Is interoceptive attention during breath-counting meditation reflected in functional connectivity ?

OHBM2020 poster No.2198

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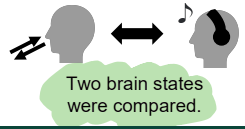
INTRODUCTION

- **Mindfulness** is focusing one's attention to the present moment without judging. → Vipassana meditation
- **Meditation and interoceptive attention**
  - An important component of meditation is **focusing and maintaining the attention to physical sensations** so as to enhance **interoceptive processing** (Melloni et al.,2013).

However, **the difference in neural responses between interoceptive and exteroceptive attentions** has not been clarified.



MATERIALS & METHODS

- **Functional MRI data analysis**

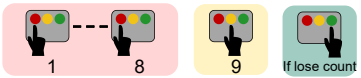
The patterns of brain activity are identified when attention can be directed to the target.

- **Behavioral data analysis**

Counting accuracy [%]

$$= \frac{The\ number\ of\ correct\ count\ sets}{The\ total\ number\ of\ count\ sets} \times 100$$

- **Behavioral data** Counting and pressing of buttons were conducted similarly for both tasks.



- **Experimental task**

Breath-counting task (BCT) [Levinson et al.,2014]

Target of counting: **breath**

1,2,3,...

It was used to induce **interoceptive attention**.

Auditory counting task(ACT)

Target of counting: **auditory stimulus**

1,2,3,...

It was used to induce **exteroceptive attention**.

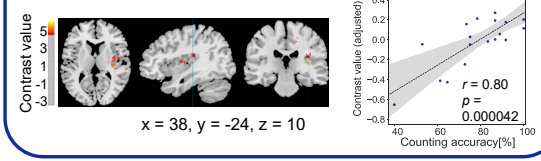
We aimed at investigating **whether or not the interoceptive attention induced by meditation is reflected in the patterns of brain activation**, through a comparison with the exteroceptive attention caused by sustained responses to auditory stimuli.

RESULTS & DISCUSSIONS

- **Functional MRI data analysis results**

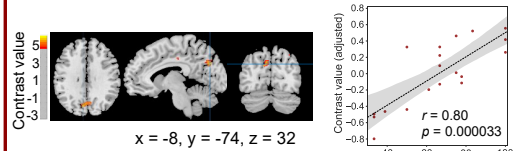
ACT

①Results Results showed that the counting accuracy significantly and positively correlated **with the contrast values** of HES.R in ACT.



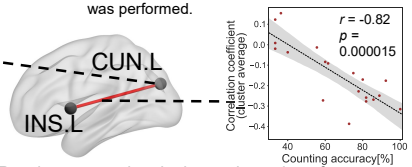
BCT

①Results Results showed that the counting accuracy significantly and positively correlated **with the contrast values** of CUN.L in BCT.



The better the task performance gets, the more is the interoceptive attention given to body sensations during BCT.

② Results **The functional connectivity analysis** in which the CUN.L and HES.R were set to the seed ROIs for BCT and ACT, respectively, was performed.



Results suggest that the better the task performance gets, **the more are the brain activity patterns of CUN.L and INS.L reversed**.

Results suggested that **the interoceptive attention caused by breath-counting meditation was reflected in CUN.L activation and the functional connectivity between it and INS.L**.

Our short video

■Please visit the link below.

https://doshishaacjp-my.sharepoint.com/:f:/g/personal/cygf1001_mail4_doshisha_ac_jp/Eq73Gq2TtY9Nm0x6BEBYKg0BPXe3Qmqw4law-eU3DCnfhw

Introduction

■Mindfulness

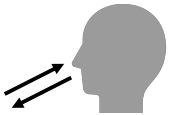
➢It is focusing one's attention to the present moment without judging.

Focused attention meditation :
It holds attention to specific objects

■Meditation and **interoceptive attention**

➢Interoceptive sense

- Senses involved in the perception of information inside the body
  e.g., breaths， heartbeats



➢Exteroceptive sense

- Senses involved in the perception of information outside the body
  e.g., visual sensation，
  auditory sensation

The development of interoceptive attention is a key component of practicing meditation.

