Multiple Human EEG Synchronous Analysis in Group Interaction-Prediction Model for Group Involvement and Individual Leadership

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Abstract. Successful communication relies on the ability to express and obtain information and fast adaptability to the communication that others think has high quality [1]. The one with high exchange quality in group-based communication is generally supposed to have leadership. The leader's neural mechanism during the communication is not deeply studied in the previous researches. In this paper, a new method is proposed to evaluate the leadership in group activity by utilizing the characteristic of EEG. We collect the brain electrical activity of the group members with non-intrusive high precision wireless EEG acquisition device to reduce the barrier in exchange activity. Through classification of interactive and noninteractive multivariate analysis with multi-person EEG electrode, it's found that the left temporal lobe cerebral region of leader elected by voting features obvious activation of electrode after receiving messages from others. Further, his α EEG is significantly inhibited and β EEG is obviously activated. This cerebral region is considered to be the one disposing and predicting errors, which indicates that the leader is good at analyzing each person's information and disposing errors and used the resources for predicting and planning after accepting the problem. Besides, the frontal lobe α wave of the leader during the stage of communication and discussion is inhibited obviously and it is the same as the voting result.

Keywords: EEG · Leadership · Synchronization and multi-person interaction

1 Introduction

When many people participate in team interaction, they exchange messages through a series of behaviors. Different individuals are adapted to their communication means through in-depth tightly coupled alignment. Multi-person team interaction process can be considered to be the frequent two-person communication with different objects. However, it is different from the two-person communication. Due to the randomness of multi-person communication object, the individual is required to fast synchronize with different objects. If the effect of tightly coupled alignment is not desirable, the communication quality will be reduced.

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To be different from team, social group is defined as two or more interacting and mutually influencing each other [2]. Some social psychologists think that the member of "group" as regards those in his group as "us" instead of "them". The difference between social group and team is that the team consists of members who are highly differentiated and mutually dependent while social group consists of members who are homogeneous and substitutive. It can be understood that team is a group with special form. Human society consists of human group. However, people are consciously divided into different teams to improve efficiency in modern society. The leader, as the core of the team, should possesses strong communication ability, for which the leader should rapidly synchronize with the followers and get to know the thought and intention of the followers so as to divide the homogeneous group into the teams with special trait.

It's poorly understood how the brain supports the social function in current researches, most of which are centrally carried out under experimental environment. However, there tends to be blank researches carried out under natural environment. In this paper, one leader marker is defined to evaluate the leadership of individual in group. Meanwhile, the similar but different experimental contents made with same members can be used as the result reference for the task completion result with or without leader. Then, the task is expanded to the practical problem (built with building blocks) from the topic discussion. According to the result, it shows that task completion and evaluation of the predicted group under the leadership of the leader is superior to the control group without leader.

To be specific, according to the previous research on synchronic dual-EEG, it's found that the power spectrum of the parietal lobe α wave (about 10 Hz) has the tendency of synchronization when focusing on common thing namely when synchronization occurs. That is to say, when focusing on the same thing, there is synchronic tendency for the beginning and ending time of the activating and inhibiting strength of α wave. When not focusing on same thing, the power spectrum strength of α wave is not obviously associated. In a bid to eliminate the error between external disturbance and wireless device, a small interactive-blink test is designed before the experiment is officially implemented. That is, the eyes are opened according to the order of experimenter and all group members are completely stochastic. Opening and closing eyes alternatively at regular of 10 s shall be regarded as the basis for static data (base-data) and evaluating wireless connection quality.

2 Materials and Methods

2.1 Participants

25 subjects (12 males, averagely aged: 23.52 ± 3.02) have no cerebral diseases and bad habits. All participants receive the experimental notes and don't repeatedly participate in experiment.

2.2 Task and Procedure

The subjects can see each other and observe the expressions of others during the dialogue. The subjects have 5 min' rest before the experiment starts and then begin discussing the topics. Two conditions are discussed in the experiment. Firstly, the whole-follower's state of the group leader is not designated. Secondly, the leader-follower of the group leader is designated.

(1) Whole-Follower. At this time, all group members can make statements freely at their will and the experimenter read the topic for all subjects once and then discuss it. There is no fixed answer for the question. The subjects can involve any fields that they are adept in during the discussion. The subjects shall keep gentle and should not be excited and nervous during the explanation. The discussion lasts 20 min all group members shall select a group leader after times run out, and the group leader will report the final result. During the discussion, two DV cameras will record video from different directions for recording such information as the demeanor of the group members, beginning & ending time of communication and mood and serve as one of reference basis for evaluating the communication quality.

