Modeling the hierarchy of the brain network for the music effect on cognitive aging

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Purpose

- Previous studies indicated that musicians differentiate from non-musicians in functional integration between various regions in the brain during naturalistic music listening. Moreover, a study examined fMRI responses during music listening and found that functional connectivity within and between auditory and reward networks was modulated by music pleasurable. However, there is limited research modeling the hierarchical architecture of the directed network under musical and aging intervention. Using the method of stepwise multivariate Granger causality(SMGC), we found specific distinctions about directed and hierarchical features between old musicians and other control groups.

Methods

- In the study, 22 old controls, 16 old musicians, 22 young controls and 20 young musicians' fMRI data were recorded during the missions of high/low award music stimulation. First, we used Specify 1st-level to calculate brain activation for different missions on the individual level, after which we used paired t-tests to obtain regions by the Brainnetome Atlas for all subjects under the high/low reward music mission. Then we used dynamic Granger Causal Metrix (dGCM) to observe the information flows in the different brain regions. Some activation regions were selected as the ROIs, which were used as the origin or destination, looking for various info-pathways. In the first step of SMGC, we obtained the ROIs where information significantly flowed away by one-sample one-tailed t-test within the four groups (p<0.05, FDR correction); we retained the top 5% of the t-value as the effective delivery ROIs. In the second step, we searched for the next level of effective delivery ROIs through the ROIs retained in the first step from the second GCM matrix. In the third step, we repeated the steps until all activated ROIs were traversed.
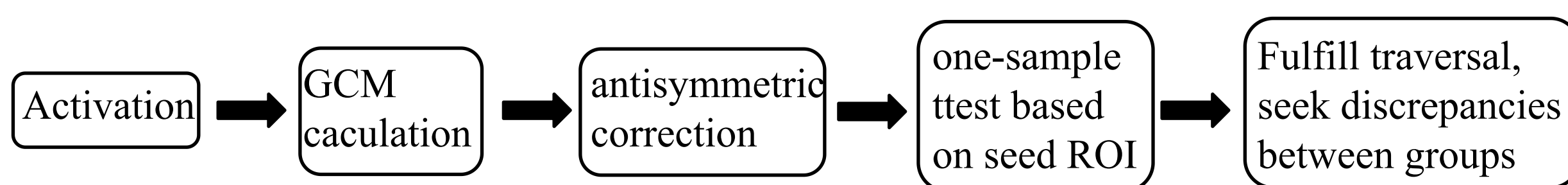
Activation → GCM caculation → antisymmetric correction → one-sample ttest based on seed ROI → Fulfill traversal, seek discrepancies between groups

Figure 1. method procedure pipeline

Results

- 170 activation ROIs after paired t-tests were shown in Figure 2, which included task-related brain regions such as cognition regions(M1), auditory regions(A1), other sensory regions(S1) and reward regions(R1) (p<0.05, FDR corrected).

- Using dGCM and SMGC, we found that there existed diverse between-ROIs pathways from A1 to M1 and S1 among groups. The observed trend from the comparison is as follows: old controls, old musicians, young controls, and young musicians. Moreover, we found the musicians have more directed stepwise from A1 to R1 and from R1 to S1. Stepwise hierarchical progression in the brains of four group subjects was shown in Figure 3.
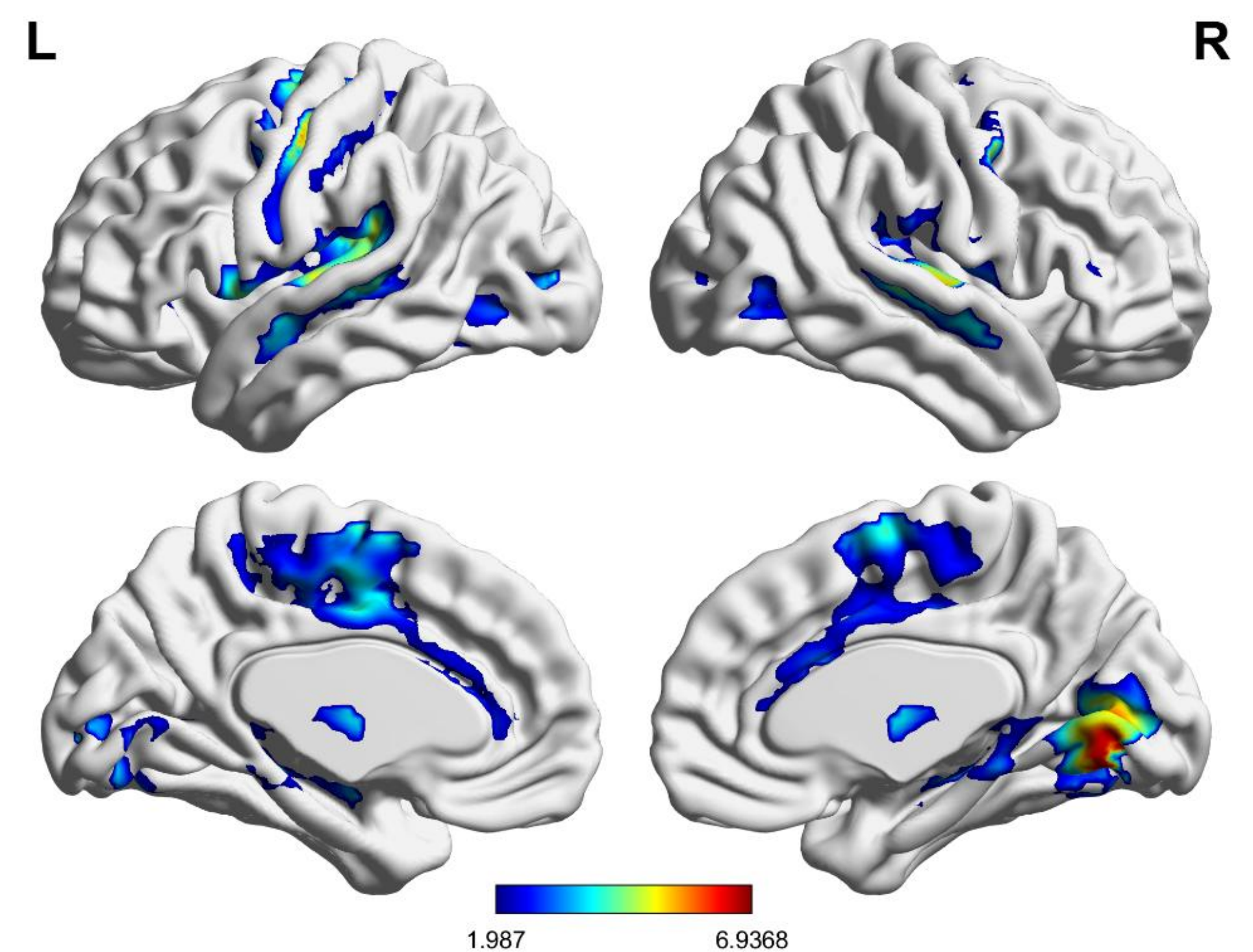
Figure 2. Activated regions after the missions of high/low award music stimulation after paired t-tests (p<0.05, FDR corrected). The task-related brain regions include M1, A1, S1, R1 and other brain regions.

