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Research article

Supramarginal activity in interoceptive attention tasks

Keyvan Kashkouli Nejad[a,*], Motoaki Sugiura[a,b], Takayuki Nozawa[a], Yuka Kotozaki[a], Yoshihito Furusawa[c], Kozo Nishino[d], Toshohiro Nukiwa[e], Ryuta Kawashima[a]

[a] Institute of Development, Aging and Cancer, Tohoku University, Sendai, Japan
[b] International Research Institute of Disaster Science, Tohoku University, Sendai, Japan
[c] Department of Physical Medicine and Rehabilitation, Graduate School of Medicine, Tohoku University, Sendai, Japan
[d] Institute of Nishino Breathing Method, Japan
[e] Department of Respiratory Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan

HIGHLIGHTS

- Confirmed supramarginal (SM) activity in interoceptive attention/awareness (IAA).
- Activation patterns were similar for IAA regarding two body parts.
- Also performed group comparison analyses between IAA experts and novices.
- Results showed rather opposite profiles of SM activity for the two groups.
- SM is rather related to other aspect of attention, might be not essential for IAA.

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ABSTRACT

Interoceptive (feelings from inside organs) attention/awareness (IAA) is a body-related aspect of cognition that pursues homeostasis by detecting afferent signals, and there are practices aimed at focusing one's attention and awareness towards such feelings inside one's own body. There is a claim that these practices improve health which is one reason that neural correlates of such practices and IAA in general have been investigated in previous imaging studies. In several of these studies which used subjects with no or limited experience in IAA practices there was a report of supramarginal (SM) activity during IAA tasks, but the role of SM in IAA remain unclear. We first investigated if we could find similar results in novices, and if this activity is sensitive to the designated body part in the IAA task. We further investigated if these regions would be similarly recruited in subjects with extensive experience of IAA tasks while comparing results with a group of age and gender matched novices. Results in the novices replicated that of previous studies, and we showed this is the same for IAA tasks regarding two different parts of the body. Group comparison results showed opposite profiles of SM activation for the two groups; novices showed activation and the experts showed deactivation of the SM. The results suggest that novices recruit SM during IAA possibly due to lack of experience in those tasks but this could be alleviated for performing IAA as illustrated by activation profile in experts.

1. Introduction

Interoceptive (feelings from inside organs) attention/awareness (IAA) [1,2] is a body-related aspect of cognition that pursues homeostasis by detecting afferent signals, alerting to the existence of internal imbalances such as dehydration or injury to body organs. In fact, there are practices aimed at focusing one's attention and awareness towards such feelings inside one's own body with the claim of improving health [3–5], possibly through raising awareness to such internal body signals. There have been various studies discussing the important role of right insula in IAA [6,7].

Several of such neuroimaging studies have reported supramarginal (SM) recruitment, especially in the right hemisphere, during execution of IAA tasks [5,8–10], but this area has not gained much attention in the literature regarding IAA. Based on lesion and functional studies, the supramarginal gyrus (SM) has been reported

* Corresponding author at: Department of Functional Brain Imaging, Institute of Development, Aging and Cancer, Tohoku University, Seiryo-machi 4-1, Aoba-ku, Sendai 980-8575, Japan. Tel.: +81 22 717 7988; fax: +81 22 717 7988.
E-mail address: keyvan@idac.tohoku.ac.jp (K. Kashkouli Nejad).

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to play a role in encoding peripersonal space [11,12] to form an egocentric representation of the corporeal self [13]. It has been suggested that the inferior parietal regions form a suitable hub for integrating sensory information across modalities [14]. The SM is located in this region of the brain and disruption of SM activity can cause impairments in various somatosensory-related cognitive functions, such as asomatognosia [15,16] and somatoparaphrenia [17], syndromes characterized by distorted awareness of the existence of a part of the body, or an 'out of body' experience [18–20]. Although this aspect of neural activity has been shown to play an important role in somatosensory [21] and motor functioning [18,22], its role in various cognitive functions regarding the body is still ambiguous.

It remains unclear why IAA induces SM activation as reported in those previous studie. As mentioned earlier, it has a role regarding attention/awareness towards peripersonal space, but this aspect of attention/awareness pursues homeostasis [12] from a rather exteroceptive perspective (i.e., avoiding harm from outside world), unlike IAA which pursues homeostasis from an interoceptive perspective. Therefore, although related, these two body-related aspects of attention/awareness could be dissociable. Intriguingly, studies on IAA that reported SM activation usually included subjects who were either total beginners in IAA practices or were beginners who had undergone a short training session in such practices. In fact, IAA places much emphasis on interoceptive feelings, and reliance on exteroceptive senses is usually minimized. Therefore, one reason for SM activation in those studies could be that beginners try to be aware of the existence of the attended-to body part from a rather exterocentive perspective and consequently recruit the SM. After long experience, this might be alleviated and subjects might not recruit SM anymore. In such case, we could expect less activation and possibly deactivation in these areas in experienced practitioners versus novices.

