Experimental Study on Cerebral Hemodynamics during Observation of Plants

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ABSTRACT

Psychological and physiological effects of plants were studied by investigating human responses while observing plants. Eighteen healthy adult male(aged between 19~25 years) participated in this study. Semantic differential method(SD method) and multi-channel near-infrared spectroscopy(NIRS) were used to survey verbal and non-verbal response, respectively. Cerebral hemodynamics as a new evaluation index of brain activity was recorded for right brain hemisphere where visual information is mainly delivered. Thirty seconds of cerebral blood flow in forty seven channels were calculated when watching five types of picture images with different rates of hedge against gray block wall; 0:10, 3:7, 5:5, 7:3, 10:0. In the SD results, similar evaluations were found in all subjects. However, the change of cerebral hemodynamics as a non-verbal response varied among subjects. Largely two patterns of hemodynamics change were found with increasing plants rate in picture images; group A showed significant decreases of blood flow volume in many cortical regions, Group B had significant increase of blood flow volume in the occipital region for the scenes seen comparatively more plant. Our findings on the cerebral hemodynamics may indicate that there are two patterns of brain activity during observation of plants; group A in which brain areas associated with visual information and thinking work simultaneously to the visual stimuli; group B in which brain areas associated only with visual information work.

Key Words: Psychological and Physiological Effect of Plant, Cerebral Hemodynamics, Nirs, Hedge, Block Wall

I. Introduction

Therapeutic effects like mental healing and stress reduction have been recognized as an important benefit derived by plants. These benefits of plants for human health, called psychological and physiological effect of plants, has been stressed for an argument in support of urban green space(Ulrich, 1986) together with the physical and biological effects. But, the quantitation and objective assessment of the psychological and physiological effect were considered as difficult work due to individual differences in psychological and physiological responses. Since 1970s, human physiological response in contact with plant has been measured using blood pressure, pulse or electroencephalogram(hereafter, EEG). Especially, EEG has been used in many studies as an important index of brain activity that shows characteristics of mental and physical activities and brain activity while viewing natural views often shows unique patterns(Tada *et al.*, 1996).

In previous studies investigated EEG, the natural and artificial scenes had different effects on cortical activity(Ulrich, 1986). Nakamura and Fujii(1992) surveyed the characteristics of EEG with gradual increase of tree rate against block wall in a view and found alpha-wave significantly increased for the higher tree rate scenes. It is also reported that alpha-wave amplitudes were higher while subjects viewed a group of trees than a tree individual(Saito, 1985). However, currently the EEG often lacks of accuracy and time resolution as an index of brain activity.

Figure 1. Five picture images with different proportions of hedge:block wall

A relatively new technique, near-infrared spectroscopy (hereafter, NIRS), has been used to measure changes in cerebral oxygenation in human subjects(Baird *et al.*, 2002). Changes of oxyhemoglobin and deoxyhemoglobin in cerebral Blood Flow Volume(hereafter, BFV) reflect changes in neurophysiological activity and can express brain activity more concretely than EEG. Therefore, cerebral hemodynamics measured by NIRS may be a useful index of brain activity. Although several studies were reported on the cerebral hemodynamics in contacting with plants(e.g. Date 2003; Kwon *et al.*, 2004), many things remain still unclear to consider the relationships between NIRS data and mental activity and data available are still limited.

Our aim is to investigate the cerebral BFV changes in the cortical areas and verbal response while observing plant and to consider the relationships between cerebral BFV changes and mental activities.