Each subject will have to fill in one questionnaire for inquiring about the voting result of the group leader selected by each subject and evaluating their attentions to the question, communication quality and level of their interest in the topic. Each question is divided into 1-10 grades. The answer of questionnaire will be used as the basis for future classification.

(2) Designated Leader-Follower. There are 10 min for rest after the last stage, then the group leader selected by the last group is designated as the leader, taking the lead in topic discussion. After the experimenter explains the question, the subjects can begin the discussion. The discussion process requirement, video recording detail and questionnaire shall be the same as those for the last stage.

Besides, two extra stages are designed to explore difference in activation of cerebral region of the leader and follower.

(3) Whole-Follower (Task). At this time, all group members can make statements at their will and complete building of electronic bricks (environment is minecraft creative model) on computer. All group members connect the network through LAN. There has existed a building in the task. All materials have been given out. The group members are required to repeatedly build a same building. The construction process can be discussed. The subjects shall keep gentle and should not be excited and nervous. The time is 20 min according to the discussion and building process, it is required to reduce head and body movements as far as possible, mutually communicate with each other over the earphone and record video with PC camera and serve as one of reference basis for evaluating the communication quality and attention in the late stage. The subjects should fill in questionnaire after completion of construction. The content shall be referred to that at the first stage.

(4) Designated Leader-Follower (Task). One leader (voted through investigation questionnaire at the third stage) shall be designated at the very beginning, then the leader give commands in completing the building of the target. To prevent the repeated

work from bringing influences to the result, the difficulty in building at the second stage is the same as that at the third stage but the structure is different from that at the third stage. All subjects participated in teaching and are all skilled at operation before. The requirements and specific details are the same as those at the third stage (Fig. 1).

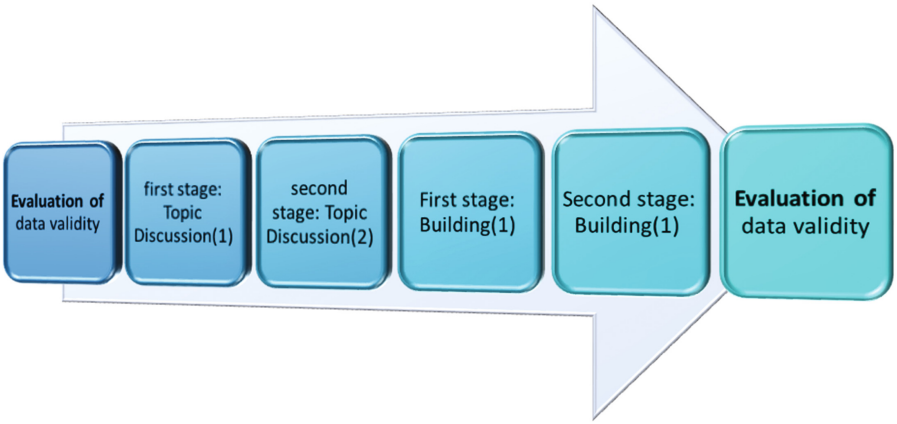

Fig. 1. Specific flow chart

2.3 EEG Recordings

All members of each group collect EEG data synchronically. 5 32-channel electrode caps are used, for which international standard electrode location (standard-10–10) is adopted. 5 groups of independent wireless receiving devices are connected in parallel with synchronic annunciator, which sends out beginning and ending signals to ensure the synchronization among 5 groups of devices. The recorded bandwidth is 0.1 Hz–60 Hz and the sampling frequency is 250 Hz.

2.4 EEG Data Preprocessing

EEGLab (version No.: 13_6_5b) is used for data processing and analysis and MATLAB software toolbox for data processing. All periods shall be expected to be manually classified. It's necessary to differentiate each subject is at the state of listening or expressing according to the video recording and record area. If the expressing time is long, it's necessary to select −1–1.5 s before start, 1 s during the expression and −1.5–1 s before the ending time. All expressing time length shall be standardized within 6 s. The data before normal form is used shall be adopted as the baseline correction standard to remove DC offset.