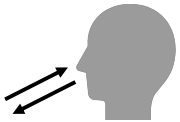
Introduction

■Problem

The difference in neural responses has not been clarified.

Target of counting：**breath**

It was used to induce **interoceptive attention**.



Target of counting：**auditory stimulus**

It was used to induce **exteroceptive attention**.

■Objective

We aimed at investigating **whether or not the interoceptive attention induced by breath-counting meditation is reflected in brain activation and functional connectivity patterns**.

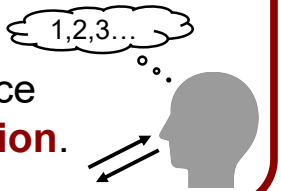
Experimental task

■Breath-counting task (BCT)

[Levinson et al.,2014]

- Participants repeatedly counted their breaths mentally from one to nine.
- **Interoceptive processing** occurring within the body

Target of counting：**breath**

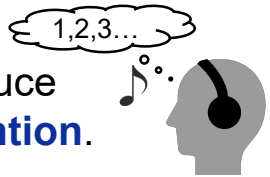


It was used to induce **interoceptive attention**.

■Auditory counting task (ACT)

- Participants were asked to focus their attention to auditory stimuli and press a button as soon as an auditory stimulus occurred.
- **Exteroceptive processing** of external stimuli

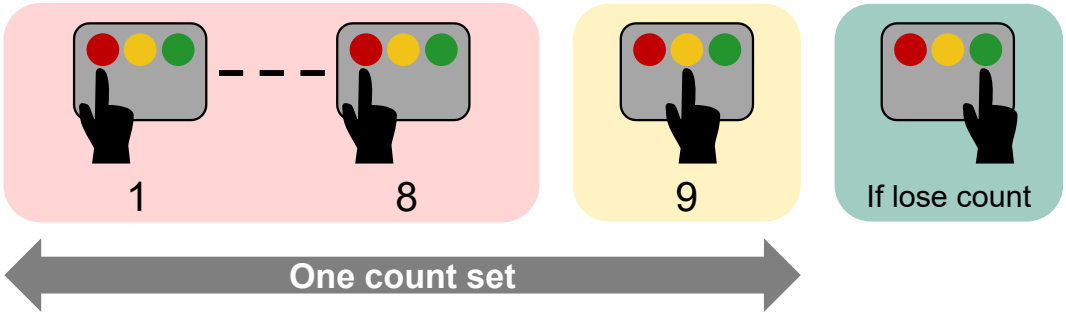
Target of counting：**auditory stimulus**



It was used to induce **exteroceptive attention**.

Behavioral data

- Participants were asked to count the attentional targets from one to nine repeatedly.
- Counting and pressing of buttons were conducted in similarly for both tasks.

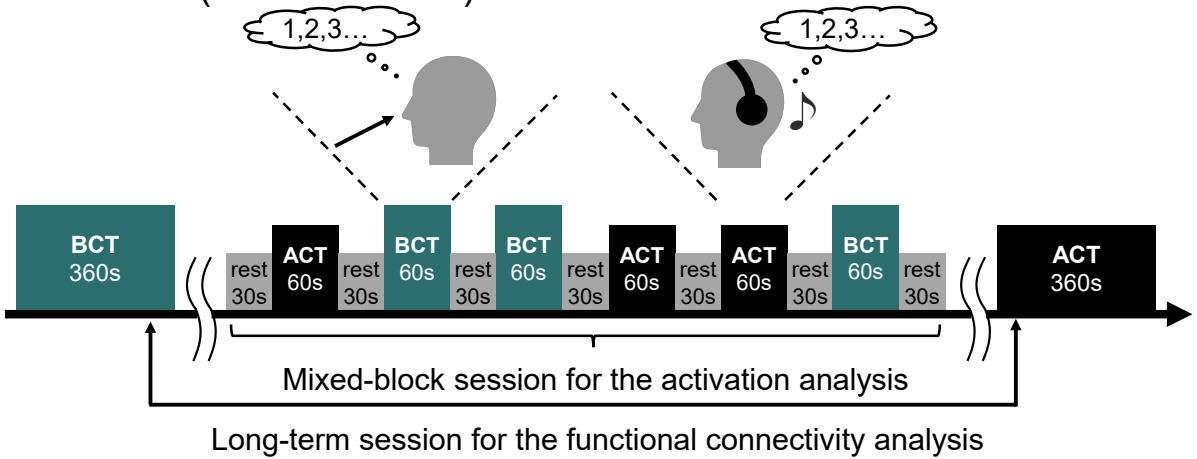


The performance of the task can be evaluated using the behavioral data.