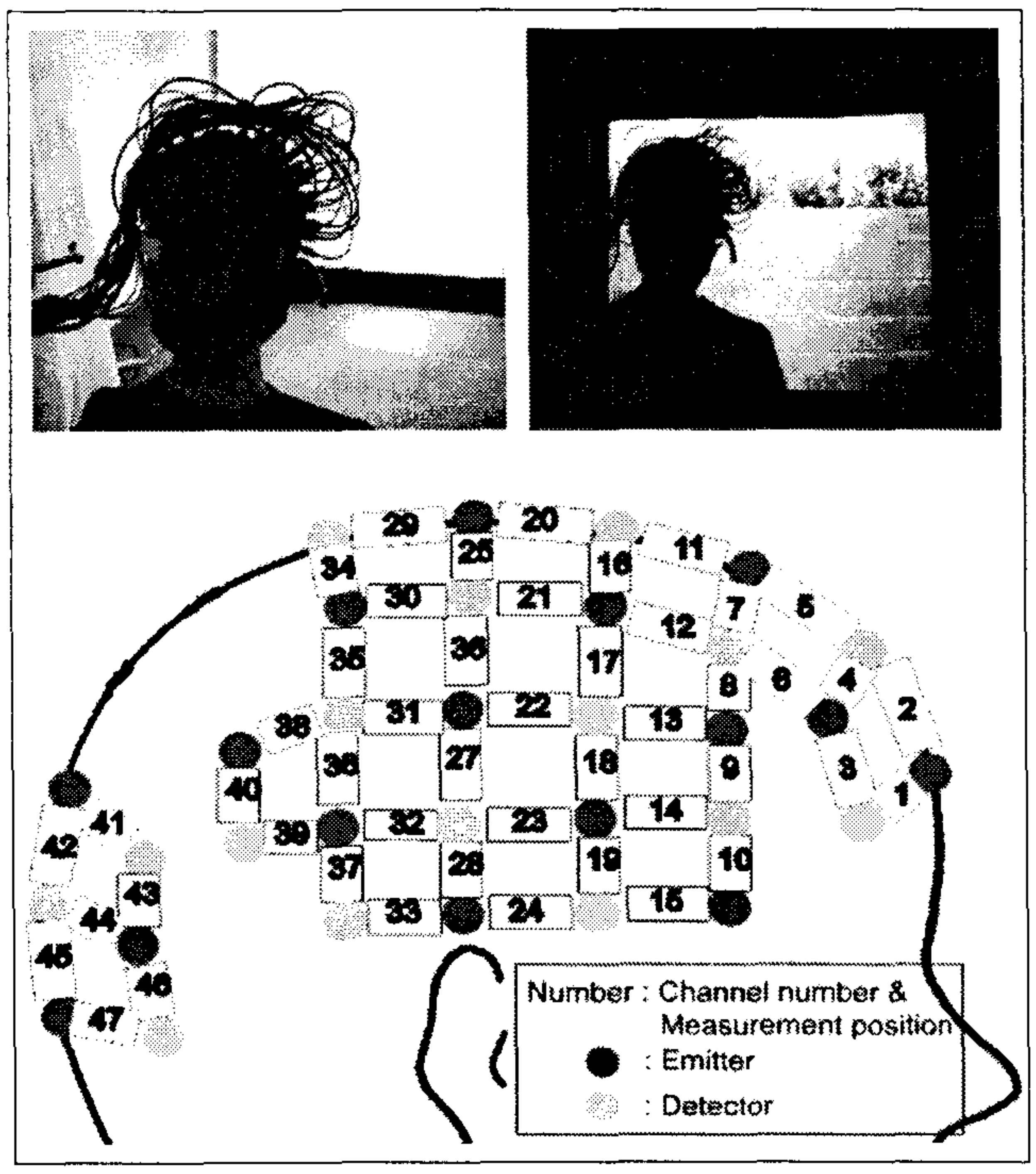

Figure 2. The NIRS was secured on the right hemisphere using headset(top). Configuration of measurement points(bottom).

II. Subjects and Methods

1. Subjects

Eighteen male volunteers(aged between 19~25 years) participated in this study. Informed consent was obtained from each subject in accordance with a protocol reviewed and approved by the Human investigation Committee of Chiba University.

