Li, S. et al.: Individual-specific subspace of altered functional connectivity predict clinical symptoms in internet gaming disorder

https://doi.org/10.1556/2006.2025.00047

Supplementary materials

Methods:

Methods S1: The inclusion and exclusion criteria for participants.

Inclusion criteria for Internet gaming disorder (IGD) were: (1) having at least five of nine DSM-5 IGD diagnostic criteria; and (2) playing internet games for more than 20 hours per week for a minimum of 1 year.

The inclusion criteria for recreational gaming use (RGU) included having played online games frequently without having developed IGD. First, the RGU subjects needed to have played online games as frequently as the IGD subjects; i.e., at least 5 of the 7 days and more than 10 hours per week during the prior year. Second, the RGU subjects needed not to have had IGD as verified by meeting fewer than 5 DSM-5 criteria for IGD.

To prepare participants for the fMRI scans, a safety screening questionnaire was administered to all subjects. Succinctly, all participants meeting any of the following criteria were deemed ineligible: (1) A history of mental or neurological diseases; (2) Cognitive impairment as indicated by the Mini-International Neuropsychiatric Interview (MINI) (Lecrubier et al., 1997) or signs of depression based on the Beck Depression Scale (Beck, Steer, & Brown, 1996), with both conditions being exclusionary; (3) Surgery, head trauma, or heart-related diseases within the past year; (4) Claustrophobia; (5) Metal implants or tattoos of the neck or head; (6) Substance use disorders within the last 12 months before recruitment; (7) Regular use of psychotropic medications.

Methods S2: Clinical measures

The BIS/BAS scale contains 20 four-point Likert-type items and is divided into BIS and BAS subscales. The BIS subscale assesses tendencies associated with inhibition/ avoidance of punishment. The BAS subscale assesses tendencies associated with seeking rewarding stimuli and outcomes. For each subscale, a higher score indicates a higher level of the tendency. The cognitive emotion regulation questionnaire (CERQ) has 18 self-report questions, with responses to each scored along a five-point Likert response pattern (ranging from "hardly" to "always"). The questionnaire was divided into 9 subscales: acceptance, positive focusing, refocus on planning, positive reappraisal, putting into perspective, self-blame, rumination, catastrophizing and blaming others. The 9 subscales could be classified into adaptive and maladaptive emotion regulation strategies. The adaptive CERQ is composed of five subscales, namely putting into perspective (e.g., "I think that it all could have been much worse"), refocusing on planning (e.g., "I think of what I can do best"), positive focusing (e.g., "I think of nicer things than what I have experienced"), positive reappraisal (e.g., "I think I can learn something from the situation") and acceptance (e.g., "I think that I have to accept that this has happened"). The maladaptive CERQ consists of four subscales, namely rumination (e.g., "I often think about how I feel about what I have experienced"), catastrophizing (e.g., "I keep thinking about how terrible it is what I have experienced"), blaming others (e.g., "I feel that others are to blame for it") and self-blame (e.g., "I feel that I am the one to blame for it"). For each strategy, a higher score indicates a higher level of the tendency.

Methods S3: Common orthogonal basis extraction (COBE)

Originally created for projecting "multi-block" data (collections of matrices) into a shared subspace among all blocks and block-specific subspaces (Zhou, Cichocki, Zhang, Mandic, & systems, 2015; Zhou et al., 2016), the COBE algorithm has been applied to isolate individual-specific features from resting-state functional magnetic resonance imaging (fMRI) data (Kashyap et al., 2021; Shan et al., 2023). For further information regarding COBE, readers are directed to prior publications (Zhou et al., 2015; Zhou et al., 2016).

