Effect of Frequent Degree of Deceiving on the Prefrontal Cortical Response to Deception: A Functional Near-infrared Spectroscopy (fNIRS) Study

Fang Li[1,2], **Huilin Zhu**[1*], **Shijing Wu**[1], **Qianqian Gao**[1,2], **Ziqiang Hu**[1,2], **Jie Xu**[1], **Guixiong Xu**[1], **and Sailing He**[1,3]

[1]Centre for Optical and Electromagnetic Research
South China Academy of Advanced Optoelectronics South China Normal University (SCNU)
Guangzhou 510006, China
[2]School of Psychology, South China Normal University (SCNU), Guangzhou 510631, China
[3]Department of Electromagnetic Engineering, Royal Institute of Technology, Stockholm 10044, Sweden

Abstract— Functional near-infrared spectroscopy (fNIRS) is an emerging brain-imaging technique which has been used to various areas. Previous studies have indicated that frequent deceiving would make deceiving easier. In this study, fNIRS was used to explore the effect of frequent degree of deceiving on the prefrontal cortical response to deception. Self-related questions were used in the experiment. The results showed different patterns of neural activation between non-frequent deceiving and frequent deceiving. In Channel 11 (in the left prefrontal cortex), non-frequent deceiving led to a greater neural activation than telling the truth, while this pattern did not appear in frequent deceiving. Our finding suggested that fNIRS has ability to detect deception under different situations.

1. INTRODUCTION

Functional near-infrared spectroscopy (fNIRS) is a new brain-imaging technique which can measure the neural activities of the cortical regions of the brain [1]. It can simultaneously assess the concentration changes of oxy hemoglobin (HbO), deoxy hemoglobin (Hb) and total hemoglobin (HbT) [2], which are the three indicators of cerebral metabolism. In recent years, fNIRS has been widely used because of its non-invasiveness, low cost, excellent temporal resolution and reasonable spatial resolution [3–5].

Deception is a common behavior in the social circumstances. In real life, deceiving requires more effort in contrast to telling truth [6]. Recent fNIRS studies have consistently revealed that deceiving could cause greater neural activation than telling truth in the prefrontal cortex [7, 8]. However, many other factors can affect the brain activities of deceiving, such as the frequent degree of deceiving. Verschuere et al. found that frequent deceiving could make deceiving easier, in other words, people needed not put too much effort to deceive when they deceived frequently [9]. In agree with this finding, other fMRI studies confirmed that deceiving more could decrease the neural activation during deceptions [10, 11].

In the present study, we firstly used fNIRS to investigate the effect of the frequent degree of deceiving on the neural activities of the deception. In order to increase the ecological validity of this study, we used self-related questions in the experiment because self-related questions are more meaningful to the participants. Furthermore, previous studies provided evidence that self-related deception could lead to greater neural activation than non self-related deception [12, 13]. Therefore, we inferred that self-related deception was more sensitive to the frequent degree of deception.

2. METHODS

2.1. Participants and Protocol

12 college students participated in this study. They were all right-handed and had no neurological or psychiatric diseases.

Before the experiment, each participant was required to fill out a questionnaire which contained 64 self-related questions (for example, “Do you have a younger male cousin?”). Then each participant was told to complete two conditions: baseline condition and task condition. In the baseline condition, participants were required to tell the truth all the time when asked self-related questions; In the task condition, participants were required to make skillful deception. They could decide by

*Corresponding author: Huilin Zhu (huilin.zhu@coer-scnu.org).

their own whether or not to deceive in a given question. Each condition had 32 questions, which were the same as the questionnaire. 32 questions in one condition were set in a random order.

2.2. Experimental Setup

42 channels of an fNIRS system (FOIRE-3000, Shimadzu Corporation, Kyoto, Japan) with three wavelengths (780 nm, 805 nm, and 830 nm) were used. The parameters of concentration changes of oxygenated hemoglobin (HbO), deoxygenated hemoglobin (HB) and total hemoglobin (HbT) were measured. These three parameters were determined with the modified Beer-Lambert law. The international 10-10 system [14] was used to localize the different areas of the prefrontal cortex (PFC) (Fig. 1).

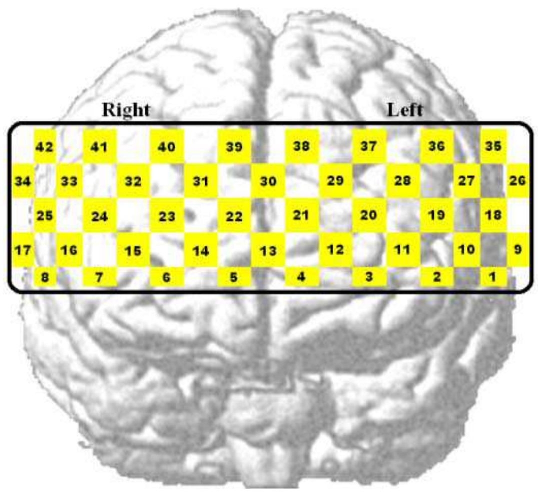

Figure 1: 42 channels covering the prefrontal cortex of the brain.

2.3. Data Analysis

By using the NIRS-SPM [15], the hemodynamic response function filter and a wavelet-MDL (minimum description length) detrending algorithm were used to remove physical noise and artifacts. In this study, only the data of change in HbO was selected because HbO signal was most sensitive to neural activation.