Experiment

■Experimental design

➢The two tasks (BCT and ACT) were executed in a random order.

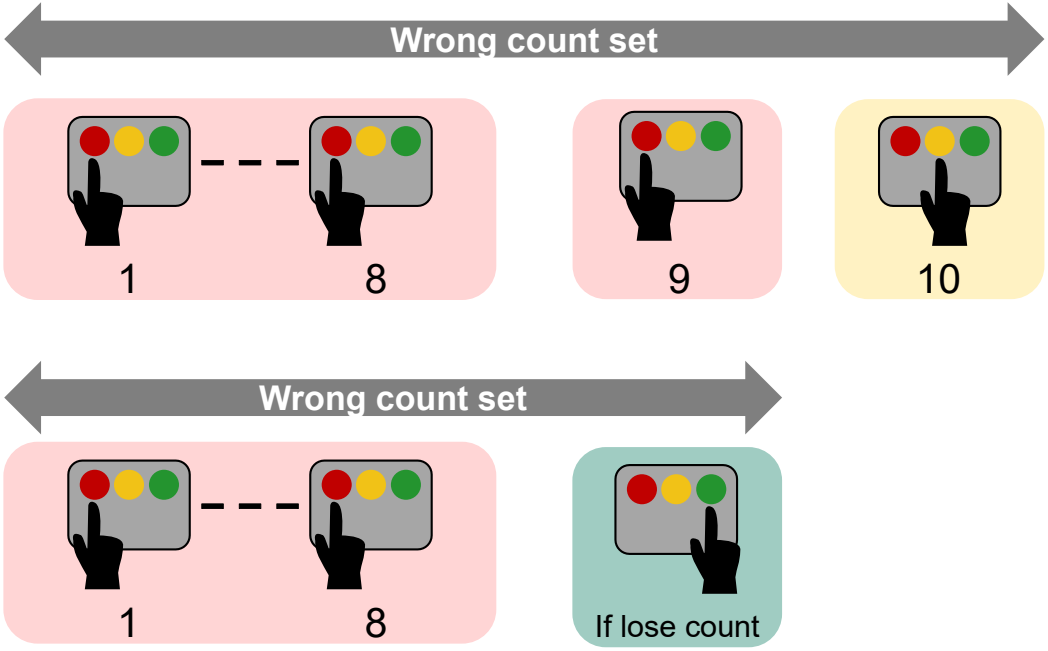


■Participants: A total of 20 male novice meditators（aged 23.0 ± 1.2 years）

■Experimental equipment: 1.5T MRI Scanner (Echelon Vega, Hitachi, Ltd.)

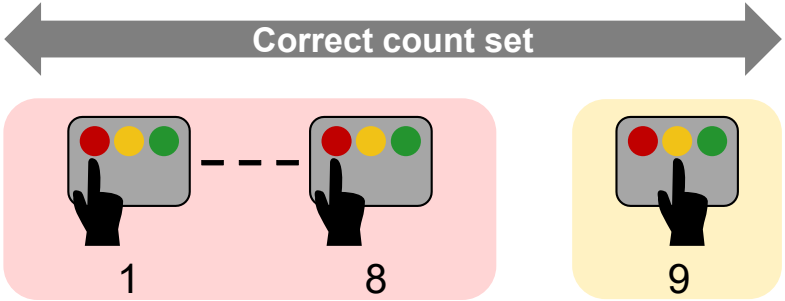
Behavioral data analysis

■The example of wrong count



Behavioral data analysis

■The correct count



■**Counting accuracy**

➢It indicates **the accuracy of the task**.

