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Relationship between prefrontal function during a cognitive task and social functioning in male Japanese workers: A multi-channel near-infrared spectroscopy study

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ABSTRACT

To investigate whether prefrontal function during a cognitive task reflects the social functioning of male Japanese workers, prefrontal function during a working memory task in 181 male workers was measured by multi-channel near-infrared spectroscopy (NIRS). Social functioning was assessed using the Social Adaptation Self-Evaluation Scale (SASS). The results indicated that cortical oxygenation level increases in dorsolateral prefrontal region showed significant positive correlations with the interest and motivation factor scores on the SASS. These results suggest that dorsolateral prefrontal function is associated with the interest and motivation factor in social functioning in male workers and that NIRS could be an addition to the medical tools for monitoring these characteristics on mental health examination.

1. Introduction

In the field of clinical psychiatry, cognitive function has become a significant treatment target since it is known to be a major determinant of the social functioning level of patients with various psychiatric disorders, including schizophrenia and mood disorders. One of the cognitive regions that are markedly affected and also related to social functioning is working memory functioning.

Working memory refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning (Baddeley, 1992, 2003). In Baddeley's model, temporary maintenance of information is supported by an active control system termed the *central executive* and modality-specific subsystems. Deployment of attentional resources, selection of strategies and coordination of information flow are mediated by the central executive. Without the central executive, behaviors become distractible, stereotypic, perseverative and insensitive to context. Obviously, intact working memory is essential for everyday functioning. Working memory tasks require several cognitive processes, such as online monitoring, continuous updating, manipulating stored information, and decision making, each of which is relevant to social activities, such as work ability and communication skills.

The hemodynamic responses related to the neural activity underlying working memory processes have been widely investigated using neuroimaging techniques (functional magnetic resonance imaging, positron emission tomography) (Wager and Smith, 2003; Owen et al., 2005). In healthy subjects, the *n*-back task, which is widely accepted as a working memory task, activates a bilateral network consisting of the ventrolateral prefrontal cortex (VLPFC) and dorsolateral prefrontal cortex (DLPFC), frontal poles, lateral and medial premotor cortices, dorsal cingulate cortex, and medial and lateral posterior parietal cortices (Owen et al., 2005).

The PFC acts not only as a neural basis of working memory, but it also plays an important role in regulating social and emotional behaviors. The ways in which the PFC regulates social activities are multifaceted. To understand the relationship between working memory and social activities, it is helpful to note the role of the PFC in the representation of both the internal and the external world and the representational guidance of behavior. It may be assumed that working memory deficits caused by PFC abnormalities may set an upper limit on how much information can be processed at any given point in time, thereby reducing the ability

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to work as well as to guide social, interactional behavior appropriately. Considering the enormous significance for social functioning in workers, elucidation of the particular relationship between the working memory-related neural activity in the PFC and social functioning in workers is an interesting topic.

Multi-channel near-infrared spectroscopy (NIRS), a recently developed functional neuroimaging technology, enables the non-invasive detection of spatiotemporal characteristics of brain function near the brain surface using near-infrared light (Strangman et al., 2002a; Boas et al., 2004). NIRS has enabled a bedside measurement of the concentrations of oxygenated ([oxy-Hb]) and deoxygenated hemoglobin ([deoxy-Hb]) in micro-blood vessels. Assuming that the hematocrit is constant, the changes in [oxy-Hb], [deoxy-Hb], and also [total Hb] (summation of [oxy-Hb] and [deoxy-Hb]) are correlated with the changes in the regional cerebral blood volume (rCBV), as shown by simultaneous NIRS and positron emission tomography (PET) measurements (Hock et al., 1997; Villringer et al., 1997; Ohmae et al., 2006). In contrast to other neuroimaging methodologies, NIRS can be measured in a relatively restraint-free environment. Accordingly, NIRS has been used to assess brain function in many psychiatric patients in daily medical practice, as well as healthy subjects (Matsuo et al., 2007; Nishimura et al., 2007; Takizawa et al., 2008; Pu et al., 2011).