2. Stimuli

Five types of picture images with different rates of hedge(*Camellia sasanqua*) to gray block wall(0:10, 0GR; 3:7, 3GR; 5:5, 5GR; 7:3, 7GR; 10:0, 10GR:GR=GREEN) were prepared according to the Nakamura *et al.*(1992)'s study (Figure 1). Picture images were projected to 1580×2440mm white screen through a high definition projector. Subjects observed the screen seated on a chair from a distance of 2800mm(Figure 2 top). Subjects were informed that they would see a screen and that they would evaluate the impressions of the scene by Semantic differential method(SD method) composed of eighteen adjective pairs describing mood.

3. Data Acquisition and Analysis

Cerebral hemodynamics was recorded using NIRS(OMM-2001, Shimazu, Japan) that can accurately measure absolute changes in the local BFV as a non-invasive method. Forty seven channels(ch1-ch47) were set on the right brain hemisphere of each subject where is known to play a critical role in the recognition of visual information(Albert, 1975). Six channels were set on frontal region, fourteen channels on parietal region, twenty channels on temporal region and seven channels on occipital region(Figure 2 bottom). Before observing the screen, the subject was allowed to take thirty seconds rest on a chair watching white screen. After rest, the subject viewed the screen with images for thirty seconds. After recording NIRS data for each image, impression evaluation using SD method were tested during approximately five minutes. Therefore, approximately six minutes were taken for one visual image and totally thirty minutes. This six minutes protocol was applied for five visual images randomly presented. Test was carried out in the sealed room of Chiba University where the air temperature was maintained at 23℃.

Data were analyzed separately for each channel. For each channel's data, BFV was examined with the changes in oxygenated hemoglobin(HbO2). BFV was recorded every 0.49-second for each channel in order to catch delicate brain activities. For each channel, we calculated the average ten seconds BFV during the rest period and compared this with each 0.49-second data during the stimuli period. Therefore, the 0.49-second time segment with significantly higher or lower value than the average of the rest period was calculated. T-test was used to verify the difference and cluster analysis was performed to compare the similarity of BFV characteristics between subjects. In addition, Steel-Dwass test was applied for the comparison of the semantic differential(SD) scoring. Factor analysis was also done to reveal underlying commonalities and differences among the SD scales.

III. Results

1. General Trend of Cerebral Hemodynamics and SD Evaluation

We could find important trends in HbO2 changes for all subjects during observing five different scenes(Figure 3). With increasing rate of plant in a screen(from 0GR to 10GR), significant increase of BFV was found around the frontal area(Figure 4 top).

For the 0GR scene, significant increase of BFV was detected in occipital region(ch44); for the 3GR, significant decrease of BFV in frontal region(ch4); for the 5GR, significant increase of BFV in occipital region(ch44 and ch45) and significant decrease of in frontal(ch2 and ch3) and temporal region(ch17 and ch22); for the 7GR, significant decrease in frontal(ch2), preparietal(ch8, ch11 and ch16) and pretemporal regions(ch9, ch10 and ch15); for the 10GR, significant decrease in overall channels in frontal, parietal and temporal regions and significant increase in occipital region(ch44).

In the verbal response using SD method, the overall evaluation to screen images presented were apparently divided between 0GR, 3GR and 7GR, 10GR by 5GR, with more positive evaluations in 7GR and 10GR(Figure 5 left). Factor analysis extracted five factors of liveliness, openness, comfortableness, brightness and largeness. Among these, liveliness

