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科学研究費助成事業　　研究成果報告書

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研究課題名（和文）The flexible brain: how brain network flexibility influences memory encoding.

研究課題名（英文）The flexible brain: how brain network flexibility influences memory encoding.

研究代表者
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研究成果の概要（和文）：Covid-19のパンデミックのため、実験は2020年から2021年まで保留されました。そのため、記憶の符号化と脳の柔軟性に関する実験は計画通りに完了していませんでした。しかし、私は、ストレスレベルと脳の柔軟性との間に強い関係があることを発見した最初の年からのパイロット結果を持っています。掲載されている出版物はありませんが、参加者全員の収集が完了した後、今後それらの調査結果を公開します。

研究成果の学術的意義や社会的意義
It helps to raise awareness of brain flexibility researchers. Previous studies have shown the differences between the brain flexibility of patients and healthy people but didn't explain stress level of the patients before performing the experiment. Our findings would be important to the study field.

研究成果の概要（英文）：The experiment has been pended from 2020 to 2021 because of the Covid-19 pandemic. Therefore, the experiment related to memory encoding and brain flexibility wasn't completed as the plan. However, I have pilot results from the first year in which I found a strong relationship between stress level and brain flexibility. There is no publication represented but I will publish those finding in the future after completing the collection of all participants.

研究分野：Neuroscience

キーワード：fMRI　stress　network flexibility

１．研究開始当初の背景

So far, no one knows whether experiences encountered in a daily life can affect memorability or other capabilities. For example, if drinking coffee makes the brain more flexible, would we be able to remember more if we have coffee in the morning?

The functional magnetic resonance imaging (fMRI) technique and advances in network neuroscience give us a better understanding of human brain cognition. It has become apparent that brain regions do not operate in isolation but coactivate simultaneously as a network to function (Smith et al. 2009). Previous studies have revealed that not only the strength of the FC between specific brain regions but the large-scale FC of brain networks is correlated with cognitive performance (Cohen 2017).

Notably, recent studies have shown that FC patterns in large-scale brain networks are not static but dynamically change over seconds to minutes (e.g., 30–60 s) (Cole et al. 2014; Cohen 2017). For example, our recent study reported that FC patterns in large-scale brain networks dynamically interact to support memory encoding (Keerativittayayut et al. 2018). More specifically, we observed a greater level of integration across brain networks during periods of greater memory encoding. Although we have successfully elucidated the neural mechanism explaining why sometimes we are able to memorize past events but other times we are not, our current data cannot be used to explain why some people have a better memory than others. A network-level mechanism underlying individual memorability of episodic memory remains unclear. Recent advances in network neuroscience allow us to investigate network flexibility, which refers to the ability of brain regions inside a brain network to reconfigure its FC over time. According to this definition, a flexible brain indicates a highly adaptive brain network in which brain regions inside the network often change their FC whereas an inflexible brain indicates a stable brain network in which the FC of the various regions remains constant over time (Figure 1). Previous studies have shown that network flexibility is correlated with working memory performance and can predict future learning ability (Bassett et al. 2011; Braun et al. 2015). Recently, a longitudinal study of one participant showed that network flexibility acquired several times during one year is modulated by levels of emotional state, fatigue, and arousal (Betzel et al 2016).

Given this information, we hypothesized that differences in memorability between people may be explained by differences in individual network flexibility. Moreover, brain flexibility during previous experiences might affect memory encoding and enhance or reduce subsequent memory performance.

２．研究の目的

1. To investigate brain flexibility during memory encoding.
2. To prove that brain flexibility during previous experiences can affect future memory encoding.
3. To investigate whether we can improve memory performance by inducing network flexibility using brain stimulation methods.

３．研究の方法

The experiment has been pended from 2020 to 2021 because of the Covid-19 pandemic.

Therefore, the experiment related to memory encoding and brain flexibility wasn't completed as the plan. However, during 2019, I investigated a network flexibility of a target population. So as to, I studied the network flexibility using resting state fMRI which was performed as a part of another experiment in Research Center for Brain Communication of Kochi University of Technology. Twenty-six participants participated the experiment. They were asked to perform 4 mental assessments in order to evaluate their mental state which might affect the network flexibility.

1. Twenty-six undergrads were recruited to join the experiment (later 1 subject was excluded, the data of the remaining 25 participants is used for data analysis.
2. The participant were asked to perform 4 assessments as follows:
    - Stress mindset measure (SMM) assessment to measure stress level
    - Beck depression inventory (BDI) assessment to measure depressive symptoms
    - Connor & Davidson resilience scale (CD-RISC)
    - Perceived stress scale (PSS) assessments to measure an ability to recover from stress.