2.5 Artifact Removal

The data is further processed with ICA. Because the normal form of experiment is mainly constituted by the dialogue, head movement and blink, the influence on EEG

cannot be avoided. The electrode cap is equipped with gyroscope, which can collect acceleration data of axis X, Y and Z, judge the component of blink, eye and head movement by combining accelerometer and PCA, and then remove it. Then, the main component is extracted through PCA to reduce the data dimension and non-main leading component. Besides, PCA is also helpful for reducing distortion of frequency domain. Main 6 components are calculated through PCA as the classification basis in the late stage.

2.6 Spectral Analysis

To standardize the state of cerebral activity of different participants, the time for communication is standardized. The expression time is intercepted. Every intercepted section only involves expression that man is the expression state with the remaining participants considered to be at listening state. WT (wavelet transform) is adopted. Hamming window length is 2 s. It's supposed that the intercepted standard length is a trail. To reduce the data error, the corresponding power spectrum is calculated after average of data overlay of each trail is taken. The range that we are interested in is centralized at two frequency bands α (8–12 Hz) and β (13–30 Hz). The selection of channel is calculated according to correlation test of whole-brain channel to select EEG channel with high correlativity. In the meantime, the previous research shows that there is obvious difference in activation of temporal lobe of the bran when the leader communicates with non-leader [3].

Figure 2 shows the change in whole brain power strength of the leader at different frequency bands during expression and listening. It could be known from the figure that the activation degree of parietal & temporal lobes in the left side and temporal lobe in

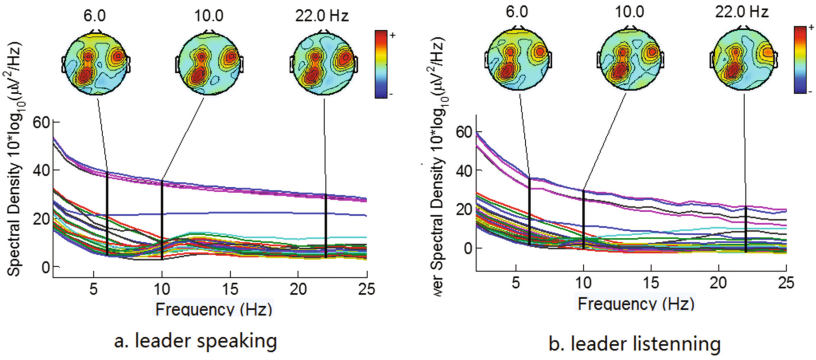

Fig. 2. Midpoint of frequency band α (8–12 Hz) mainly marked in a and b 10 Hz represents wave α and midpoint 22 Hz of β frequency band (13–30 Hz) marked in the figure represents wave β. It could be found that the electrode in parietal lobe in the left side and temporal lobe in the right side of the brain is activated obviously during the communication. B wave power during the talk is obviously larger than that during listening while α wave power during listening is obviously larger than that during the talk. The energy during listening is mainly centralized in low-frequency band (0 < 15 Hz); the energy distribution during listening is more average than that during listening. The proportion of high frequency band (15 > 30 Hz) is larger.

the right side during the expression is obviously higher than that during the listening. According to psychological and related research results, it's supposed that the errors that have already made or might be made during the expression are judged and corrected in advance. Figure 2a and b shows that the leader is more relaxed during listening and more concentrated during the expression.

Figure 3 shows the change in whole brain power strength of follower during representation and listening at different frequency bands. Similarly, the cerebral region in the left side is activated obviously during communication. However, to be different from the leader, the difference in energy of activated and other electrodes of follower is small. Besides, energy of wave α and β is obviously smaller than that of leader. It indicates that the follower is more relaxed during the talk for the error-tolerant rate of follower during expression is higher and the responsibility is small. Therefore, the follower is in relaxing state during expressing.