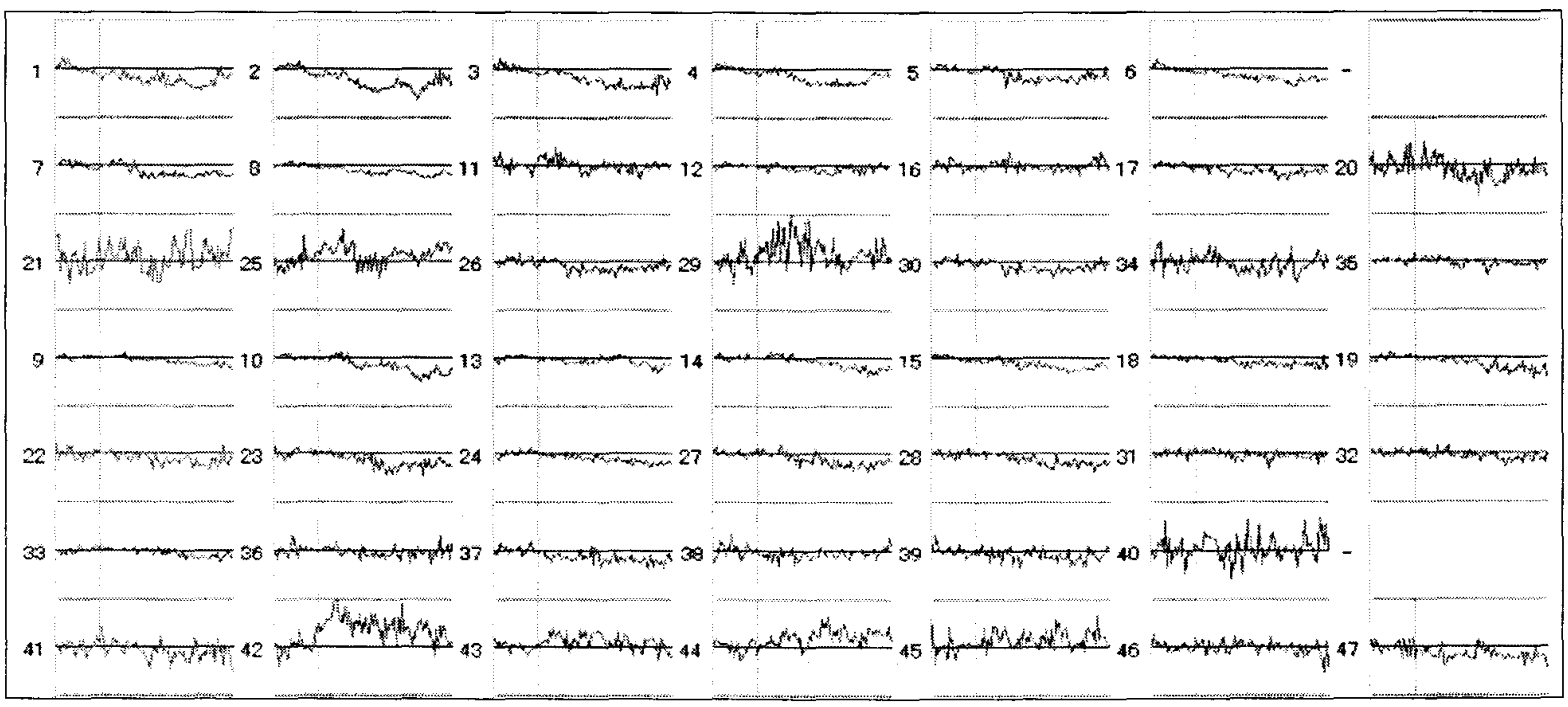

Figure 3. Changes of the blood flow volume(HbO2) in 47 channelsfor all subjects while viewing the 10GR
Average 0.49-sec values are presented. Vertical scale is ±0.02 mol/secμ and horizontal scale is -10~30sec; vertical line in a graph means the beginning of visual stimuli.

