Exploring Associations between Social Participation and Resting-State EEG Microstates in Older Adults

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Abstract: This study examines the associations between social participation and EEG microstate dynamics in 90 older adults. Participants reported involvement in four types of social activities (card games and chess, group fitness dancing, community-organized group activities, and volunteer activities) and completed five-minute resting-state EEG recordings. Microstate features—including duration, occurrence, coverage, and transition probabilities—were extracted and analyzed using multivariate general linear models while controlling for age, gender, and education. Results showed that group fitness dancing was significantly associated with longer duration and greater coverage of microstate B. Participation in community-organized group activities was linked to higher occurrence of microstate C, increased coverage of microstate B, and greater transition probabilities from microstates A and B to D. These findings suggest that socially and physically interactive activities may be associated with large-scale brain dynamics in late life, highlighting the potential value of promoting community-based activities to support brain health in older adults.

1. Introduction

Social participation is an organized process in which individuals consciously and voluntarily engage in collective activities, integrating into group contexts to achieve shared goals [1]. Research has demonstrated that developing and maintaining social participation is an important need across all age groups [2]. For older adults, social participation is widely regarded as a crucial component of aging, with both individual and environmental antecedents and consequences that significantly influence overall well-being [3]. It is one of the most critical elements of healthy aging, closely linked to disease outcomes, mortality, and quality of life [1, 4], and is considered a core component of successful aging [5].

Although existing research has established the behavioral and psychological benefits of social participation, its neurophysiological correlates remain underexplored. Most studies have focused on self-reported or behavioral measures [6, 7], with limited attention to the brain activity patterns associated with social engagement. For example, little is known about how culturally embedded group activities such as square dancing—a common and socially meaningful form of collective fitness among Chinese older adults—may influence brain function. Investigating the neural features linked to different types of social activities may provide a complementary perspective for understanding how social participation is reflected in brain dynamics.

EEG microstates are brief, quasi-stable topographical configurations of brain activity that typically last 60–120 milliseconds [8]. They are thought to represent the activation of large-scale neural networks and are often interpreted as the building blocks of spontaneous brain activity [9]. Prior studies have identified four canonical microstates (A–D) (Figure 1), each associated with distinct cognitive and perceptual processes. Microstate B has been linked to better language abilities, while microstate D has been associated with attentional processes and greater engagement with the external environment [10]. Recent studies have also begun to explore associations between these four canonical microstates and psychosocial characteristics. For instance, a meta-analysis of 787 participants across age groups found that increased occurrence of microstate A was linked to higher anxiety levels [11]. An experimental study of 55 healthy males reported that increased microstate A

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was significantly associated with stronger prosocial tendencies and greater empathy [12]. Microstate C appears to be related to comfort and post-social relaxation [10], and has also been associated with increased prosocial behavior [13, 14].

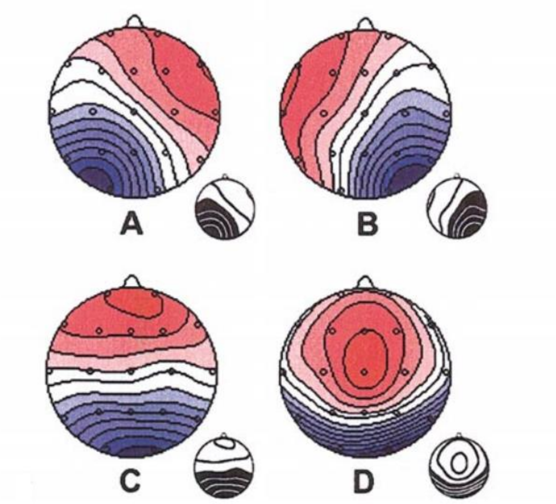

Figure 1 Topographic maps of the four canonical EEG microstates, adapted from Koenig et al [15].

