Available online at www.sciencedirect.com
SCIENCE DIRECT®
Neuroscience Letters 375 (2005) 53–58
Neuroscience Letters
www.elsevier.com/locate/neulet

Multichannel NIRS analysis of brain activity during semantic differential rating of drawing stimuli containing different affective polarities

Miho Suzuki*, Jiro Gyoba, Yuiko Sakuta

Department of Psychology, Graduate School of Arts and Letters, Tohoku University, 27-1 Kawauchi, Aoba-ku, Sendai 980-8576, Japan

Received 3 August 2004; received in revised form 28 September 2004; accepted 25 October 2004

Abstract

We used 24-channel near-infrared spectroscopy (NIRS) to measure activity in the temporal, parietal, and frontal regions of the brain in eight Japanese women while the participants rated line drawings using semantic differential scales. Participants rated the seven line drawings on 15 bipolar semantic scales, each of which belonged to one of three semantic classes: Evaluation, Activity, or Potency. Suzuki et al. [M. Suzuki, J. Gyoba, Y. Sakuta, Multichannel near-infrared spectroscopy analysis of brain activities during semantic differential rating of drawings, Tohoku Psychologica Folia 62 (2003) 86–98.] had reported previously that the right superior temporal gyrus and the right inferior parietal lobule are associated with Activity rating, while the brain regions around the central fissure were related to Potency rating. Based on these suggestions, we investigated the brain activity in these regions during rating of stimuli containing different affective polarities. When drawings were reported as 'static' or 'calm', oxyhemoglobin concentration was higher around the right superior temporal gyrus as compared to when they were considered 'noisy' or 'excitable'. Oxyhemoglobin concentrations around the central fissure were also higher when drawings were rated as 'soft', 'smooth', or 'blunt' compared to 'hard', 'rough', or 'sharp'. Any characteristic oxyhemoglobin changes were not found during the ratings on the evaluation scales. Our results suggest that activation patterns of the temporal and parietal regions are significantly modified by semantic polarities of Activity and Potency.

Keywords: Near-infrared spectroscopy; Hemoglobin concentration; Auditory cortex; Somatosensory cortex; Semantic differential; Drawing

The semantic differential technique developed by Osgood et al. [15] has been widely used and found to be very useful for measuring the affective meanings of various stimuli. In this technique, participants rate stimuli on adjective scales, and potential factors that structure the multivariate data are extracted by factor analysis. In most cases, three factors are extracted: Evaluation (representative scale: good–bad), Activity (active–passive), and Potency (strong–weak). These factors have been commonly found across different cultures and various stimulus domains [14,15,27].

Different brain activity patterns have been observed when word stimuli belonging to different semantic classes defined by these three factors are being processed. Previous studies have reported that the connotative meanings of words can systematically alter event-related brain activity [2,3,20,21]. Chapman et al. [3] recorded evoked potentials in an electroencephalogram (EEG) while participants read words that belonged to each semantic class. They found that different components of the EEG correlated with each semantic class. Furthermore, Skrandies [20] and Skrandies and Chiu [21] reported that the topography, latency, and field length of event-related potentials (ERPs) correlate with the semantic class of the word stimulus, especially at short latency. These findings suggest that different cortical regions are responsible for processing different semantic classes. However, since these previous studies mainly used ERP for their investigations, they were not able to clarify precisely the region related to each class.

It has been argued that the factors extracted by the semantic differential technique contain connotative aspects rather than denotative aspects of meaning in the sense that they are more broadly affective than discriminatively cognitive [14]. Also, it has been pointed out that the three main

* Corresponding author. Tel.: +81 22 217 6048; fax: +81 22 217 3703.
E-mail address: suzukim@sal.tohoku.ac.jp (M. Suzuki).

0304-3940/$ – see front matter © 2004 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.neulet.2004.10.065

factors (Evaluation, Activity, and Potency) have different information-processing bases, especially with respect to their sensory relevance. Many previous studies reported that during judgment of drawings, words, and music, the scales related to the Activity factors are often refer to auditory perceptions such as dynamic-static, excitable-calm, and noisy-silent [16,23,22,25]. Furthermore, Takahashi [25] and Suzuki and Gyoba [22,23] also reported that when judging line drawings, Potency factors often involve adjective scales related to tactile perception, such as soft-hard, smooth-rough, or blunt-sharp. In contrast, the Evaluation factor is characterized by scales such as likable–repugnant, beautiful–ugly, and unpleasant–pleasant. Thus it is highly likely that the Evaluation factor is associated with subjective emotional concepts that are not dependent upon sensory processing or modalities, whereas the Potency and Activity factors are much more closely related to sensory properties.

