Network-based approach in fMRI experiment with affective touch

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***Abstract*—This research aimed to identify potential differences in resting-state brain networks between the experimental group and healthy individuals. We analyzed 27 experimental subjects (EX) and 11 healthy controls (HC), who all underwent clinical evaluation and functional resting-state Magnetic Resonance Imaging (fMRI) testing. We applied network-based measures with the intention of examining functional connectivity network measures across both groups, comparing Rest1 and Rest2 states occurring before and after the experiment, respectively.**

***Index Terms*—network measures, fmri, experiment, affective touch, functional connectivity.**

I. Introduction

Studying fMRI during affective touch is important because it provides insights into the neural mechanisms underlying social bonding and emotional processing. Touch is a fundamental aspect of social interaction, playing a crucial role in fostering bonding and attachment. Touch can evoke a wide range of emotions, from pleasure and comfort to pain and distress [1]. fMRI can reveal the brain regions involved in processing social touch, helping to understand the neural basis of social connection. Understanding the neural mechanisms of touch can have implications for clinical interventions [2]–[4]. For example, fMRI findings might inform the development of touch-based therapies for conditions like anxiety, depression, and autism. Affective touch activates specific brain regions. By studying these regions, researchers can understand how they contribute to emotional experience. This research study seeks to investigate the functional connectivity within the brain's neural correlates following a lower limb massage, which may contribute to a deeper understanding of how touch experiences can have enduring effects on our behavior and emotional state. Our aim is to identify differences in resting-state brain networks in the experimental group compared to the control group after the massage is administered.

II. Experiment and data preparation

Our study involved 27 healthy experimental participants (EX; 13 male, 14 female) and 11 healthy control individuals (HC; 5 male, 6 female), all within the age range of 20–40 years. The study involved the administration of a 5-minute foot massage, preceded and followed by a rest period for each participant. This resulted in two periods of interest: Rest1 and Rest2. In addition, there was a control group in which subjects only lay down in the scanner for 5 minutes instead of receiving a massage. For each subject, two resting state functional magnetic resonance imaging (fMRI) sessions were acquired, each lasting 480 seconds. Functional and anatomical images were acquired using a 3.0T Philips Achieva MRI scanner with a 20-channel head coil. Each functional run consisted of 360 T2 echoplanar images, with 240 slices for each resting condition. The imaging parameters were as follows: 2x2mm in-plane voxel size, 4 mm slice thickness, no interslice gap, repetition time (TR) = 2000 ms, and echo time (TE) = 30 ms.

The data were preprocessed using the SPM12 statistical software package [5]. Specifically, the preprocessing procedure included motion correction, co-registration of the structural data, and normalization to the Montreal Neurological Institute (MNI) standardized space. To determine connectivity between various brain regions, we calculated and detrended the average time series for each node within the Automated Anatomical Labeling (AAL3) atlas [6], and then computed Pearson correlation coefficients for all possible pairwise combinations of the averaged parcellated activity patterns.

III. Methods and results

To analyze the topology and larger-scale features of the functional network [7], we calculated the following network metrics [8], [9]: node strength (NS) [10], betweenness centrality (BC) [11], eigenvector centrality (EC) [12], and clustering coefficient (CC) [13], [14]. The analysis involved a brain network consisting of AAL nodes. For each node, four network measures were obtained for each subject in each group. Significant nodes were determined by comparing the mean difference between the groups. However, to account for the possibility of false-positive findings, subjects were permuted between groups 50000 times, and only nodes with p-values below 0.05 were considered significant. This process aimed to ensure that significant nodes are robust and unlikely to occur by chance.

The distributions across nodes of the differences between the group averaged network measures for the EX group (rest 2>rest 1) for different network measures are presented in the Fig. 1 and Table. I.

When comparing the measures between themselves, the highest number of meaningful different nodes between groups was obtained for the NS and CC measures, and the lowest for the BC measure. It should be noted, however, that the nodes are mostly the same for the three measures, except for measure BC. The most frequently occurring nodes include the thalamus (intralaminar (IL), ventral aposterior (VA), mediodorsal magnacellular (MdM)) and the anterior cingulate cortex (ACC).

IV. Discussion and conclusions

Sensory information is first transmitted to the spinal cord via peripheral nerves when a person makes tactile contact with an object. This information then travels upwards to the brain via two primary pathways: the medial lemniscus pathway (responsible for discriminative tactile sensations such as texture and pressure) and the spinothalamic tract.

The MdM nucleus is also engaged in social and cognitive functions, including social cognition and decision making, and it is connected to the prefrontal cortex, which is intricately involved in touch processing [15], [16]. The ACC is connected anatomically to several brain regions, including the thalamic nuclei, periaqueductal gray, and amygdala. Functionally, it plays a crucial role in processing the affective component of noxious stimuli and learning to anticipate and avoid noxious stimuli [17], [18].