   Note that, here after will be called. SMM1, BDI1, CD-RISC1, and PSS1.
3. Many days later, the participants were asked to come for fMRI session. The participant s took all assessments (i.e., SMM2, BDI2, CD-RISC 2, and PSS2; 2 denotes the second measurement) again before start the experiment.
4. The participant took 10 mins to finish the resting state fMRI scan.
5. Brain flexibility during resting state scan was computed and related with behavioral scores.

４．研究成果

There is no publication represented but I will publish research findings related to stress and brain flexibility in the future after completing the collection of all participants. The findings are reported here as follows.

1. **Correlation between whole-brain network flexibility and behavioral scores**

Whole-brain network flexibility was computed by average flexibility of all two-hundred twenty-seven nodes inside the large-scale network (Power et al., 2011). Among 8 assessment scores (i.e., SMM1, BDI1, CD-RISC1, PSS1, SMM2, BDI2, CD-RISC2, and PSS2), whole brain flexibility negatively correlated only with SMM2 score (r = -0.5050, P = 0.0100) as shown in figure 1. Note that, it could not observe a correlation between whole brain flexibility and SMM1 score although there was a positive correlation between SMM1 and SMM2 scores (r = 0.6680, P = 0.0002). It might be because stress level right before the fMRI experiment but not many days before affected whole brain flexibility.

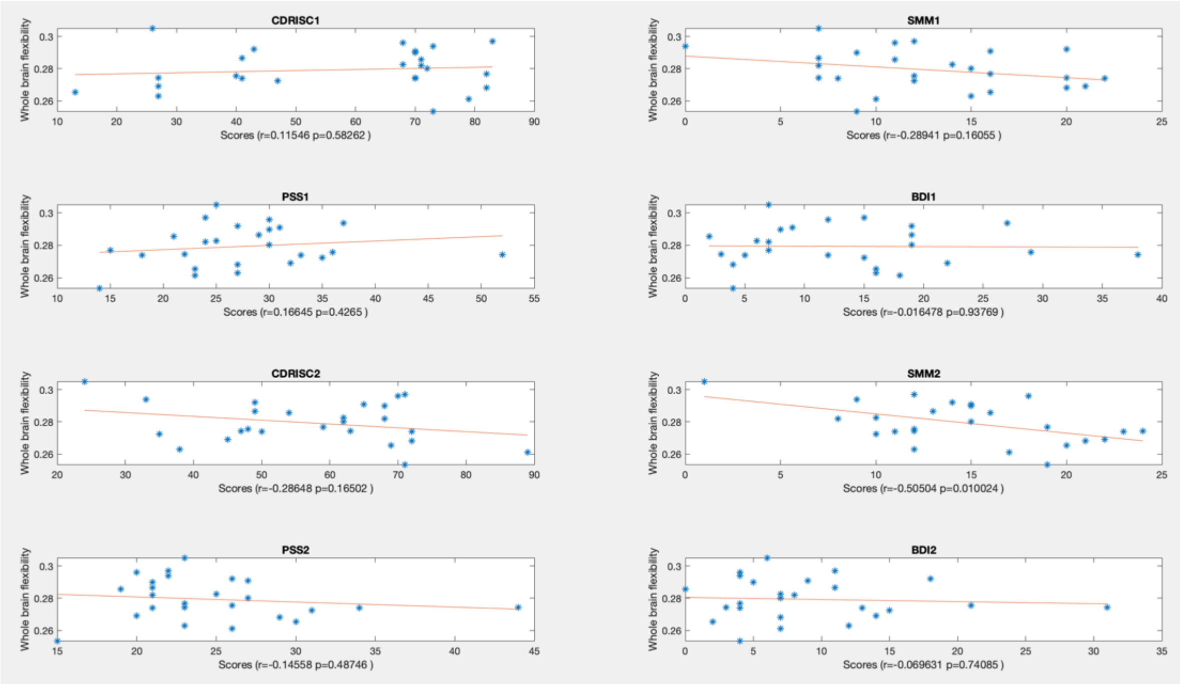

Figure 1 The correlation between whole brain flexibility and scores

2. **Correlation between sub-network flexibility and behavioral scores**

The large-scale network used in this study consisted of ten subnetworks (Power et al., 2011). The subnetworks had the following labels: sensorimotor networks (SMN), cingulo-opercular network (CON), auditory network (AUD), default mode network (DMN), visual network (VIN), fronto-parietal network (FPN), salience network (SAN), subcortical nodes (SUB), ventral attention network (VAN), and dorsal attention network (DAN). To investigate whether any specific subnetwork flexibility correlates with behavioral scores, flexibility of nodes inside each subnetwork were averaged and correlated with 8 assessment scores. The negative correlations with SMM2 were observed in many subnetworks as follows and in figure 2.