Based on these considerations, Suzuki et al. [24] investigated the regions corresponding to each factor during a semantic differential task applied to affective drawings using multichannel NIRS (near-infrared spectroscopy). They reported that the right superior temporal gyrus and right parietal gyrus were activated when line drawings were rated on Activity scales, whereas the left pre- and post-central gyri were activated during judgments on Potency scales. These results suggest that activity in brain regions corresponding to auditory, kinesthetic, and somatosensory modalities are modified during the judgment of affective meaning related to Activity or Potency. During the ratings on Evaluation scales, no specific activation was observed in those sensory-related areas.

Some previous research using ERP recordings [2,3,20,21] also reported that brain activity correlated with the rating itself along a bipolar semantic scale. In this study, therefore, we used NIRS to examine how brain activity is related to the polarity of semantic differential judgments of drawings, focusing on areas involved in auditory, kinesthetic, and somatic sensation. Multichannel NIRS allowed us to measure only the surface-level cortical activity. However, we can confirm the extent of sensory relevance for each semantic factor by measuring changes in hemoglobin concentration within sensory-related association cortices. Therefore, we expect that the activation patterns of auditory-related areas would be modulated by the polarity of the Activity dimension and those of kinetic or somatosensory-related areas by the polarity of Potency dimension. The Evaluation dimension, on the other hand, would not substantially affect the activation of those areas.

NIRS measures spectroscopic reflection and scattering from a single region with a light source and a detector [1,5,6,28]. Multichannel NIRS is able to record temporal changes in hemoglobin oxygenation simultaneously from multiple regions [8,9,30]. There are several advantages of multichannel NIRS compared with other neuro-imaging methods, such as its flexibility, portability, and low cost. Several studies have reported that multichannel NIRS is a useful measure of brain activity, including those involved in motor systems [10], speech recognition [19], epileptic seizures [29], post-traumatic disorders [11], mood disorders [12], language lateralization [7], emotional induction [4], and language recognition [17].

In the present study, we reanalyzed the data collected by Suzuki et al. [24]. The procedure used in our previous study was briefly described below. We employed a 24-channel (12 on each side) near-infrared spectroscopy (ETG-100, Hitachi Medical Corporation, Tokyo, Japan). Laser diodes at two wavelengths (780 and 830 nm) were used as the light sources. The reflected lights were detected with avalanche photodiodes located 30 mm from an incident position. The signal was separated into two components corresponding to the two wavelengths using lock-in amplifiers. The relative concentration changes of oxyhemoglobin, deoxyhemoglobin, and total hemoglobin were calculated using the difference in the absorption indices for the two wavelengths. The sampling interval was 100 ms. In the present study, the (6 cm × 6 cm) arrays covered a portion of the bilateral temporal, parietal and frontal regions (Fig. 1). The open circles and filled circles denote light-source fibers and detection fibers. The numbers signify the measurement channel corresponding to the central zone of the light path between the source and the detection fibers. A pair of head shells with probe sockets was attached, one shell on either side of the participant's head. The center column of the probe sockets was adjusted to be aligned with the lughole (Fig. 1). The 3D coordinates for the location of each probe and the scalp shape of each participant were measured using a Polhemus sensor system.

We used the same seven line drawings developed in Suzuki et al. [24] (Fig. 2). These stimuli had high factor scores on the Evaluation, Activity, or Potency scales of the semantic differential technique. They had also been confirmed in previous studies [22,23,25] to be representative of abstract concepts such as depression, joy, anxiety, human energy, femininity, anger, and tranquility.

The 15 adjective scales were selected from those used by Suzuki and Gyoba [22,23]. Five of them belonged to each of the semantic classes (Evaluation, Activity, or Potency). The 15 scales were as follows. Evaluation; beautiful–ugly,

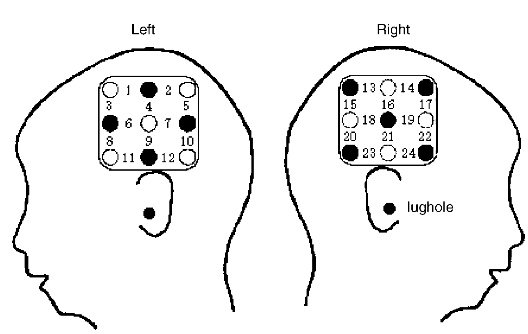

Fig. 1. The position of the NIRS head shell. The open circles, filled circles and numbers signify light source fibers, detection fibers, and the measurement channels, respectively.