Our study helped to investigate the differences in brain activity between an experimental group of healthy subjects before and after receiving lower limb massage, compared to healthy controls who did not receive massage. In particular, we observed distinct changes in connectivity patterns, particularly within the thalamic and anterior cingulate cortex brain regions.

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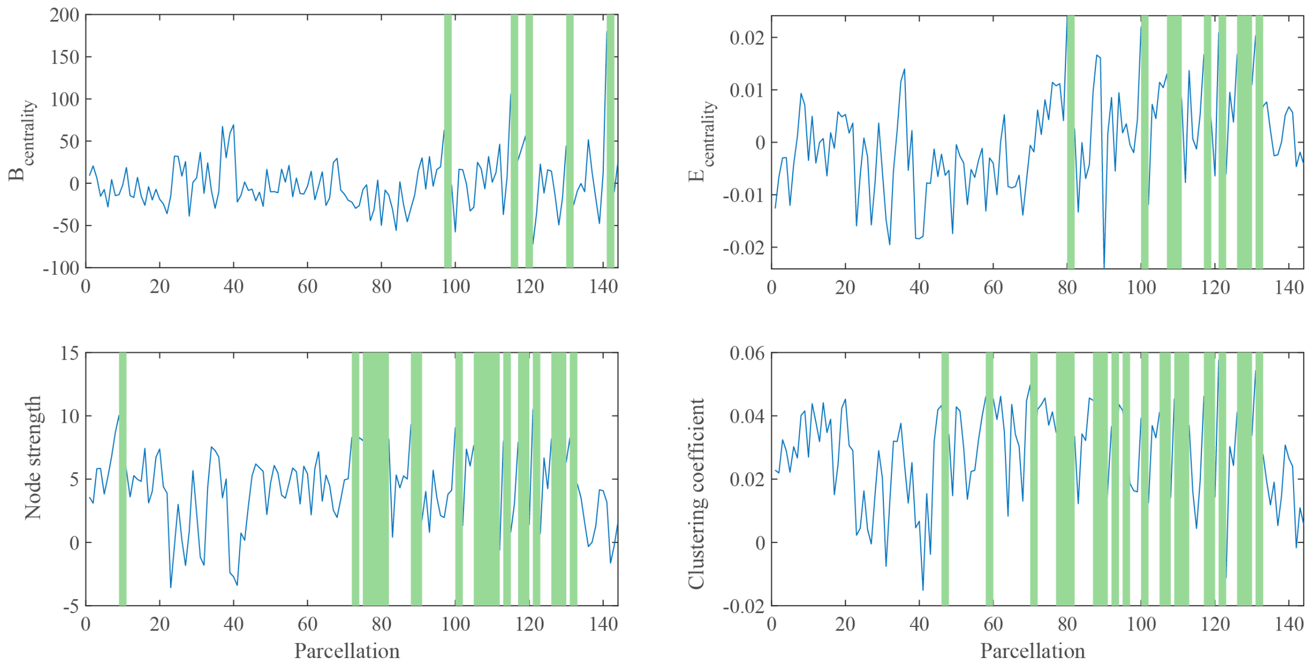

Fig. 1. The distributions across nodes of the differences between the group averaged network measures for the HC and EX groups (HC>EX) for different network measures in rest 2. Color shows significantly different nodes

TABLE I

SIGNIFICANTLY DIFFERENT NODES BETWEEN THE GROUP AVERAGED NETWORK MEASURES FOR THE HC AND EX GROUPS (HC>EX) FOR DIFFERENT NETWORK MEASURES IN REST 2.

Betweenness centrality	Eigenvector centrality	Node strength	Clustering coefficient
Thal AV R	Heschl R	Frontal Inf Tri L	Calcarine R
Thal MGN L	Thal VA L	Paracentral Lobule R	Fusiform R
Thal PuM L	Thal IL R	Putamen L	Precuneus R
ACC sup R	Thal MDm L	Putamen R	Pallidum L
LC L	Thal PuI L	Pallidum L	Pallidum R
	Thal PuA L	Pallidum R	Heschl R
	ACC sub R	Heschl R	Temporal Pole Mid L
	ACC pre L	Temporal Pole Mid R	Temporal Inf L
	ACC pre R	Temporal Inf L	Vermis 3
	N Acc L	Thal VA L	Vermis 7
		Thal VPL R	Thal VA L
		Thal IL R	Thal VPL R
		Thal MDm L	Thal IL L
		Thal MDm R	Thal MDm L
		Thal LGN L	Thal MDm R
		Thal PuI L	Thal MDl L
		Thal PuI R	Thal PuI L
		Thal PuA L	Thal PuI R
		ACC sub R	Thal PuA L
		ACC pre L	ACC sub R
		ACC pre R	ACC pre R
		N Acc L	N Acc L

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