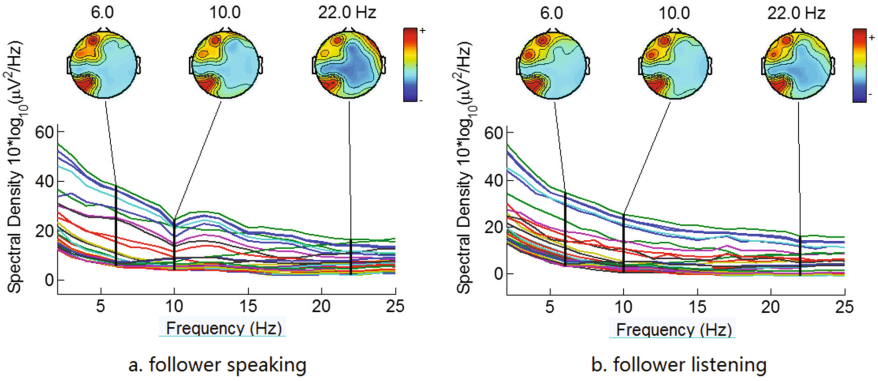

Fig. 3. Midpoint 10 Hz of a (8–12 Hz) mainly marked in the figure represents wave α while midpoint 22 Hz of β frequency band (13–30 Hz) marked in the figure represents wave β. It could be found that the cerebral region in the left side is similarly activated during the talk. It indicates the participants think about and analyze questions and try to correct the errors. However, the activation degree of the follower is not as remarkable as that of the leader. EEG tendency of follower and leader is just on the contrary. The energy of follower during listening is obviously larger than that during expressing, which is the same that in video. That is, the follower is further not good at expressing but is inclined to listen.

2.7 Analysis of Regression

The ultimate goal of this research is to find out specific EEG index evaluating the individual leadership and build a prediction model through this index to predict the efficiency of the group, and give out the recommended leader. Therefore, it's ultimately necessary to build a regression model. There are 5 members in each group. Each participant collects 32 channels of EEG data and has discussion or numerous groups of dialogues will be had in the experiment. The data dimensionality for EEG analysis is large. The specific characteristic is selected for the data. SVM is finally selected as the classifier and RBF kernel is selected for kernel function.

Due to data nonlinearity, the data is not completely stochastic. The classification effect of linear kernel function and Gaussian kernel is not good. When the regression function is made, the data is divided into two parts: 80% for training set and 20% for the test set. The training data is put into SVM to monitor learning. To improve the performance of classifier, the parameter c and g of SVM is optimized through grid search to search for the optimal parameter. Searching range: parameter c:2^(−8)–2^8; parameter g:2^(−8)–2^8. The stepping is 1. Because the experimental content is fixed and the noise reduction & filtering and standardization of data is implemented before it is finally put in SVM. To simplify calculation step, once the optimal parameter is determined through grid search it will be no longer modified. Though it may not be optimal parameter for different data sets, it can be considered to approach the optimal parameter.

2.8 Effectiveness Evaluation of Data

For EEG is collected with wireless device. There is high requirement for environment. Channel disturbance and mutual interference among devices might have great influence on experimental result. Therefore, the data validity is evaluated before beginning and ending of experiment. The specific step is: order group members to sit when facing the wall for 5 min, and then open and close eyes alternatively according to the order of the experimenter. The eye opening or closing state lasts 10 s. 3–5 groups shall be made cyclically. Then, the subjects shall sit when facing the wall according to the order of experimenter. If the data validity proves that the environmental interference belongs to the acceptable range, it's necessary to start the experiment after resting for 5 min.

After the experiment is finished, it's necessary to repeat the same evaluation step. If the assessment result is data validity, then it's considered that the data is reliable. Once the assessment result is data invalidity, the data for the experiment will be abandoned and the subjects also cannot join in experiment again.

Up to now, there have been research on influences of eye opening & closing on EEG carried out. There are unified opinions in the circle. Therefore, it's necessary to verify the data validity through alternative eye opening and closing. If the data analysis result is the same as the opinions in the circle, the data will be considered to be valid, vice versa.

3 Result

3.1 Individual Leadership

It's mentioned in the above text that the activation of left hemisphere of leader or follower during communication is obvious, in which the electrode activation of temporal and parietal lobes is obvious. The cerebral region activation of the leader is obviously higher than that of the follower. Simultaneously, the leader is more relaxed during listening and communication than the follower. In this way, the leader has clear thought and improves the efficiency in solving the problem. However, there is no especially obvious trend for the follower. Even if some followers are more concentrated during listening, the activation level of their cerebral region is far lower than that of the leader's.

Because there are many featured electrodes and activated electrodes of different subjects and role are also not the same, the features might be lost if few featured electrodes are selected for the classification. Therefore, 8 motors in left parietal and temporal lobes, etc. are selected for classification. To facilitate Fig. 4, feature of P3 electrode (international standard motor location is channel 24) is only displayed. By combining the time frequency map and investigation questionnaire of follower's P3 electrode, it's found that the electrode activation of left temporal lobe of followers with high executive force during listening is obvious, which indicates that the followers summarize and extract the orders or tasks of the leader consciously or subconsciously. Meanwhile, it also indicates that the leader has good expressing ability.

