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Cortical activation changes and sub-threshold affective symptoms are associated with social functioning in a non-clinical population: A multi-channel near-infrared spectroscopy study

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ABSTRACT

Few studies have examined the relationship between social function and brain activation in non-clinical populations. The aim of the present study was to assess this relationship and examine the underlying cortical mechanisms in a non-clinical population. Eighty healthy volunteers performed a serial arithmetic task according to the Uchida–Kraepelin performance test while hemoglobin concentration changes were assessed on the surface of the prefrontal cortex (PFC) using 32-channel near-infrared spectroscopy. Participants were also assessed for quality of life (QOL) using the Short-Form 36-item Questionnaire (SF-36), for affective symptoms using the Zung Self-rating Depression Scale (SDS), for apathy using the Apathy Scale, for feelings of stress using the Stress Arousal Checklist (SACL), and for task performance using the number of answers in a serial arithmetic task. Activity in the frontopolar PFC displayed a significant positive correlation with social functioning on the SF-36. SDS and SACL scores correlated negatively with social functioning. Furthermore, in multiple regression analysis, social functioning was predicted by activity of the frontopolar PFC and SDS scores. These results suggest that the association between changes in cortical activation and sub-threshold affective symptoms may objectively identify individuals with QOL on social functioning.

1. Introduction

In recent years, attention has focused on quality of life (QOL) for patients with a variety of diseases. In patients with schizophrenia, negative symptoms, psychological discomfort, and resistance predict the dysfunction of psycho-social activity score and the dysfunction of motivation and energy score on QOL scales (Fujimaki et al., 2012). Chan et al. (2012) suggested a moderate association between psychosocial variables and QOL in patients with end-stage renal disease. Furthermore, substantial evidence suggests negative impacts of depressive symptoms and apathy on QOL in many diseases, including human immunodeficiency virus infection (Tate et al., 2003), Parkinson's disease (Schrag, 2006; Oguru et al., 2010), and brain tumors (Mainio et al., 2006). These studies suggest that disease severity and levels of psychosocial variables significantly impact the relationship between disease and QOL. QOL is known for being a key part of problems in mental health and recovery among individuals with mental illness. Mental health problems are associated with reduced QOL in the general population of children and adolescents (Ravens-Sieberer et al., 2008; Rajmil et al., 2009; Bot et al., 2011). Recovery from mental illness involves not only symptom remission, but also quality of life and social functioning (Leucht and Lasser, 2006). Included in a broadening of the concept of health in the middle of the 20th Century (World Health Organization, 1949), the concept of social health generally focuses on social activities, social well-being, social network quality, interpersonal communication, social support, and social role participation and satisfaction (Castel et al., 2008). Despite the importance of mental health for the QOL of the general population, biological assessment of QOL in non-clinical populations is poorly understood. QOL is typically considered to comprise three to six dimensions or life domains (Shumaker et al., 1990; Spilker, 1990; Ferrell et al., 1997). For example, a previous study suggested that comprehensive models should specify three broad QOL domains (physical, social, and psychological), with various specific, interrelated aspects and dimensions identified within each (Spilker, 1990). Recently, in dimensions of QOL, social functioning has received widespread attention as one of the most important outcomes in psychiatric disorders and has been related

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to cognitive functioning and underlying brain activity (Pu et al., 2014). Furthermore, in general, participants with problems in aspects of social functioning show lower QOL scores than those without such problems (Trompenaars et al., 2007). Consequently, investigation of the relationship between social functioning and brain activation is one approach to understanding the underlying nature of QOL in greater depth. Many brain activation studies using a combination of brain images and cognitive tasks have helped reveal the neural basis of psychiatric disorders such as major depressive disorder (Hugdahl et al., 2004; Harvey et al., 2005; Pu et al., 2008). For example, Pu et al. (2008) reported that reduced activation of the frontopolar region correlated positively with lower self-assessment of social functioning in a patient group. However, only a small number of studies have examined the relationships between social functioning, affective symptoms, cognitive function, and brain activation in non-clinical populations. Sawa et al. (2013) suggested that the degree of affective symptoms was associated with lower QOL in a nonclinical population, and that cortical hypoactivation during a verbal fluency test measured by near-infrared spectroscopy (NIRS) may objectively identify individuals with a high-degree of affective symptoms. Pu et al. (2014) reported a significant positive relationship between total score for the social adaptation self-evaluation scale (SASS) and activation of the prefrontal cortex (PFC) in healthy, elderly adults. Those findings suggest that PFC activation is associated with social functioning in non-clinical populations. Despite those studies, how the social functioning of individual subjects interacts with brain activation during a mental task remains difficult to explain.

