Tutorial Note

A priori prediction of therapist-client compatibility for better therapy outcomes: A possible procedure using resting-state functional magnetic resonance imaging data and a machine learning algorithm

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Abstract

The relationship quality between therapists and clients is crucial for obtaining a good outcome from long-term therapeutic relationships such as counseling and physical/occupational therapy. Although findings on the relationship between the compatibility of therapists and clients and their self-reported psychological characteristics/behaviors have been accumulated, it has been suggested that the compatibility of interpersonal relationships cannot be predicted by psychological constructs. Recently, using resting-state functional magnetic resonance imaging (fMRI) data and a newly developed similarity index, we overcame the limitations of self-report psychological constructs and succeeded in predicting the compatibility of interpersonal relationships a priori. We propose a procedure to predict therapist-client compatibility for better therapeutic outcomes. We hope that this tutorial note will promote the development of a prediction system and help make it more practical in the near future.

Keywords: therapist-client compatibility, a priori prediction, functional connectome, machine learning, interpersonal relationship

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1 Introduction

In long-term therapeutic relationships, such as counseling and physical/occupational therapy, the quality of treatment should be greatly influenced not only by the technical aspect of therapy, but also by the quality of interpersonal aspects of therapy between therapists and clients. The interpersonal aspect, the so-called therapeutic alliance in psychotherapy [1,2], is composed of (i) the agreement between the therapist and client regarding the goals of the treatment, (ii) the tasks necessary to achieve treatment goals, and (iii) the quality of the emotional bond between them [3,4]. Once the alliance ruptures, repairing the relationship becomes difficult and it sometimes ends. The alliance-based conformity of interpersonal relationships is essential for effective therapy; however, the alliance is affected by the compatibility of the relationship, which is difficult to improve [5] and takes time to nurture [6]. Although empirical investigations are needed, the importance of therapeutic alliances should also be considered in physical/occupational therapy. Treatment begins at the point where the therapist-client pairing is decided and before the therapist and client meet for the first time. Is the compatibility of the quality alliance between the therapist and the client predictable?

Among the components of a therapeutic alliance, interpersonal aspects, such as the quality of the emotional bond between the therapist and client, is a core factor for the growth of the alliance [3,7], and thus, is the most important target to be predicted. The therapeutic alliance can be better or worse, depending on the interaction between the psychological characteristics and behaviors of both the client and therapist. For example, a warm or flexible therapist is positively associated with quality alliances [6,8]. On the other hand, avoidant personality or interpersonal difficulties of clients and rigidity or criticality of therapists are associated with worse alliance quality [6,9]. These findings support the expectation that the compatibility of clients and therapists for better alliances can be predicted a priori using such psychological constructs.