Why EEG microstates matter for social participation. Rich social participation can reduce loneliness and negative affect in older adults [16, 17], both of which are closely coupled with resting-state brain dynamics [18, 19]. Social engagement also requires the rapid integration of attentional orienting, visuospatial/coordination demands, language exchange, and socio-emotional regulation during interpersonal interactions [20, 21]. EEG microstates are millisecond-scale, quasi-stable topographies that capture moment-to-moment configurations of large-scale brain networks [8, 9]. Consistent with prior work, canonical microstates have been related to these processes—e.g., B to language/visuospatial functions, D to attentional orienting and external engagement, and A/C to psychosocial–affective characteristics such as anxiety, prosociality, and post-social relaxation [10–14, 28]. Accordingly, microstate features (duration, occurrence, coverage, and transition probabilities) offer sensitive, network-level indicators by which social participation may be reflected in resting-state brain dynamics in late life. Guided by this rationale, we examine whether common community activities among older adults are associated with distinct microstate profiles.

As mentioned above, most existing studies have focused on cognitive and psychosocial features of EEG microstate dynamics in clinical or younger populations, while their relevance to social participation in older adults remains underexplored. This study examines how different dimensions of social participation relate to EEG microstate parameters among Chinese older adults. The aim is to deepen understanding of the neural correlates of social engagement and to inform the design of community-organized group activities that promote healthy aging.

2. Methods

2.1. Participants

Ninety older adults were recruited from two communities in Beijing, China. Inclusion criteria were: (1) aged 60 or older; and (2) residing in the community for at least one year. Exclusion criteria included: (1) diagnosed mental illness, cognitive impairment, or severe emotional problems; and (2) diagnosed visual, auditory, or speech impairments that would interfere with normal communication.

2.2. Social participation

Social participation was assessed using four standard questions [22, 23]: (1) Do you usually participate in card games or chess activities? (2) Do you usually take part in group fitness dancing (e.g., square dancing)? (3) Do you usually engage in community-organized group activities (e.g., movie watching or social gatherings in the community center)? (4) Do you usually participate in volunteer activities (e.g., anti-fraud awareness campaigns, waste sorting)? Participants' responses were coded as binary variables, with "Yes" scored as 1 and "No" scored as 0.

2.3. EEG data acquisition and preprocessing

EEG data were collected using the Yingzhi Quick-20r portable EEG recorder in a quiet room provided by the local community committee. A trained experimenter assisted each participant in fitting the EEG cap, with dry electrodes placed according to the international 10–20 system. The sampling rate was set at 500 Hz, and electrode impedance was kept below 2 kΩ. Participants were instructed to sit still in a relaxed state with their eyes closed and to avoid active thinking. For each participant, five minutes of resting-state EEG data were recorded from 19 channels.

EEG data preprocessing was performed using the EEGLAB toolbox (Version 24.0) in MATLAB 2021a. Steps included removing the reference and ground electrodes, then re-referencing to the average of all electrodes. Based on prior resting-state EEG studies, the band-pass filter was set to 0.1–100 Hz [24, 25]. Unusable electrodes and segments were manually removed. Independent Component Analysis (ICA) was then applied to remove artifacts such as electrooculographic (EOG), electrocardiographic (ECG), electromyographic (EMG), and environmental electrical noise.

2.4. Microstate analysis

EEG data were first band-pass filtered between 2–20 Hz and re-referenced to the average of all electrodes. Electrodes with amplitudes exceeding ±100 μV and recordings with less than 15 seconds of valid data were excluded. Microstate analysis was conducted using the Microstate Analysis Toolbox following standard procedures. First, global field power (GFP) was computed, and microstate topographies were extracted at GFP peaks to ensure an optimal signal-to-noise ratio. A modified K-means clustering algorithm was applied, disregarding polarity, with the number of microstate templates set from 3 to 8. Each clustering solution was iterated 1,000 times and repeated 100 times to determine the optimal number of microstate classes. Based on these results, four microstate prototypes were identified. Back-fitting was then performed on all participants' data using the original microstate maps. Microstate segments lasting less than 30 milliseconds were removed to smooth the results, and microstate features were computed for each participant.