The code for COBE algorithm is accessible to the public (http://bsp.brain.riken.jp/~zhougx/resources/mcode/demo_CIFE.zip or https://github.com/ClinicalBrainLab/OCD_Cerebellar-Visual-Community)

Methods S4: The number of common components in the common subspace

Based on previous studies(Tang et al., 2020), we presumed that common components inferred from various AFC datasets were consistent and comparable. Thus, We first applied the COBE algorithm to the AFC matrix from the original dataset comprising 326 IGD subjects, estimating 2 to 9 common components. Secondly, we randomly sampled 200 subjects from the original dataset (326 IGD subjects) to create a new dataset, repeating this process 1000 times. Each time, the COBE algorithm was applied to the new dataset, estimating 2 to 9 common components. Thirdly, we compared the common components obtained from the original and new datasets, identifying the optimal matches. Afterward, the common components from both datasets were correlated, and these correlations were averaged over 1000 iterations, providing an average similarity for each C value ranging from 2 to 9. We observed robust estimations when C=4, thus focusing on 4 common components for subsequent analyses.

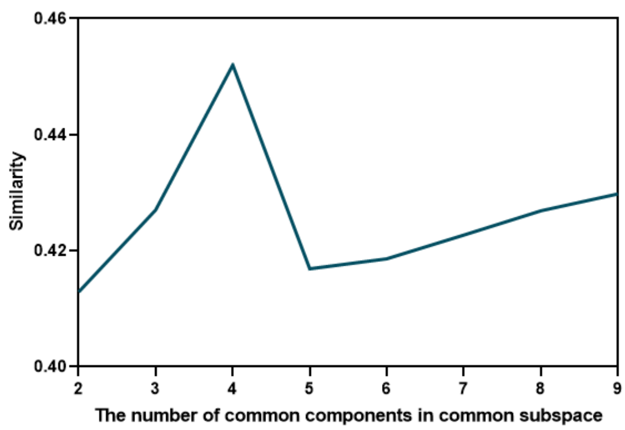

Figure S4. Similarity between the final estimation and decomposition from 1000 random iterations.

Results:

Results S1: Relationships between AFC in the individual-specific subspace and clinical symptoms