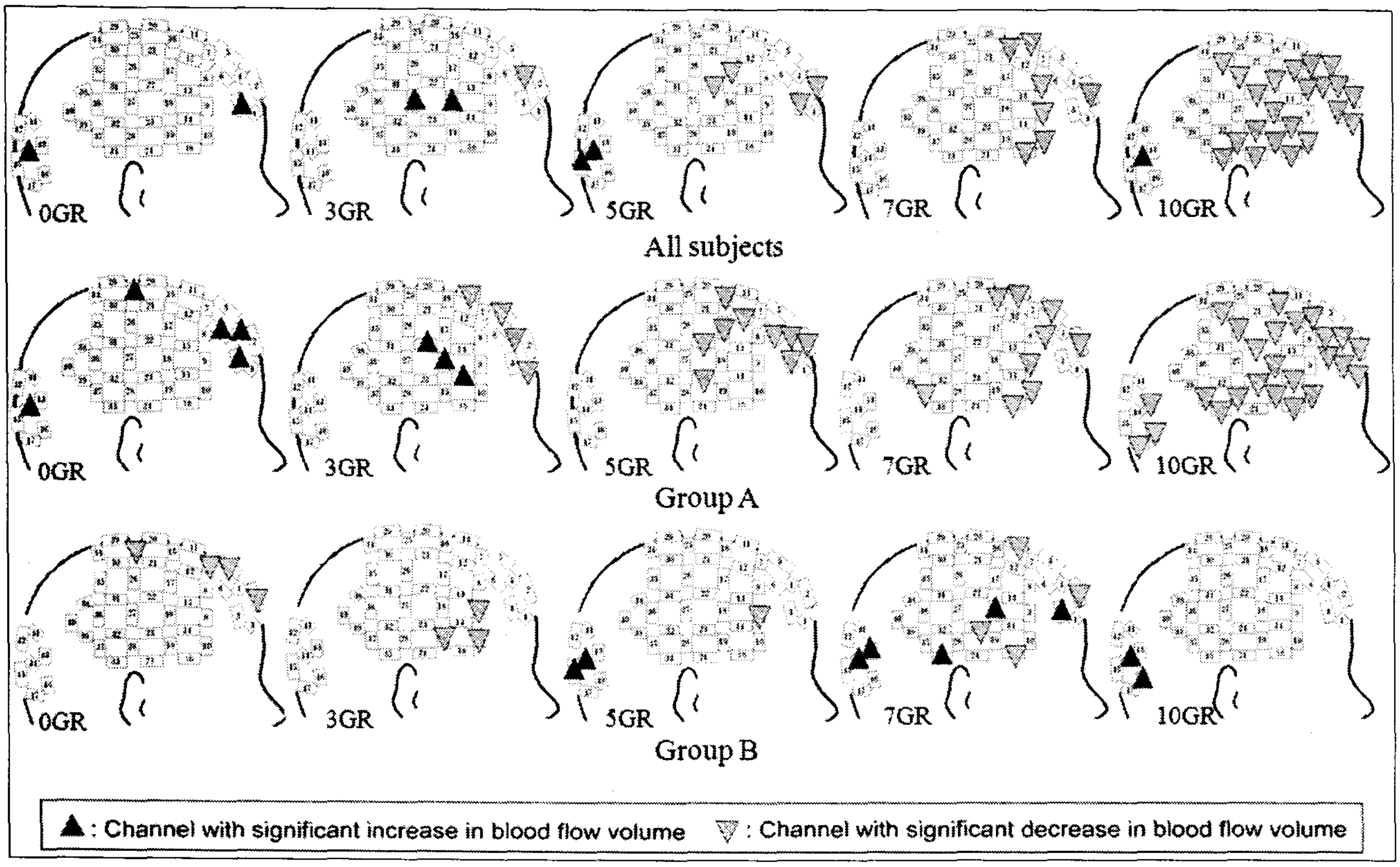

Figure 4. Temporal changes of the cortical regions with significant changes in the concentration of HbO2 along with increasing plant proportion of plant in a scene

and openness were positively correlated with the increasing plant proportion in a screen image(Figure 5 mid).