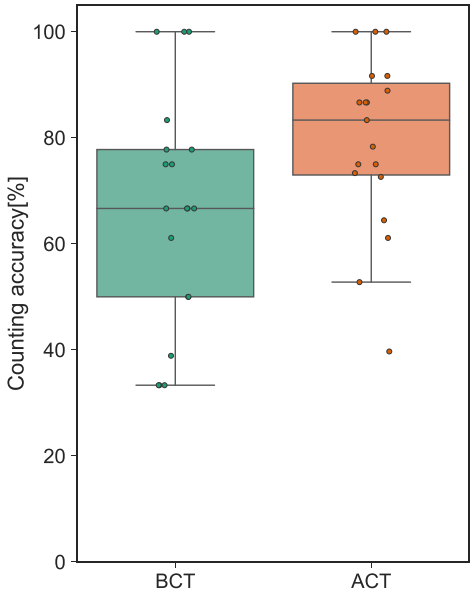
$$\text{Counting accuracy [\%]} = \frac{The\ number\ of\ correct\ count\ sets}{The\ total\ number\ of\ count\ sets} \times 100$$

■Mixed-block session (60s)

➢The average counting accuracy was significantly lower in BCT than in ACT.

- BCT : 66.1% ± 21.4%
- ACT : 79.4% ± 15.9%

It was suggested that it was more difficult to focus the attention in BCT than in ACT.



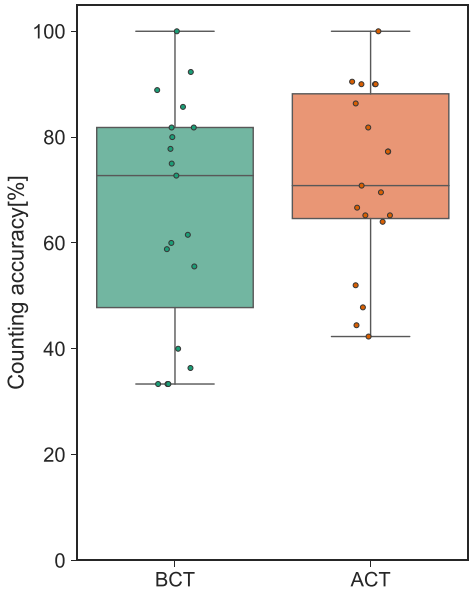
■Long-term session (360s)

➢There was no significant difference in the counting accuracy during the task between ACT and BCT.

- BCT : 65.7% ± 21.4%
- ACT : 72.2% ± 16.7%

■Comparison between sessions

It was suggested that the shorter the task time, the more difficult it was to focus the attention in BCT than in ACT.



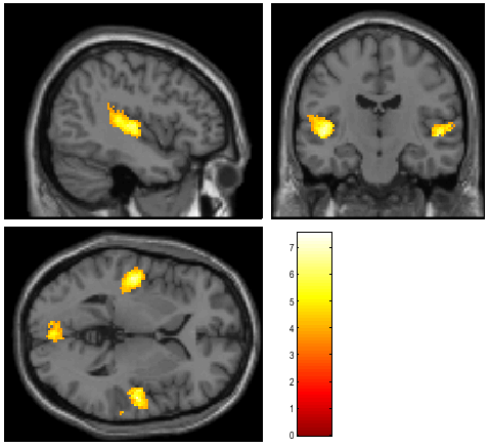
■**ACT - BCT** (peak: p<.001, uncorrected, cluster: p<.05, FWE corrected)

➢STG.L・R

The region belongs to
the ventral attention network.

- It is associated with **bottom-up attentional processing**.

It was suggested that bottom-up attention was directed to an auditory stimulus.



➢CAL.L

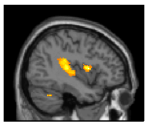
The region belongs to
the primary visual network.