- DMN-SMM2, $r = -0.5172$, $p = 0.0081$
- SUB-SMM2, $r = -0.4047$, $p = 0.0448$
- VAN-SMM2, $r = -0.4759$, $p = 0.0162$
- VIN-SMM2, $r = -0.5383$, $p = 0.0055$
- DAN-SMM2, $r = -0.5447$, $p = 0.0049$

These results suggested that the DMN, the SUB, the VAN the VIN, and the DAN flexibility during resting state scan could explain level of stress of individual participants. It might indicate that stress level should be took into account when investigating network flexibility.

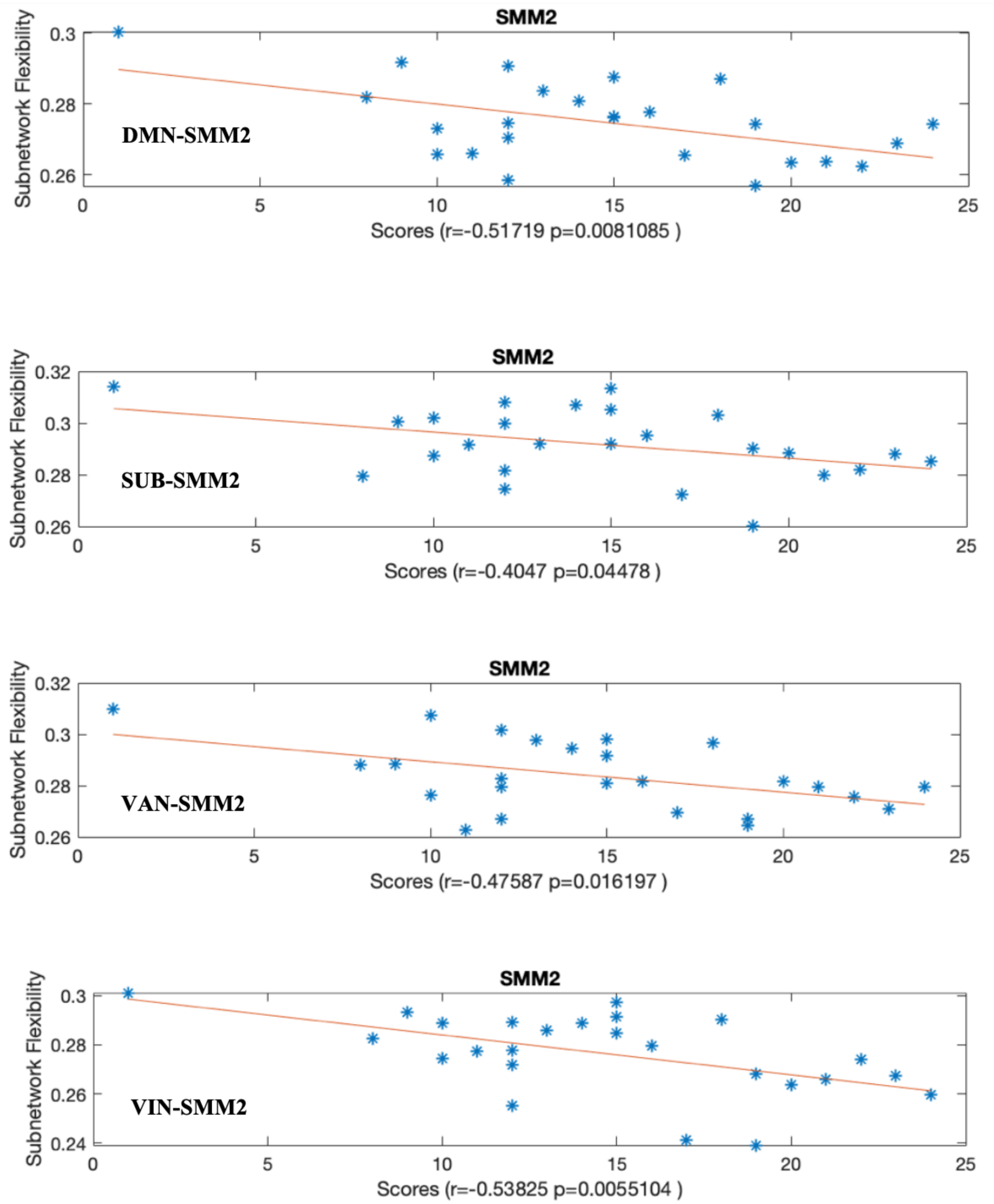

Figure 2 The correlation between subnetwork flexibility and SMM2 score

5．主な発表論文等

〔雑誌論文〕　計0件

〔学会発表〕　計0件

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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6．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

7．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

8．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関