2. Two Different Patterns in Hemodynamics

We focused on the BFV changes in occipital cortex where is known as one of the most responsive area when viewing plants(Kim and Fujii, 1995) to survey the individual differences in brain activity. Therefore, we analyzed the BFV changes of each subject in occipital region during observing the 10GR screen and we could find twelve subjects with significant decrease of BFV(Group A) and six with significant increase of BFV(Group B) compared to the rest period.

Subjects in group A were characterized by significant decrease of BFV along with increasing rate of plant in a screen image, and by significant decrease in overall regions for the 10GR scene(Figure 4 mid). More concretely, for the 0GR, significant increases of BFV were found in frontal(ch3, ch4 and ch6), parietal(ch25) and occipital regions(ch11); for the 3GR, significant increases in temporal regions(ch18 and ch22) and significant decreases in frontal(ch1, ch4 and ch5) and temporal regions(ch11); for the 5GR, significant decreases in frontal(ch2, ch3, ch4 and ch6), preparietal(ch12, ch16 and ch17), temporal(ch22 and ch23); for the 7GR, significant decreases in frontal(ch2, ch5 and ch6), parietal(ch11, ch16, ch22 and ch23) and temporal regions(ch9, ch10, ch15 and ch37); for the 10GR, significant decreases in many channels over the right brain cortex.

Subjects in group B were characterized by partial decrease in 0GR and 3GR and significant increase in occipital regions in 5GR, 7GR and 10GR(Figure 4 bottom). For the 0GR, significant decreases of HbO2 volume were detected in frontal(ch2 and ch5) and parietal regions(ch7 and ch23); for the 3GR, significant decreases in temporal regions(ch9, ch10 and ch19); for the 5GR, significant decreases in temporal region(ch9); for the 7GR, significant decreases in frontal(ch2), parietal(ch11) and temporal regions(ch15 and ch23) and significant increases in frontal(ch3), parietal(ch11), temporal(ch18 and ch33) and occipital regions(ch43 and ch44); for the 10GR, significant increase in occipital regions(ch44 and ch46).

There were no significant differences in SD evaluation between Group A and B.

Ⅳ. Discussion

Our BFV data showed general characteristics of psychological and physiological responses when observing plant. Furthermore, our multi-channel NIRS data suggested that there can be differences in the psychological and physiological response while viewing plant among individuals and these differences could be categorized largely into two groups. Distinctive differences in brain activities between Group A and B may be explained by different traits of neurophysiological response to the visual stimuli. It has been generally recognized that different brain area plays different role, with frontal region involved mainly in mental activity, preparietal region in eye movement, pretemporal region in recognition and memory of the objects, and occipital region in perceiving visual stimuli. Miyazaki(2003) reported that cerebral BFV around frontal region tended to decrease under the relaxation condition and Kim *et al.*,(1994) revealed that the eye movement of subjects got slower when viewing green color than viewing white color similar with the block wall. In this perspective, hemodynamic characteristics seen in Group A are likely to be the results of the psychological relaxation during observation of plant that might cause slow eye movement, which indicates both visual area and thinking area in brain cortex respond simultaneously. And hemodynamics detected in Group B could be considered by the activation of recognition of visual information to the images with higher proportion of hedge that presents more complex modes of shapes and colors than block wall, which means only visual area in cortex respond to the stimuli.

It is also worth noting that Both Group A and B had significant changes in hemodynamics and SD evaluation around the 5GR. This result was almost entirely consistent with the Nakamura *et al.*,(1992)'s results(Figure 5 right). Given that there were no significant differences in verbal response among individuals despite individually different attributes of brain activities, it is estimated that viewing plant may significantly increase positive affects such as liveliness and openness. In this view, it is likely to be supported that visual encountering with plant can inspire people to feel better when they are uncomfortably stressed or anxious.