Based on previous studies, four microstate feature metrics were extracted and used in this study: duration, occurrence, coverage, and transition probabilities between microstates [26, 27].

2.5. Statistical analysis

All statistical analyses were performed using SPSS version 29.0. Continuous variables with normal distributions were presented as Mean (SD), and categorical variables as N (%). Associations between variables were examined using multivariate general linear model (Multivariate GLM) analysis.

3. Results

Among the 90 participants, four EEG microstates were identified and labeled as A through D. The topographic polarity distributions of these microstates were: right anterior–left posterior, left anterior–right posterior, anterior–posterior along the midline, and central–parietal with a posterior focus, respectively (see Figure 2). These spatial patterns are consistent with classifications reported in previous studies.

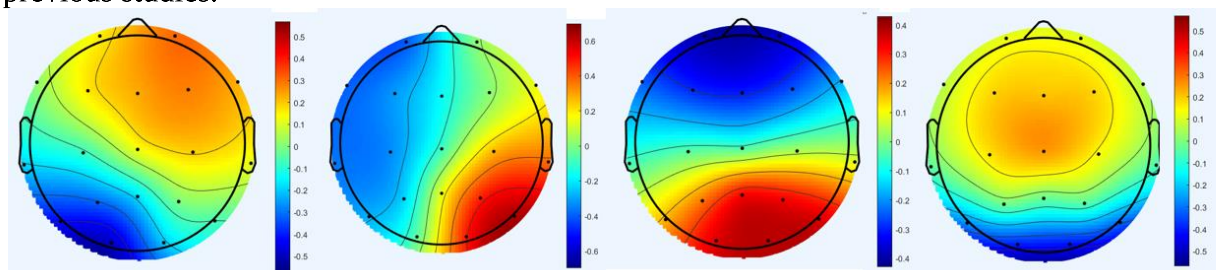

Figure 2 Topographic maps of the four EEG microstates (A–D).

The demographic characteristics of the participants are summarized in Table 1.

After controlling for age, gender, and years of education, results from the multivariate general linear model (GLM) indicated a significant association between participation in fitness dancing and the duration of microstate B (Table 2). This association remained statistically significant after correction for multiple comparisons, suggesting a robust link between fitness dancing and the prolonged presence of microstate B. The average duration of microstate B for participants (Mean = 74.23) was higher than for non-participants (Mean = 72.57), indicating that engaging in fitness dancing may contribute to longer duration of microstate B.

Table 1 Demographic characteristics of participants (N = 90).

Variable	Value
Gender, n (%)	
Male	37 (41%)
Female	53 (59%)
Age, M ± SD	67.14 ± 5.39
Years of Education, M ± SD	6.96 ± 2.92
Card Games and Chess, n (%)	
Yes	14 (16%)
No	74 (84%)
Fitness Dancing, n (%)	
Yes	16 (18%)
No	76 (82%)
Group Activities, n (%)	
Yes	35 (39%)
No	55 (61%)
Volunteer Activities, n (%)	
Yes	23 (26%)
No	67 (74%)

Table 2 Associations between social participation and EEG microstate durations (A–D).

Social Participation Variable	Microstate Indicator	*F*	*P*	Partial η^2
Card games and chess	Duration A	0.161	0.690	0.002
	Duration B	2.730	0.103	0.035
	Duration C	0.634	0.428	0.008
	Duration D	3.516	0.065	0.045
Group fitness dancing	Duration A	0.424	0.517	0.006
	Duration B	6.087	0.016	0.075
	Duration C	0.661	0.419	0.009
	Duration D	0.728	0.396	0.010
Group activities	Duration A	0.024	0.877	0.000
	Duration B	2.180	0.144	0.028
	Duration C	0.299	0.586	0.004
	Duration D	0.698	0.406	0.009
Volunteer activities	Duration A	0.145	0.704	0.002
	Duration B	0.009	0.926	0.000
	Duration C	0.306	0.582	0.004
	Duration D	0.153	0.697	0.002

After controlling for gender, age, and years of education, participation in group activities showed a significant correlation with the occurrence of microstate C (Table 3). Further analysis revealed that participants had a significantly higher mean occurrence of microstate C compared to non-participants (e.g., Mean = 3.27 vs. Mean = 3.02), suggesting that having group activities may help enhance brain functional patterns associated with microstate C.