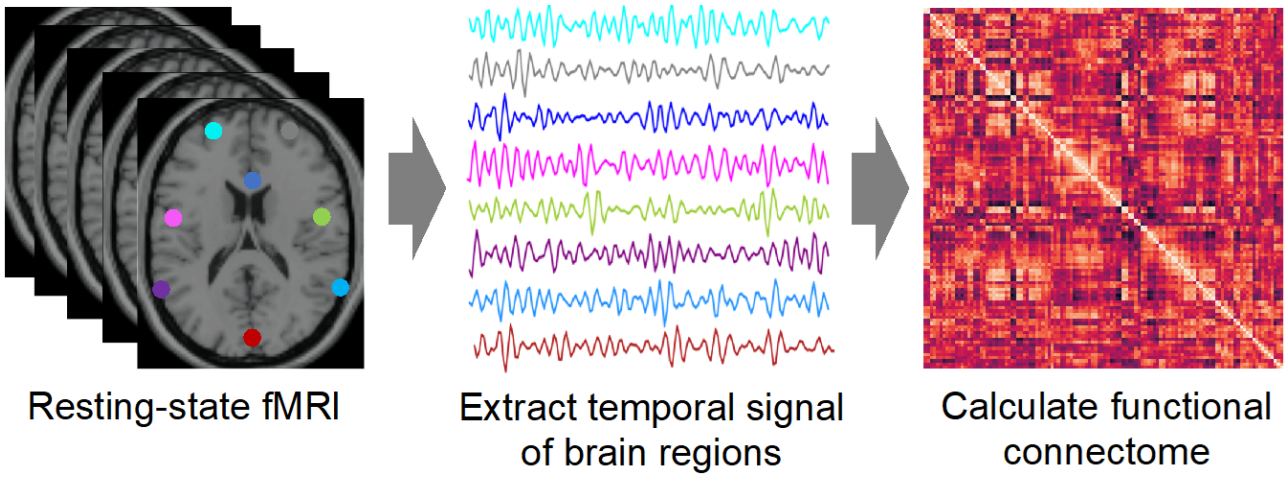

Figure 1: Flow from fMRI data acquisition to functional connectome acquisition
To obtain the functional connectome, which is a matrix of brain regional temporal correlations of the signals, as the first step, the volumes of interest (VOIs) or brain regions are defined (simply represented by colored dots in the leftmost sequential brain images). The mean temporal signal in each VOI is then extracted. Finally, the temporal correlation was calculated for every pair of VOIs, and the functional connectome is obtained (each row and column represents a VOI, and each element is a correlation coefficient).

2 Difficulty of predicting compatibility of individuals from psychological constructs

Psychological research has revealed the difficulty of predicting compatibility between two individuals using self-reported psychological constructs. Although irrelevant to the clinical context, Joel et al. [10] attempted to predict the compatibility of relationship initiation among healthy heterosexual individuals. In their experiment, participants completed questionnaires comprising more than 100 psychological constructs. Subsequently, they participated in a multiple-participants experiment in which they had a short conversation, referred to as a "speed-date," with every other participant of the opposite sex. After each speed date, the participants completed a three-item measure of their romantic desires for their potential partners, and compatibility was assessed based on the response. Romantic desire was predicted using a machine-learning algorithm with psychological constructs as features. The results revealed that, even with more than 100 psychological constructs, the degree to which individuals desired one another could not be predicted. This may be because of the discrepancy between the behaviors assessed by self-reported psychological constructs and those in unfamiliar situations [5]. The basic purpose of using psychological constructs measured via self-report questionnaires is to assess an individual's general tendency, but not in specific situations. These can be vastly different, and thus, psychological constructs have less information needed for prediction. This would also be the case for therapist-client compatibility in quality alliances. As the therapeutic situation is generally unfamiliar compared to daily situations, psychological constructs during therapy are not easily assessed, and the prediction of therapist-client compatibility results in poor performance. Is it possible to predict the therapist-client compatibility?

3 Overcoming the limitation of psychological constructs and predicting compatibility

To overcome the limitations of self-reported measures and enable the prediction of dyadic interaction-derived phenomena, we focused on task-free spontaneous brain activity. Brain activity during the resting state has been extensively investigated because it carries invaluable information with an easy procedure for data collection. Resting-state brain activity was acquired using no more than 10 min of functional magnetic resonance imaging (fMRI). Information in the resting-state fMRI data was obtained from the correlation pattern of temporal signals across brain regions (i.e., the functional connectome, Figure 1). The resting-state functional connectome enables us to predict various psychological constructs that represent general tendencies of behaviors and thoughts (e.g., Big Five personality traits [11]) and activation patterns during various social cognitive tasks [12–15], which require abilities essential for dyadic interactions (e.g., emotional processing, language, and social cognition) [16]. The (dis)similarity of psychological constructs or behavioral tendencies between two individuals is also reflected in the (dis)similarity of the functional connectome between them [17]. Furthermore, recent research has succeeded in predicting social closeness based on the similarity in the resting-state functional connectome. This indicates that the functional connectome may represent latent interpersonal similarities that are not fully represented by commonly used personality measures [18].