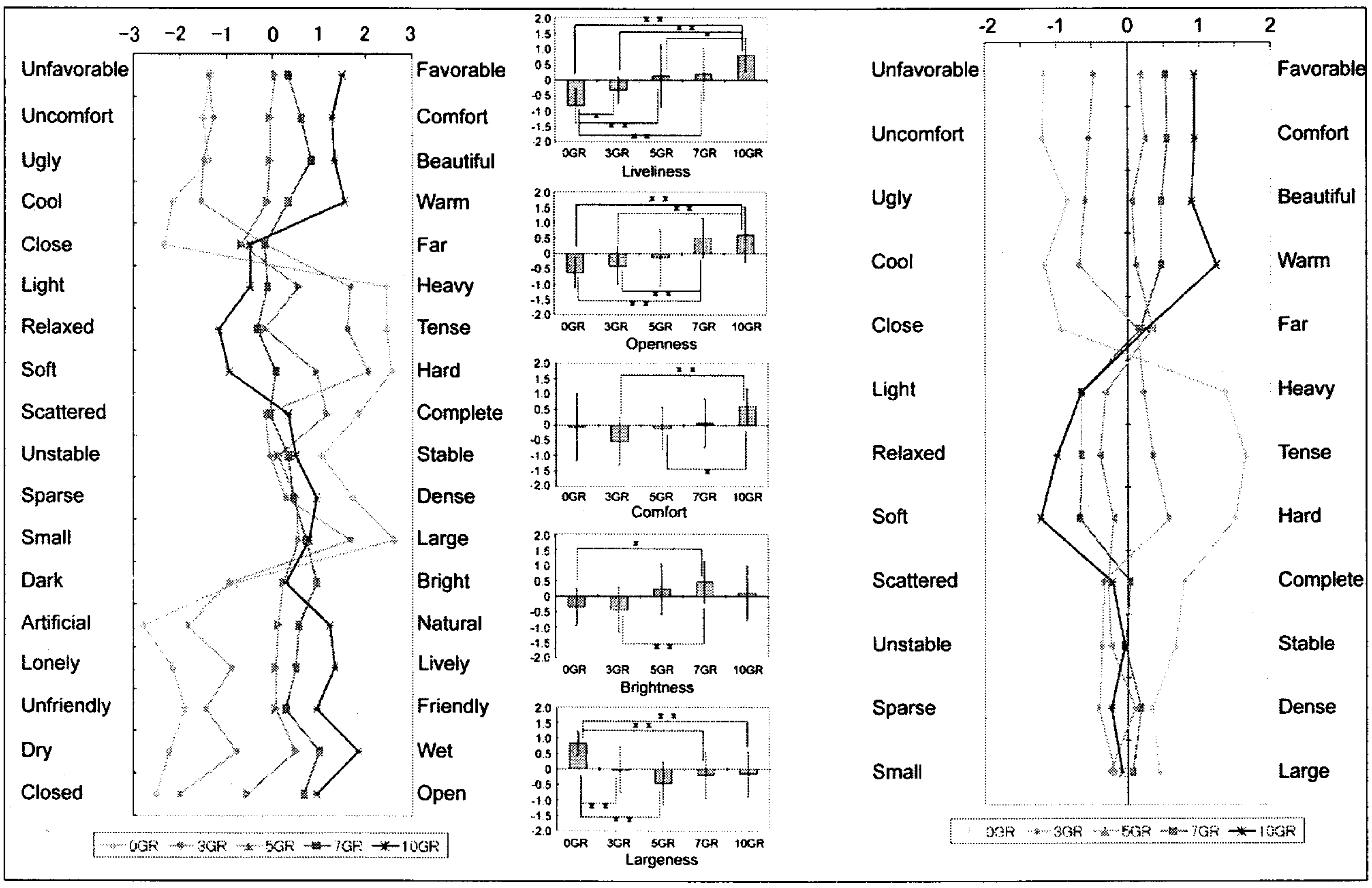

Figure 5. The results of impression evaluation by SD method(left) and factor analysis(mid) for five picture images. Nakamura et al.(1992)'s results using Magnitude method is on the right.

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