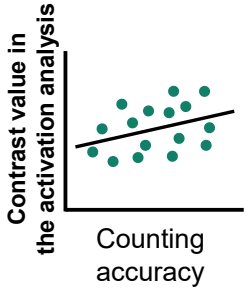
Analysis

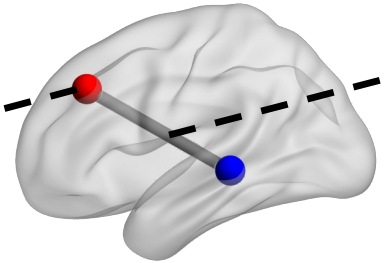
The patterns of brain activity are identified
when attention can be directed to the target.

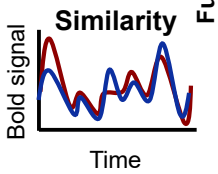
■when attention can be directed to the target ＝ high counting accuracy

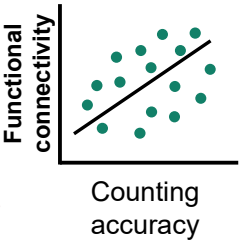
➢The correlation analysis between the patterns of brain activity and task performance











ROI identification

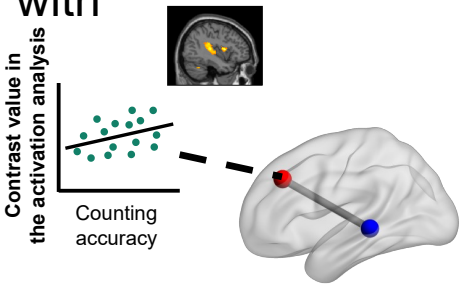
①Extracting the regions-of-interests associated with the task performance

▶

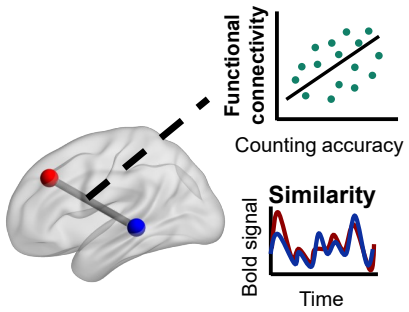
②Extracting the functional connections that have significant correlations with the counting accuracy

Analysis

1. **Extracting the regions-of-interests** associated with the task performance
   - ROI identification
   - **Voxel-wise multiple regression analyses** were performed between the contrast values in the activation analysis and the counting accuracy for each task.



2. **Extracting the functional connections** that have significant correlations with the counting accuracy
   - The anatomical regions (defined by AAL), where the clusters found in the correlation analysis existed, were set as the seed ROIs for the subsequent **seed-to-voxel functional connectivity analysis**.

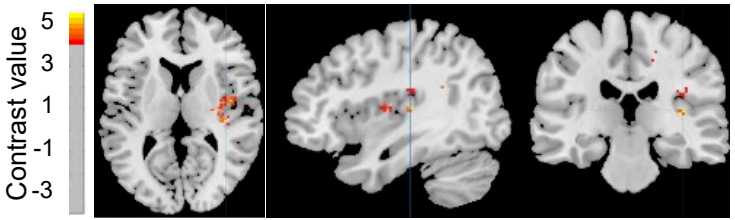


■ACT (peak: $p < 0.001$, uncorrected, cluster: $p < 0.05$, FWE)

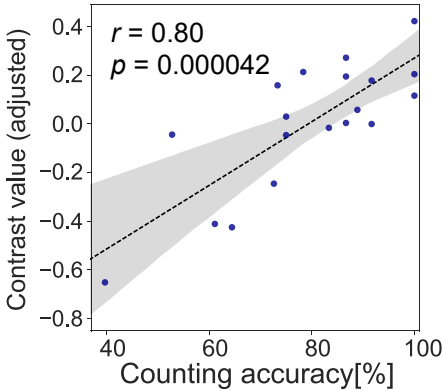
➢Positive correlation: HES.R

The HES is included
in the primary auditory cortex.