We proposed and applied the functional connectome to predict compatibility in heterosexual relationship initiation by defining a new brain-science index: connectome similarity [5]. This is the absolute value of the Euclidean distance for each element of the two vectorized functional connectomes, which is identical to that used by Hyon et al. [18]. As connectome similarity has

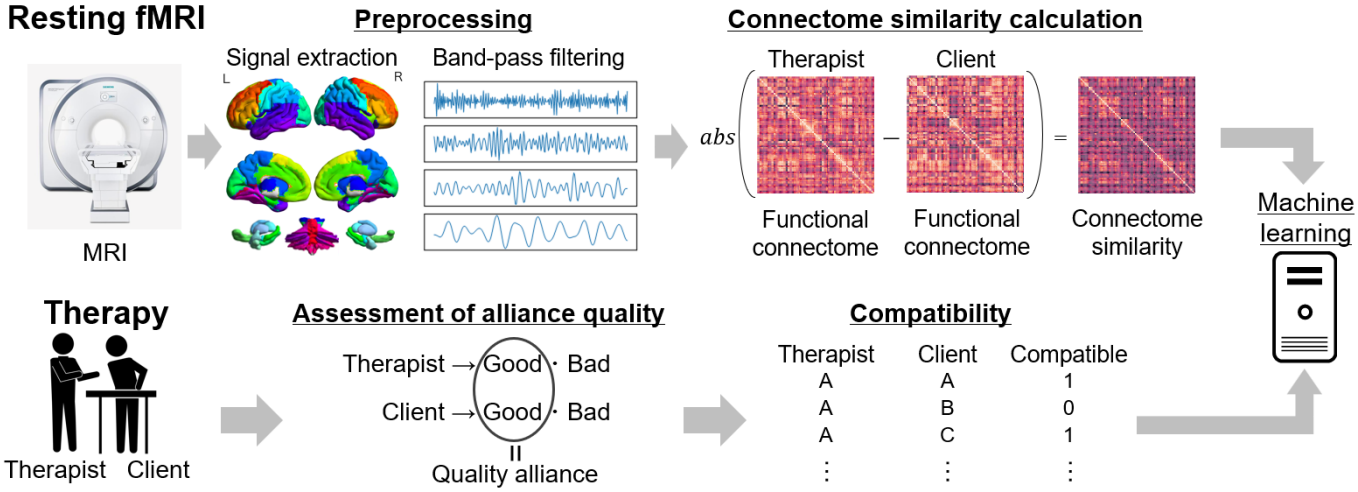

Figure 2: Schematic flow of the construction of proposed therapist-client alliance prediction algorithm
There are sequences of brain imaging and behavioral data acquisition. In the sequence of brain imaging data acquisition, both the therapist and client who agreed to provide their data first participated in a short-minute resting-state functional magnetic resonance imaging (fMRI) scan. From these data, the functional connectome is obtained through several preprocessing steps, such as frequency band filtering and signal extraction. The absolute value of the difference between the functional connectome of the therapist and that of the client (i.e., connectome similarity) is then obtained to predict compatibility. In the sequence of behavioral data acquisition, both therapists and clients who have already undergone resting-state fMRI scanning start and proceed with therapy and assess the outcome of their therapy when the therapy ends. Then, a machine learning algorithm is constructed to predict the compatibility of the therapist-client relationship. Once the algorithm is successfully constructed, the newly obtained clients' fMRI data enable the prediction of the most compatible therapist for him/her.

the same number of elements as the vectorized functional connectome, information on the functional connectome is insufficient as a feature value of machine learning algorithms. The participants underwent resting-state fMRI scanning several days prior to the experiment. Following Joel et al. [10], we conducted a speed-dating experiment with approximately 40 participants. They had a three -min conversation with each participant of the opposite sex. Following this, participants were asked to select at least half of the participants that they would be interested in conversing with again. Mutually liked pairs (i.e., both participants selected each other) were labeled as compatible pairs and the other pairs as incompatible pairs. Regarding the resting-state fMRI data, the functional connectome was calculated after appropriate preprocessing procedures for each participant, and then the connectome similarity was calculated for each pair. A machine learning algorithm was constructed using connectome similarity. For the performance evaluation, a leave-one-pair-out cross-validation (CV) method was employed. In this CV method, one male and one female participant were excluded from the training set and the excluded pair was used as the test set. Thus, individuals whose data were employed as the training data were not employed as the test data, and vice versa. As a result, we demonstrated that this method enables the prediction of the compatibility of relationship initiation, which is a psychological phenomenon caused by the interaction between individuals that cannot be predicted by self-reported psychological indices [10].