Results from the multivariate GLM also indicated significant associations between both fitness dancing and group activities and the coverage of microstate B. Further analysis showed that individuals who participated in fitness dancing and group activities had higher mean coverage values (0.25 and 0.26, respectively) compared to non-participants (0.18 and 0.22), suggesting stronger brain activity in microstate B (Table 4).

Subsequent analyses examined transition probabilities between microstates in relation to social participation. For transition probabilities originating from microstate A, participants engaged in group activities showed significantly higher A→D transition probabilities (Mean = 0.33) compared to non-participants (Mean = 0.29) (Table 5).

For transition probabilities originating from microstate B, participants engaged in group activities had higher B→D transition probabilities (Mean = 0.32) compared to non-participants (Mean = 0.29) (Table 6).

Table 3 Associations between social participation and EEG microstate occurrences (A–D).

Social Participation Variable	Microstate Indicator	*F*	*P*	Partial η^2
Card games and chess	Occurrence A	0.000	0.996	0.000
	Occurrence B	0.024	0.877	0.000
	Occurrence C	0.777	0.381	0.010
	Occurrence D	0.407	0.526	0.005
Group fitness dancing	Occurrence A	0.763	0.385	0.010
	Occurrence B	1.732	0.192	0.023
	Occurrence C	0.416	0.521	0.006
	Occurrence D	1.154	0.286	0.015
Group activities	Occurrence A	0.785	0.378	0.010
	Occurrence B	3.623	0.061	0.046
	Occurrence C	5.005	0.028	0.063
	Occurrence D	0.006	0.940	0.000
Volunteer activities	Occurrence A	0.080	0.778	0.001
	Occurrence B	0.773	0.382	0.010
	Occurrence C	3.553	0.063	0.045
	Occurrence D	0.081	0.776	0.001

Table 4 Associations between social participation and EEG microstate coverage (A–D).

Social Participation Variable	Microstate Indicator	*F*	*P*	Partial η^2
Card games and chess	Coverage A	0.004	0.948	0.0
	Coverage B	0.846	0.361	0.011
	Coverage C	0.933	0.337	0.012
	Coverage D	1.563	0.215	0.02
Group fitness dancing	Coverage A	0.916	0.342	0.012
	Coverage B	4.166	0.045	0.053
	Coverage C	0.628	0.43	0.008
	Coverage D	0.836	0.364	0.011
Group activities	Coverage A	0.153	0.696	0.002
	Coverage B	4.219	0.043	0.053
	Coverage C	0.311	0.579	0.004
	Coverage D	0.737	0.393	0.01
Volunteer activities	Coverage A	0.009	0.926	0.0
	Coverage B	0.383	0.538	0.005
	Coverage C	1.584	0.212	0.021
	Coverage D	0.099	0.753	0.001

Table 5 Associations between social participation and transition probabilities originating from microstate A.

Social Participation Variable	Microstate Indicator	*F*	*P*	Partial η^2
Card games and chess	A→B	0.706	0.403	0.009
	A→C	1.126	0.292	0.015
	A→D	0.146	0.703	0.002
Group fitness dancing	A→B	1.608	0.209	0.021
	A→C	1.289	0.26	0.017
	A→D	0.002	0.963	0.0
Group activities	A→B	2.898	0.093	0.037
	A→C	0.4	0.529	0.005
	A→D	4.157	0.045	0.053
Volunteer activities	A→B	0.072	0.789	0.001
	A→C	0.574	0.451	0.008
	A→D	0.939	0.336	0.012

Table 6 Associations between social participation and transition probabilities originating from microstate B.