We first investigated IAA induced neural activations regarding two parts of the body (the knees and the lower abdominal areas) for subjects with no experience in IAA and confirmed similar activation patterns in SM and other brain regions as previous studies, for both designated body parts. We then performed a group comparison study with a group of expert IAA practitioners and a age/gender matched group of novices using the same IAA tasks.

Similar to previous studies on IAA, subjects were asked to attend to and be aware of sensations within their body parts. An important part of experiment set up in this study was that subjects were explicitly instructed to close their eyes while performing IAA tasks. This way, we can eliminate the possibility of SM activation as an effect of subjects directly attending to those body parts by visually attending to them and therefore, the reliance on the peripersonal information can be reduced. Thus, we can expect a more exclusive IAA performance especially in the experienced group. Although this is not unique to this study, we can better study the SM activity which has been majorly ignored in previous IAA studies.

2. Materials and methods

2.1. Participants

The experimental protocol was approved by the Ethics Committee of Tohoku University Graduate School of Medicine. Written informed consent was obtained from each subject.

First, we recruited Twenty-nine right-handed subjects (20 males, nine females) with a mean age of 52 (SD: 8) and with no previous experience with concentration, meditation, or similar techniques via advertisements in a local magazine.

For the group comparison study, we recruited 10 (9 males and 1 female) right-handed experienced practitioners (E group) with a mean age of 56.9 years (standard deviation, SD = 11.1 years) from the Institute of the Nishino Breathing Method. This method is one of the Kokyu-ho, or breathing method, styles where practitioners train focusing on breathing patterns and concentrating on their body parts. There are both practices where concentration is accompanied by body movements and practices without such movements. The group had an average of 16 (SD = 8.2) years of IAA experience; each subject had more than 3 years of experience, and had been practicing regularly during the last 6 months. Also, we chose a group of novices (N group) such that they would be age and gender matched with the expert group (mean age, 55.1; SD = 7.9 years).

All subjects were Japanese, and no subject had any history of neurological or psychiatric illness or any auditory problem.

2.2. Experimental overview

The experiment consisted of blocks comprising trials during which attention/awareness was directed to certain parts of the body and rest periods. The target body areas were the lower abdominal/upper pubic region, which is the focus of several East Asian meditation disciplines, and the knees, which are involved in movements. Subjects were tested under three conditions (each 24 s in duration): rest (R), attention to the lower abdominal region (L), and attention to the knees (K). Each condition commenced with a 0.5 s cue indicating its onset and the condition tested. The cue "rest" indicated that the subjects should not concentrate on any body part, whereas "knee" and "lower abdominal" indicated that the subjects should attend to their knees or lower abdominal/upper pubic region, respectively, and be aware of the sensations in the designated region. Each K or L condition was preceded by an R condition.

According to experienced IAA practitioners, it is easier for subjects to attend to areas of their body with their eyes closed. Thus, we presented all cues through headphones, and subjects were instructed to close their eyes during the experiment.

During the attention task, subjects were told to attend to and be aware of the sensations in the designated area. The order of L and K trials was counterbalanced across subjects. All subjects practiced the tasks for approximately 5 min prior to the start of the experiment until they verbally acknowledged that they understood the tasks. During the trials, subjects were instructed to return their focus to the task if they found themselves attending to other thoughts.

3. MRI data acquisition and preprocessing

This part has been described in details in the supplementary material.

3.1. Data analyses

After preprocessing, a general linear model (GLM) design matrix was constructed for each subject to model the onset and duration of each of the seven repetitions of the K and L conditions. First, a parameter estimate image was created for activation during each of the K and L conditions (K and L parameter maps).

Effects of interest were assessed in group-level random effects analyses using *t*-tests on contrast images generated from subject-specific analyses. These effects included activations (deactivations) for each condition and the sum of the conditions (K, L, and K + L) in each group (and also for the whole group of novices), higher activation in N compared to the E group for each condition, and the sum of the conditions (NK–EK, NL–EL, and N(K + L)–E(K + L)).

For the group comparison analyses we explored the analyses in a region of interest (ROI) including the bilateral supramarginal gyri (SM).