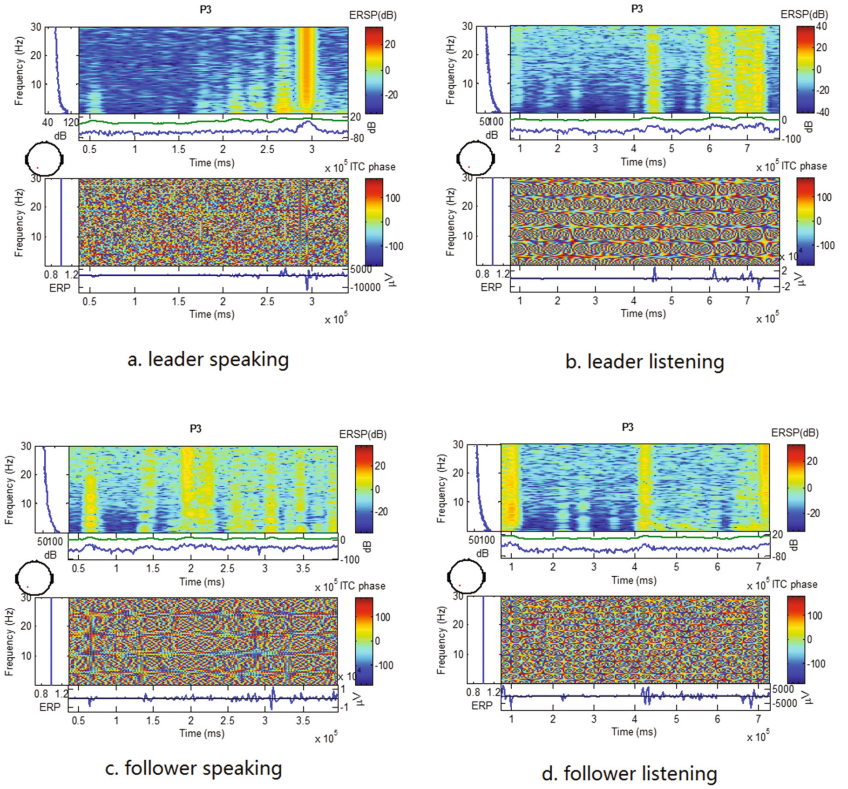

Fig. 4. Middle-stage (about 3 s of data after standardization, representing the middle part of communication stage) P3 electrode activation of leader during the talk is obvious. (a) P3 electrode activation of leader during the middle and back periods (about 4.5 s and 6–7.5 s of data after standardization, representing the middle and ending parts of listening stage) during listening is obvious, in which α wave plays a dominating role. (b) P3 electrode of follower during the whole stage of communication is activated but the activation level is obviously lower than that of leader. (c) P3 electrode activation of follower at beginning and ending stage during communication and listening is obvious, which indicates that beginning and ending of communication excites the follower greatly.

It's also found that the cerebral region of follower doesn't have obvious features at all stages, which is identical to the research conclusion reached previously. For high precision EEG acquisition device is used in this paper, the inconspicuous activation features still can be found. It proves that the followers participate in discussing and thinking about the topic but the strength is not the same. This conclusion fills the blank in analysis of thinking mode in previous researches. In addition, the hypothesis is verified with experimental data.

Further, data is classified through the searched out. The average classification accuracy reaches above 90%, which proves that the features searched out can indeed be regarded as the classification basis and can differentiate from the follower and leader. By building regression model through classifier to predict the individual leadership and comparing the predicting result into the voting result of questionnaire, it's found that the predicting accuracy is about 70% and even higher. If the prediction accuracy is found out for the optimal parameter of classification parameter during construction of prediction model, there is still the trend for promoting.

3.2 Behavioral Results

Through analysis of the communication video of experimental paradigm, it's found that the individual leader is not directly associated with communication frequency, but the person with high communication frequency is indeed easily selected by voting. The individual with high leadership can fast understand others' thought and give satisfying answers to others. When the individual with high leadership makes speech, short-term collaboration comes up with others' α EEG. That is, when the individual makes speech, the difference in change trend of power spectrum intensity of others' α EEG is small. This feature only will emerge when the communication quality of individual with high leadership is high. Besides, once the expressing stage ends, EEG of others will fast lose synch state.

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