Social Participation Variable	Microstate Indicator	*F*	*P*	Partial η^2
Card games and chess	B→A	0.137	0.712	0.002
	B→C	0.811	0.371	0.011
	B→D	0.375	0.542	0.005
Group fitness dancing	B→A	0.378	0.541	0.005
	B→C	0.721	0.399	0.01
	B→D	2.195	0.143	0.028
Group activities	B→A	0.408	0.525	0.005
	B→C	2.019	0.159	0.026
	B→D	4.469	0.038	0.056
Volunteer activities	B→A	0.043	0.837	0.001
	B→C	1.915	0.171	0.025
	B→D	1.638	0.205	0.021

No significant associations were found between the four types of social participation and transition probabilities originating from microstates C and D (Ps > 0.05).

4. Conclusion

This study examined the associations between different forms of social participation and EEG microstates among older adults in China. The results revealed that participation in group fitness dancing was significantly associated with longer duration and greater coverage of microstate B. Participation in community-organized group activities was also related to greater coverage of microstate B, as well as higher occurrence of microstate C and increased transition probabilities from microstates A and B to D. These findings suggest that certain types of social engagement may be associated with distinct patterns of resting-state brain activity, potentially reflecting enhanced functional network dynamics in later life.

EEG microstates are thought to reflect large-scale functional networks, with different classes linked to distinct cognitive functions as well as psychosocial–affective characteristics. Prior studies suggest that microstate B is associated with language-related processing, microstate C with prosocial and relaxation states, and microstate D with attentional orientation toward the external environment [10, 13, 28]. According to previous studies, an increase in microstate B may reflect enhanced verbal functions. Compared to card games, chess, and volunteer activities, group fitness dancing and community-organized group activities typically involve more participants and foster larger-scale collective interactions, which may require greater verbal coordination and communication. Therefore, the observed associations may suggest that engaging in such group activities helps strengthen verbal abilities among older adults. Therefore, the observed associations may suggest that engaging in such group activities helps strengthen verbal abilities among older adults, reflecting enhanced verbal and language-related processing that is particularly relevant for communication functions. The positive association between group activities and the occurrence of microstate C may indicate increased prosocial tendencies as well as greater psychological relaxation in social contexts [10, 14, 28], and therefore may support better social orientation and lower psychological stress in older adults. In addition, prior research has shown that microstate D is linked to greater external attention, reflecting higher levels of social orientation [29]. The increased transitions toward microstate D observed among participants of group activities may further suggest that such activities promote social engagement among older adults, may further suggest that such activities promote social engagement among older adults, thereby enhancing attentional control and supporting social well-being.

These findings have important implications for promoting healthy aging through community-based social engagement. In many communities, especially those with limited access to formal cognitive training or mental health resources [30, 31], encouraging participation in collective activities such as group fitness dancing or group social events could serve as a feasible and culturally appropriate approach to support brain health. The observed associations between social participation and EEG microstate parameters suggest that these everyday activities may influence functional brain dynamics even without structured cognitive interventions. Incorporating socially interactive programs into existing community services may help strengthen older adults' social inclusion and neurocognitive resilience.

Several limitations should be noted. First, this study employed a cross-sectional design, which precludes conclusions about causality between social participation and EEG microstate characteristics. Longitudinal or experimental studies are needed to clarify the direction of these associations. Second, social participation was assessed using binary self-report items, which may not fully capture the frequency, intensity, or subjective experience of engagement. Future research could benefit from more detailed behavioral measures or ecological momentary assessments. Third, because the sample was drawn from a relatively homogeneous population, regional and cultural diversity was not adequately represented. Expanding recruitment across varied geographic locations and sociocultural backgrounds would enhance the generalizability of the findings.

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