[Pekkola et al.,2005]



x = 38, y = -24, z = 10



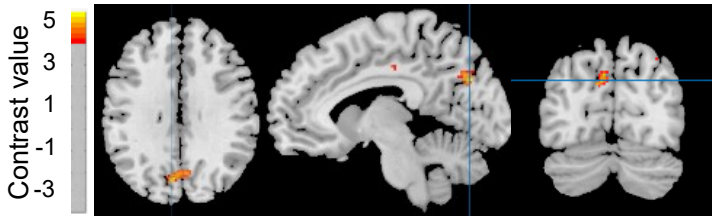
Results suggest that **the better the task performance gets, the more is the exteroceptive attention given to the auditory stimuli during ACT**.

■**BCT** (peak: $p < 0.001$, uncorrected, cluster: $p < 0.05$, FWE)

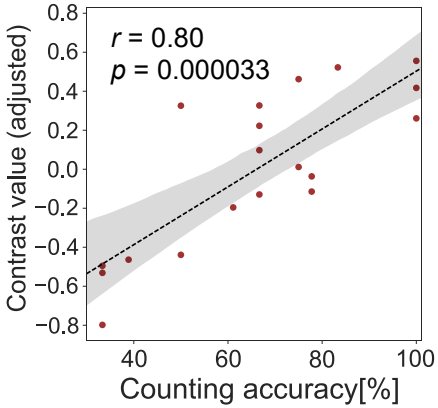
➢Positive correlation: CUN.L

The activation of CUN can be associated with interoceptive attention.

[Wang et al.,2019]



x = -8, y = -74, z = 32

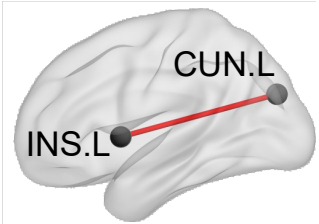


Results suggest that **the better the task performance gets, the more is the interoceptive attention given to body sensations during BCT**.

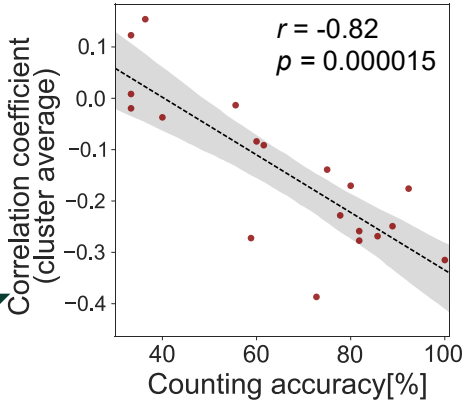
■**BCT** (peak: $p < 0.001$, uncorrected, cluster: $p < 0.05$, FWE)

➢Negative correlation: INS.L

The region associated with self-awareness [Tang et al.,2015]



decrease of functional connectivity



increase of counting accuracy

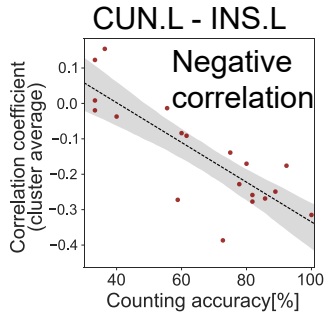
➢Low functional connectivity

The patterns of brain activity are reversed.

Results suggest that **the better the task performance gets, the more are the brain activity patterns of CUN.L and INS.L reversed.**

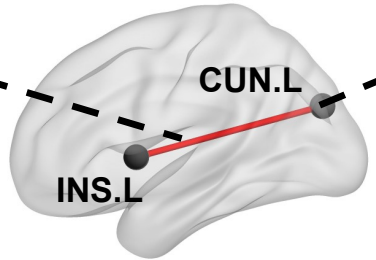
Conclusion

■The brain activity pattern
that could be associated with **interoceptive attention**

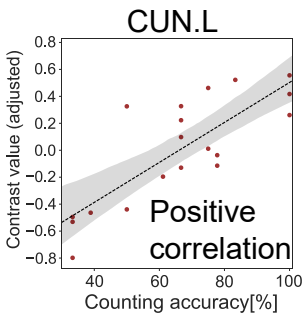


The brain activity patterns of CUN.L and INS.L are reversed.

The activation of CUN can be associated with **interoceptive attention**.



The INS is associated with **self-awareness**.



CUN.L is activated.

It was suggested that the interoceptive attention caused by breath-counting meditation was reflected in patterns of brain activity.