4 Proposal of a method to predict therapist-client compatibility for better alliance

Based on our previous study, we propose a system in which therapist-client compatibility for a better alliance may be predicted a priori (Figure 2). First, we need the resting-state fMRI data of therapists and clients. Although the resting-state fMRI measurements can be performed in as little as 10 min and do not require any tasks, access to an MRI system is the first hurdle. In the meantime, we plan to establish a method of compatibility prediction with a brain activity measurement methodology that can be easily accessed (e.g., electroencephalography, EEG; near-infrared spectroscopy, NIRS). Therefore, we may be able to overcome the first hurdle in the future. The fMRI data undergo a preprocessing procedure (e.g., noise reduction and decomposition into multiple frequency bands), and the time-series signal of each brain region is extracted. The functional connectome is calculated from the regions' signal data for both therapists and clients, and the connectome similarity is calculated for each therapist–client pair. Second, training data for the machine learning algorithm are needed to contain the connectome similarity of therapist-client pairings and the resultant quality of the alliance. By training the algorithm with the data, a novel therapist-client pairing can be predicted, whose possible quality of alliance is the result of therapy. The second hurdle is that the resultant quality of the alliance requires time

to be assessed, because it grows gradually and is not obtained in a single session. However, once these hurdles are overcome, it may be possible to predict therapist-client compatibility for a quality alliance before the first session begins. Therapists and clients are paired to improve their alliance by developing the prediction algorithm. This will result in a positive outcome and reduce the risk of alliance rupture.

As previously mentioned, it is natural to consider why this system does not choose treatment outcome as the target of prediction. This is because of the complexity and uncertainty of the relationship between the connectome similarity of therapist-client and treatment outcome, in addition to the fact that the therapist-client alliance is the core of therapy. This alliance is comparable with the compatibility of heterosexual relationships, which has been demonstrated to be predictable by connectome similarity [5], in terms of interpersonal relationships. Alternately, treatment outcome is influenced by various factors, not only the quality alliance but also the level of client involvement in the therapy process [19], patients' intelligence [20], and therapists' experience [20,21]. However, whether a machine learning algorithm with connectome similarity can predict the outcome of treatment is worth exploring. In this case, adding outcome-related information (e.g., as mentioned above) as the feature values for the machine-learning algorithm may help improve the prediction performance.

If this algorithm becomes active in the real world, its effective application will require high accessibility to the system. When clients need treatment, they must search for medical facilities where they would receive appropriate treatment. In the current medical facilities, it is not easy to choose an appropriate therapist or to change the current therapist. We hope that the proposed system eliminates unnecessary steps that both clients and medical facilities have to take before treatment commences. Ideally, clients undergo fMRI scanning before they need treatment and are ready to benefit from the system. To achieve this, we need to develop the environment where people easily obtain their fMRI data as part of scientific projects. We hope to make such an environment a reality in the not-too-distant future.

Of course, this system would have limitations, even when it starts working in the real world. Diversities prevent the application of the system to every relationship. First, the therapist-client relationship is diverse; there may be a large age gap between therapist and client, and the latter may suffer from different diseases or psychiatric conditions such as dementia. Second, the neurophysiological conditions of clients are also diverse; clients who need rehabilitation therapy sometimes have brain injury. In such cases, pre-acquired fMRI data are useless. Even if the data are acquired after the injury, it is necessary to verify whether the outcome of treatment (i.e., a possible index of compatibility) can be predicted by the data, so that the system can benefit as many clients as possible. It should be noted that even after overcoming such diversities, it is unlikely that every client will be able to use the system regardless of how accessible it becomes (e.g., because of the limited number of MRI). Therapists must remember that the interpersonal aspect of the therapy is as important as the technical aspect and efforts to improve relationships with clients on the job help to scaffold quality care.

5 Conclusion

The absence of neuroscientific investigation regarding the prediction of dyadic interaction-derived phenomena is because it cannot be handled by traditional methodology for individual-based analyses. Although research on the prediction of dyadic interaction-derived phenomena is still in its infancy, the neuroscientific methodology of connectome similarity defined in our study is expected to play an important role in understanding a wide variety of interpersonal relationships in the real world. Therapist–client compatibility is one of the most important themes in the future.

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Conflicts of Interest

The authors declare no conflicts of interest directly relevant to the content of this article.

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