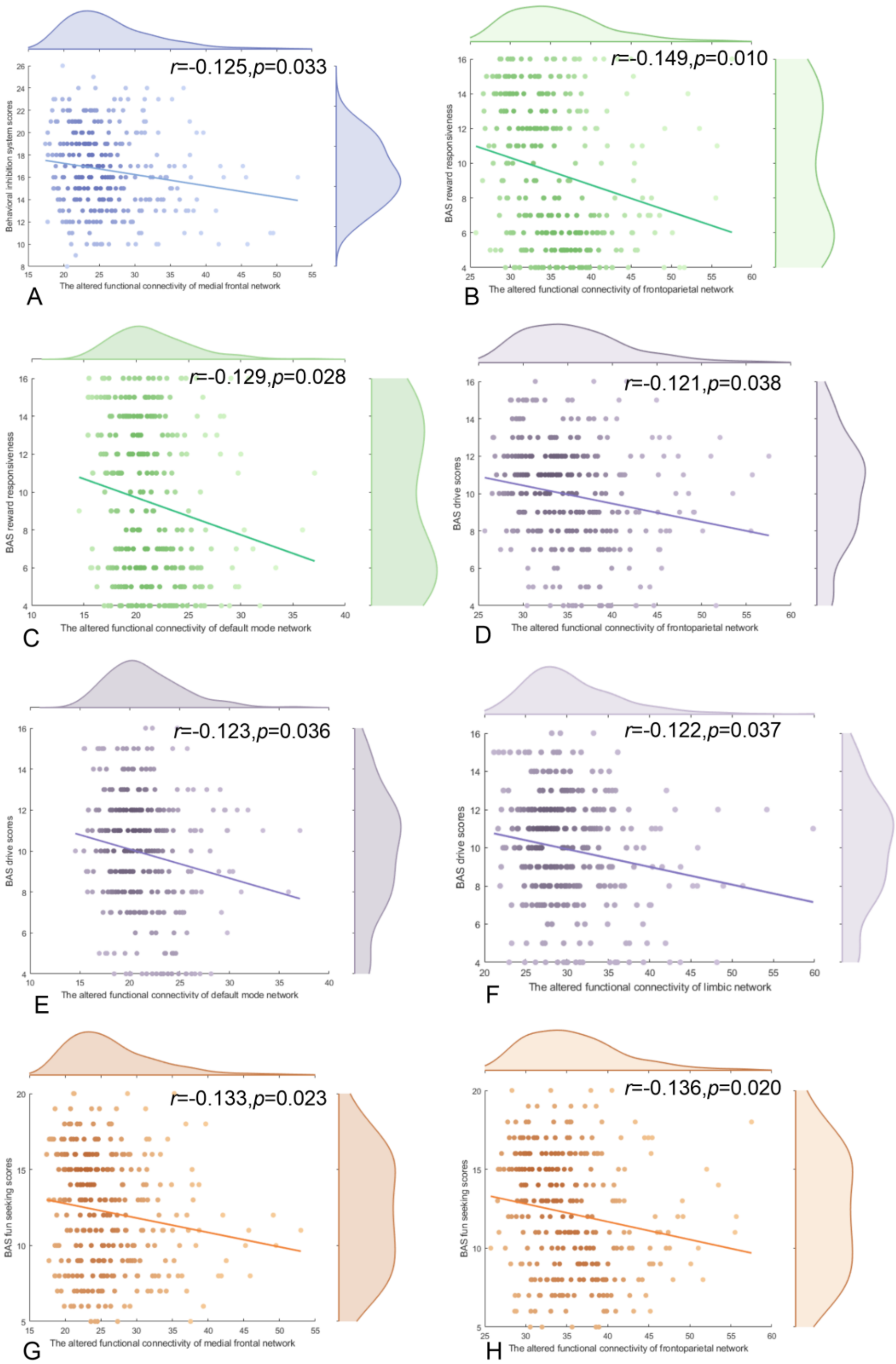

Figure Results S1. Relationships between AFC in the individual-specific subspace and clinical symptoms. (A) FAFC within MFN exhibited a negative association with BIS scores. (B) FAFC within FPN showed negative associations with BAS-Reward Responsiveness scores. (C) FAFC within DMN showed negative associations with BAS-Reward Responsiveness scores. (D) FAFC within FPN was negative association with BAS-Drive scores. (E) FAFC within DMN was negative association with BAS-Drive scores. (F) FAFC within LN was negative association with BAS-Drive scores. (G) FAFC within MFN showed a negative association with BAS-Fun Seeking scores. (H) FAFC within FPN showed a negative association with BAS-Fun Seeking scores

References:

Beck, A. T., Steer, R. A., & Brown, G. J. P. a. (1996). Beck depression inventory–II.

Kashyap, R., Eng, G. K., Bhattacharjee, S., Gupta, B., Ho, R., Ho, C. S., . . . Chen, S. A. J. S. R. (2021). Individual-fMRI-approaches reveal cerebellum and visual communities to be functionally connected in obsessive compulsive disorder. *Scientific Reports, 11*(1), 1354.

Lecrubier, Y., Sheehan, D. V., Weiller, E., Amorim, P., Bonora, I., Sheehan, K. H., . . . Dunbar, G. C. J. E. p. (1997). The Mini International Neuropsychiatric Interview (MINI). A short diagnostic structured interview: reliability and validity according to the CIDI. *European Psychiatry, 12*(5), 224-231.

Shan, X., Uddin, L. Q., Ma, R., Xu, P., Xiao, J., Li, L., . . . Duan, X. (2023). Disentangling the Individual-Shared and Individual-Specific Subspace of Altered Brain Functional Connectivity in Autism Spectrum Disorder. *Biol Psychiatry*. doi:10.1016/j.biopsych.2023.09.012

Tang, S., Sun, N., Floris, D. L., Zhang, X., Di Martino, A., & Yeo, B. T. J. B. p. (2020). Reconciling dimensional and categorical models of autism heterogeneity: a brain connectomics and behavioral study. *Biological Psychiatry, 87*(12), 1071-1082.

Zhou, G., Cichocki, A., Zhang, Y., Mandic, D. P. J. I. t. o. n. n., & systems, l. (2015). Group component analysis for multiblock data: Common and individual feature extraction. *IEEE transactions on neural networks and learning systems, 27*(11), 2426-2439.

Zhou, G., Zhao, Q., Zhang, Y., Adalı, T., Xie, S., & Cichocki, A. J. P. o. t. I. (2016). Linked component analysis from matrices to high-order tensors: Applications to biomedical data. *Proceedings of the IEEE, 104*(2), 310-331.