Body Sensations (13)	-0.25	-0.55*	-0.53*	-0.12	0.08	0.31	-0.18	0.71	0.21	0.32	0.53	0.40	3.48	1.08

Figure 2: Intercorrelations between IRI and MAIA Subscales and Descriptive Statistics (same subscale correlations not flagged for significance). * represents correlations statistically significant after multiple comparison correction. Uncorrected Mean and STD reported.

NEUROIMAGING RESULTS

[SPATIAL CONNECTIVITY]

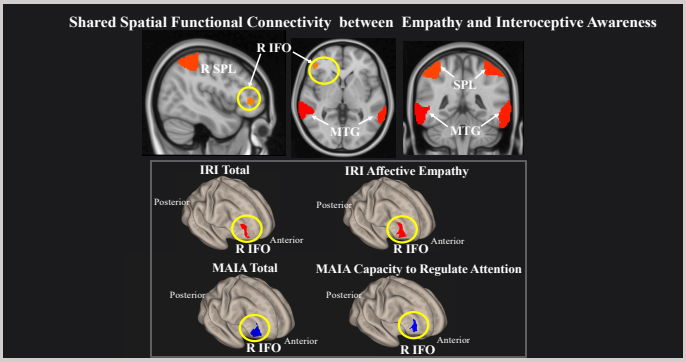

Figure 3: Greater spatial rsFC in the right IFO is associated with lower total IA and greater Affective empathy. Statistical maps are thresholded at FDR-corrected cluster-based $p < 0.05$ after voxel threshold at $p < 0.001$.

[TEMPORAL VARIABILITY]

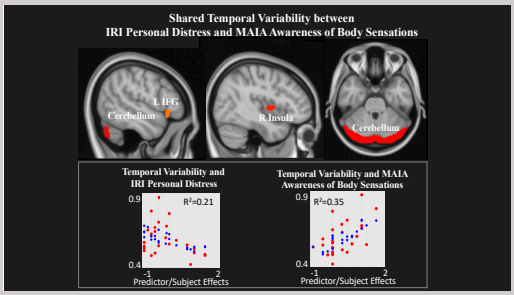

Figure 4: Shared temporal variability between IRI Personal Distress and MAIA Awareness of Body Sensations. Statistical maps are thresholded at FDR-corrected cluster-based $p < 0.05$ after voxel threshold at $p < 0.001$. Note: Red dots in graphs represent observed values, Blue dots fitted values.

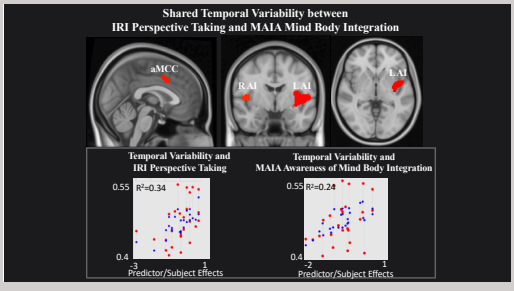

Figure 5: Shared Temporal Variability between IRI Perspective Taking and MAIA Mind Body Integration. Statistical maps are thresholded at FDR-corrected cluster-based $p < 0.05$ after voxel threshold at $p < 0.001$. Note: Red dots in graphs represent observed values, Blue dots fitted values.

CONCLUSIONS

- The current research provides novel information about the relationship between internal body sensation awareness and empathy.
- We used a rsFC approach to test whether distinct empathy facets are spatially and/or temporally are to IA.
- We demonstrate a complex bidirectional relationship between empathy and IA, depending on the type of empathy interrogated.
- Affective empathy and IA are distributed across similar spatial and temporal neural systems, while Cognitive empathy and IA are only related temporally
- Increased vicarious emotional experience and decreased IA were associated with increased rsFC within the R IFO, while on the temporal domain, increased IA and reduced personal discomfort arising from witnessing another's pain was related to enhanced information processing within an internal sensation network.
- Perspective-taking ability and a sense of mind-body connectedness related to improved processing between brain regions subserving the salience network.
- Importantly, we show that the ability to feel and understand another's emotional state is related to the awareness of internal body changes, and that this relationship is not task-dependent, but is reflected in intrinsic neural architecture.

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