Conclusion and Discussion

- Prior studies focusing on musicians and non-musicians found that music listening engages specific cortical regions within the temporal lobes. Our study indicated that distinct brain regions exhibit varying degrees of activation in response to music stimuli with different levels of pleasure. Subsequently, some research uses stepwise functional connectivity to observe the cerebral hierarchical information transfer between musicians and non-musicians. We found a more prominent pathway in musicians, extending from the A1 through the R1 to S1. This could suggest that musicians have a heightened demand for information processing in reward-related systems such as the basal ganglia.
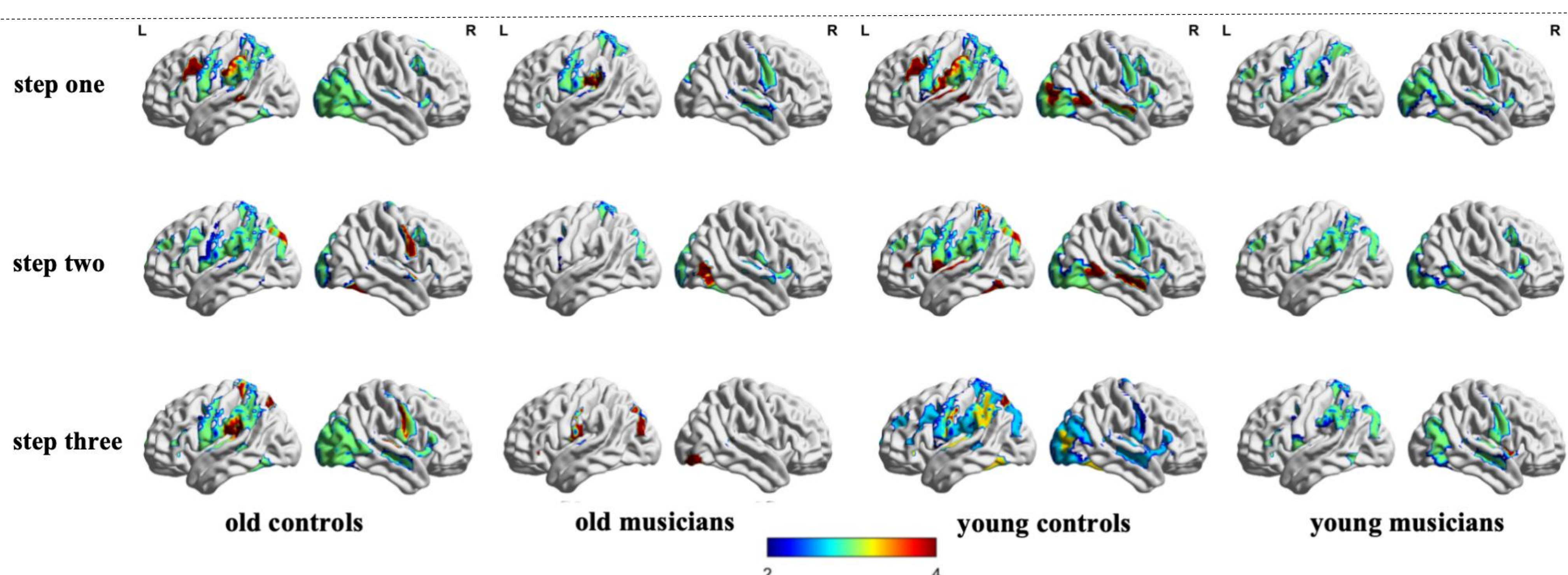

Figure 3. The t map after each SMCG step within the four groups (one-sample one-tailed t-test p<0.05, FDR corrected). The figure shows the directed and hierarchical features from auditory regions to the other activated ROIs, which only requires three steps to traverse all activated ROIs.

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