One of the most useful tools for assessing social functioning is the Social Adaptation Self-Evaluation Scale (SASS). The SASS is a 21-item scale developed by Bosc et al. (1997) for the evaluation of depressed patients' social motivation and behavior; the reliability and validity of its Japanese version have subsequently been confirmed (Goto et al., 2005). Each item is scored from 0 to 3, corresponding to minimal and maximal social adjustment, with a total score range of 0–60. The subjects are asked to give their opinion at this moment about the question. Previous studies, using principal component analysis, demonstrated that the 21 items in the SASS could be classified into the following three factors: interpersonal relations, interest and motivation, and self-perception (Table 1, Goto et al., 2005). In mood disorder patients, although their mood symptom levels may have improved to a remission level, not a few fail to reintegrate into society, presumably due to their residual social functioning deficit, which is not irrelevant to their cognitive capacity. Extending the view to nonclinical populations, cognitive dysfunction in healthy workers may affect their social functioning capacity and also obstruct their social adaptation. We have demonstrated the association of reduced [oxy-Hb] activation induced by a working memory task in the prefrontal region with functional impairment assessed by the SASS in patients with geriatric depression using 52-channel NIRS (Pu et al., 2012), although medication as a possible mediator of the association could not be entirely excluded. If similar findings could be obtained for unmedicated workers, it would indicate the relevance of prefrontal hemodynamic response to social functioning in the absence of the possibly confounding effect of medication. Although the SASS has been developed for assessing social motivation and behavior in depression, at least a few studies suggest its applicability to healthy individuals. First, it has been reported that SASS scores are significantly elevated in healthy individuals compared to patients with depression (Dubini et al., 1997; Ueda et al., 2011). Next, Okuno et al. (2011) has demonstrated a significant relationship between SASS scores and stress-related biological markers such as plasma levels of 3-methoxy-4-hydroxyphenylglycol (MHPG) and brain-derived neurotrophic factor (BDNF) in healthy populations. In addition, good test–retest reliability of SASS scores has been reported in healthy controls (Ueda et al., 2011). In case the association is demonstrated, NIRS may be added as one of the medical tools for monitoring these characteristics on mental health examination; for example, it may be useful in the assessment of social functioning at the time of change in work. Change in the workplace is inevitable for a variety of essential and unavoidable reasons and often may be associated with change in social functioning, such as motivation and behavior, which may lead to depression and other psychiatric illnesses.

One of the primary objectives of the present study was to investigate the relationship between hemodynamic response during a working memory task in the PFC and SASS total and factor scores in male Japanese workers, using a 52-channel NIRS machine (ETG-4000, Hitachi Medical Co.). We hypothesized that activity in the PFC, in particular the DLPFC, associated with working memory processes would be related to social functioning in male workers, which was also the case in patients with geriatric depression as we previously demonstrated (Pu et al., 2012).

Table 1
The items included in each factor obtained by principal component analysis of the Japanese version of the Social Adaptation Self-Evaluation Scale (SASS).

First factor: interpersonal relations
10. External relationship quality
9. Relationship seeking behavior
8. Gregariousness
12. Social attractiveness
7. Family relationship quality
11. External relationship appreciation
6. Family seeking behavior
13. Social compliance
Second factor: interest and motivation
16. Intellectual interest
3. Work enjoyment
1. Job interest or 2. Home work interest
4. Interest in hobbies
15. Social inquisitiveness
14. Community involvement
21. Control of surroundings
5. Quality of spare time
Third factor: self-perception
18. Rejection sensitivity
17. Communication difficulties
19. Vainess
20. Difficulties in coping with resources

2. Methods

2.1. Subjects

The subjects were participants in medical mental health examinations carried out for a single company, which is listed in the First Section of the Tokyo Stock Exchange. Employees working in a certain branch of the company underwent a medical health examination at Tottori University Hospital 3 months after a change in work assignment. Between April 2008 and August 2011, 258 subjects aged between 21 and 54 years participated in the examination.

In this study, the exclusion criteria were the following: (1) current use of psychotropic drugs such as antidepressants, mood stabilizers, and antipsychotics; (2) history of head injury; (3) current or past history of psychiatric illnesses including substance and/or alcohol abuse; and (4) left-handedness. Only 9 out of 258 subjects were female; therefore, only male subjects were included in this study. All the subjects gave informed consent before participation in the study, and the protocol was approved by the Ethical Committee of the Tottori University.

2.2. Self-report measures

Subjects completed the Beck Depression Inventory (BDI), which is a self-reported measure designed to assess current depressive symptomatology (Beck et al., 1961), and the SASS was used to evaluate social functioning. Participants completed the questionnaires within 1 week before the medical examination.

2.3. Cognitive task

We used a 2-back task with a blocked periodic baseline-activation-baseline (Fig. 1) design to activate brain regions specialized for maintenance components of verbal working memory, as originally described by Cohen et al. (1994). Two