Appendixes

Introduction

■Mindfulness meditation

- ➢It is said to influence physicality, cognition, and mentality and also has positive effects on well-being.
- ➢It reduces stress and improves work efficiency.

■Problem

- ➢Practicing meditation is difficult because meditation novices don‘t know whether they are in a meditative state or not.

Our purpose is to support meditation practice by quantifying the brain state during meditation and providing feedback.

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Focused attention meditation & open monitoring meditation

- Focused attention (FA) meditation
  - Training to focus your attention on a specific target
  - Target of attention: Specific body sensations, such as breathing

- Open monitoring (OA) meditation
  - It monitors current experience without value judgments.

- Practicing FA meditation is easier than practicing OM meditation.
- Sustaining attention with intentionally is an important component of mindfulness.

Breath-counting meditation

- Participants were asked to breathe through their nose.
- Their eyes were kept closed consistently in the scanner.
- Participants were asked to try not to change the breath interval.
- They counted their breath silently from one to nine.
- They were also instructed to restart counting from one if they reached the count of nine or if their mind got distracted.
- In the rest block, they were instructed to stay relaxed without focusing on their breathing.

MRI sequence parameters

Parameter	Functional image	Structural image
TR [ms]	2500	9.8
TE [ms]	40	4.0
Flip angle [°]	85	8
Field of view [mm]	240	256
Matrix size [pixel]	64 × 64	256 × 256
Thickness [mm]	5.0	1.0
Slice number	25	192

Counting accuracy calculation method in the mixed-block session (BCT)

■Subjects do not count their breaths up to nine

→Using outliers

1. The correct count set was extracted from the section long-term session.
2. The mean and standard deviation of the button press intervals were calculated using this count set.
3. Whether or not the task was performed correctly was determined using the following expression:

$$t_i \geqq mean + (3 \times standard\ deviation)$$

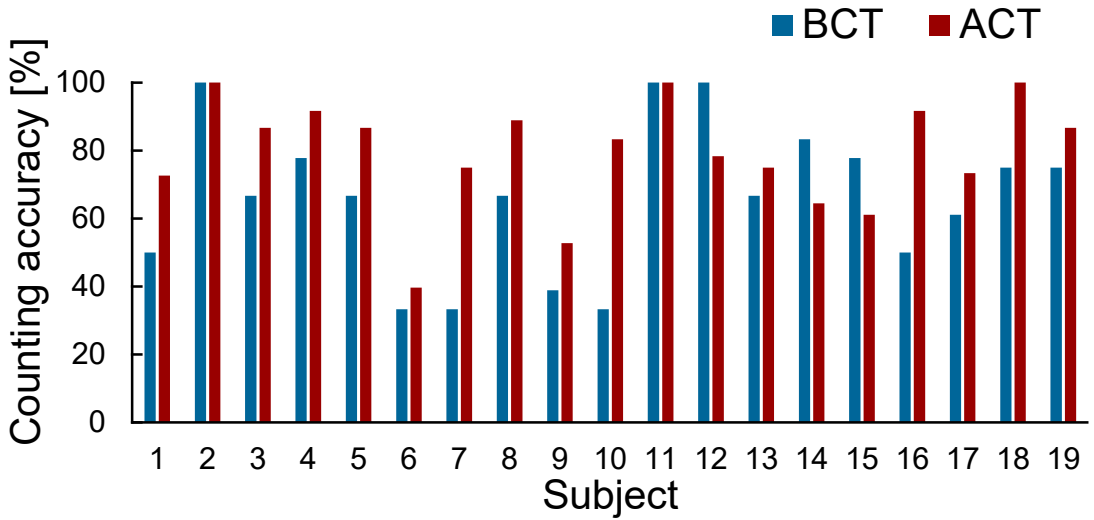
■Behavioral data analysis results

- ➢One out of 20 people judged that the task could not be executed because the counting accuracy in BCT was 0%.

The data of 19 people other than that one was used as the object of analysis.

Results & Discussions｜Behavioral data analysis（Mixed-block session）

■Mixed-block session



■Long-term session