NIRS has been investigated as a noninvasive means of assessing functional activity in the brain via measured hemodynamic responses (Sitaram et al., 2007). Unlike electroencephalography, however, NIRS measurements do not require cumbersome skin preparation and electrode gels. Moreover, the thought processes required to intentionally generate NIRS signals are relatively simple and reflect cognitive function more directly (Coyle et al., 2004). NIRS has been used for the non-invasive measurement of concentration changes in oxygenated hemoglobin (oxy-Hb), deoxygenated hemoglobin (deoxy-Hb), and total hemoglobin (total-Hb) related to brain functions. Optical topography is an application of NIRS using multiple measurement positions that allow brain activation to be imaged (Maki et al., 1995). Optical topography is uniquely useful as a non-invasive modality that can be used without restraining the subject. NIRS determines the properties of brain tissue by transmitting near-infrared electromagnetic radiation (wavelengths, 650–950 nm) through the skull and comparing the intensities of returning and incident light. Because the fraction of light absorbed versus the fraction transmitted is dependent on the concentrations of intervening chromophores, NIRS can be used to assess hemodynamic responses in regions such as the motor cortex (using motor imagery tasks (Sitaram et al., 2007)) and prefrontal cortex (using music imagery (Blood and Zatorre, 2001), mental arithmetic (Villringer and Chance, 1997), or preference tasks (Luu and Chau, 2009)). The present study used NIRS to assess PFC activity during an intelligence task.

This study aimed to evaluate whether PFC activity measured by NIRS might represent a biological assessment of social functioning when the affective state is evaluated in a non-clinical population. We hypothesized that abnormal cortical activation in a non-clinical population, as measured by NIRS, would be associated with social functioning in a neuro-psychological profile. We performed the following study to test this hypothesis directly.

2. Methods

2.1. Subjects

Eighty healthy volunteers (30 males, 50 females) participated in this study (mean age, 20.94 ± 0.48 years; range, 20–22 years). All subjects were determined to be right-handed using the Edinburgh Handedness Inventory Scale (Oldfield, 1971). Participants were recruited from the Prefectural University of Hiroshima. Participants were recruited primarily via e-mails, advertisements in a campus newspaper, and recruitment posters. Participants also had to be able and willing to attend the research study. All participants were students. No subject had a history of neurological disorder, major psychiatric disorder, substance abuse, head injury, or major physical illness, or was using any psychotropic medications at the time of the study. Assessments for affective states were based on self-rating scales with a structured diagnostic interview (Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition). All study protocols were approved by the ethics committee of the Prefectural University of Hiroshima. The content of the study and ethical considerations related to subjects were explained to subjects, and written informed consent to participate in the study was obtained prior to participation.

2.2. Activation task

The activation task consisted of a 3-min pre-task baseline, a serial arithmetic task, and a 3-min post-task baseline. Each subject sat on a comfortable chair in a quiet room and was instructed to keep their head as immobile as possible and not to speak. The task was a serial addition test (Sugimoto et al., 2009) that required subjects to perform calculations as fast and accurately as possible within 15 min. This was achieved using pre-printed paper containing 15 lines of random, single-digit, horizontally aligned numbers. For each minute of the test, the subject was instructed to begin a new line regardless of their position on the current line. Each line contained an excess of calculations such that the subjects would be unable to finish any line in a particular minute before being prompted by the examiner to move to the next line for the next minute. The number of answers for each test was used as an index of task performance (Yoto et al., 2014).

2.3. Assessment of intelligence quotient (IQ), affective symptoms, extent of apathy, feelings of stress, and QOL

Each subject was assessed for estimated IQ, affective symptoms, extent of apathy, and feelings of stress. The National Adult Reading Test (NART) was used as simple and quick assessment of intelligence. The NART is widely used as a measure of premorbid IQ. A Japanese version of the NART (JART) was used that contained 50 Japanese irregular words, all of which were kanji (ideographic script) compound words. Reading performance based on JART and IQ as measured by the Wechsler Adult Intelligence Scale-Revised (WAIS-R) was examined in a sample of 100 normal elderly individuals. A linear regression equation was obtained in which the observed full-scale IQ was regressed on the reading errors of the JART (Matsuoka et al., 2006).

Subjective affective symptoms were measured using the Zung Self-rating Depression Scale (SDS) (Zung, 1965), a self-rating scale that consists of 20 questions. The SDS score ranges from 20 (best) to 80 (worst), and mean (± standard deviation (SD)) score in a normal control Japanese population was 35.1 ± 8.0 (Fukuda and Kobayashi, 1983). Higher score on the SDS is indicative of a relatively greater degree of affective symptoms.

The extent of apathy was measured using the Apathy Scale