To explore the effect of the frequent degree of deceiving on the neural activities of the deception, several steps were performed: Firstly, the number of deceiving in the task condition was calculated for each participant. Then all the participants were ranked according to the number of deceiving from high to low. The top 50% of the participants were divided into frequent deceiving group, and other half were divided into non-frequent deceiving group. Secondly, the truth-telling trials in the baseline condition and the deceiving trials were selected for further analysis. The truth-telling trials were defined as the trials in which the answers of self-related questions were consistent with the questionnaire, and the deceiving trials were defined as the trials in which the answers of self-related questions were not consistent with the questionnaire. Thirdly, truth-telling trials in the baseline condition and deceiving trials in the task condition were averaged channel by channel for each participant. At last, 2 (truth-telling vs. deceiving) $\times 2$ (frequent deceiving vs. non-frequent deceiving) repeated measurement analysis of variance was performed.

For depicting HbO activation maps of different groups, the HbO data of truth-telling trials and deceiving trials were averaged across the participants respectively in each group, then the HbO data of "deceiving trials *minus* truth-telling trials" of the two groups were calculated.

3. RESULT

HbO activation maps were shown in Fig. 2. Greater HbO activation was observed in the case of deceiving (whether non-frequent deceiving or frequent deceiving) as compared to the case of telling the truth. In addition, different HbO activation patterns were shown in non-frequent deceiving and frequent deceiving.

The statistical analysis showed that the main effects of trial type were significant ($p < 0.05$) in channels 36 and 42. In these two channels, deceiving trials during deception led to significant increase in HbO than truth-telling trials in the baseline. The results also showed that the main

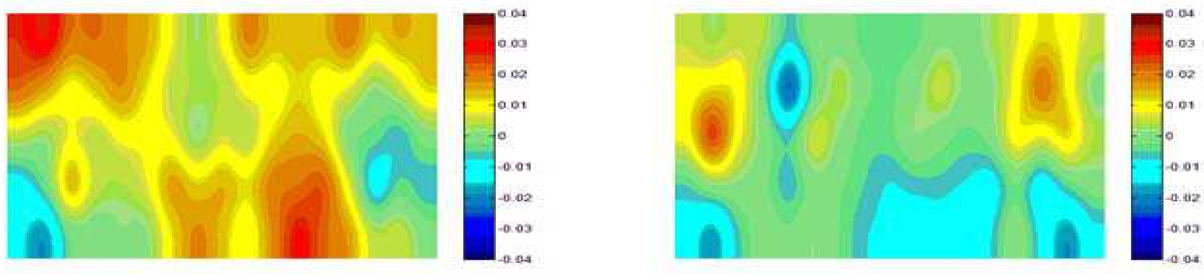

Figure 2: HbO activation maps of two groups. (a) The brain response to "deceiving trials *minus* truth-telling trials" of non-frequent deceiving group. (b) The brain response to "deceiving trials *minus* truth-telling trials" of frequent deceiving group.

effects of group were significant ($p < 0.05$) in Channel 30, 38 and 39. In these three channels, the non-frequent deceiving group showed significant increase in HbO than frequent deceiving group. In particular, the results indicated that the interaction effect of trial type and group was significant ($p < 0.05$) in channel 11. Simple effect analysis showed that the left prefrontal area of non-frequent deceiving group showed significant increase in HbO in deceiving trials during deception than truth-telling trials in the baseline, whereas the comparison between the deceiving trials and truth-telling trials in the frequent deceiving group was not statistically significant (Fig. 3).

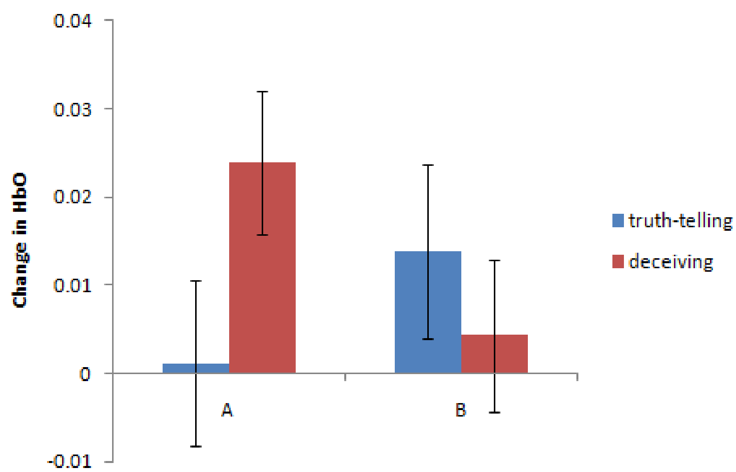

Figure 3: Change in HbO in channel 11 of two groups. A represents non-frequent deceiving group, and B represents frequent deceiving group.

4. DISCUSSION

Recently, fNIRS has been increasingly used in various areas. In this study, we utilized fNIRS to explore the effect of frequent degree of deceiving on the neural activities of deception. We used self-related questions in this experiment.

In this study, we have found that in general deceiving led increased HbO in the prefrontal cortex of the brain than telling truth. This result was in accordance with previous study [12, 13], indicating that when people made self-related deception, they also needed more cognitive effort than telling the truth. Specially, our study showed that when participants deceived, non-frequent deceiving group exhibited greater neural activation in channel 11 in the left prefrontal cortex. However, this pattern did not appear in the frequent deceiving group. This result was in line with previous fMRI studies [10, 11], suggesting that frequent deceiving would make deceiving easier so that people no longer need to put much effort in it [9]. In addition, the function of the prefrontal cortex was related to inhibiting and task switching [16]. Thus frequent deceiving participants did not need too many cognitive resources to inhibit the truth and produce a new response. The present study demonstrated that fNIRS could distinguish the neural response between non-frequent deceiving and frequent deceiving, which implied that fNIRS could be used to detect deception under different situations.

5. CONCLUSION

In summary, we have used fNIRS to examine the effect of frequent degree of deceiving on the prefrontal cortical response to deception. Our findings have shown that non-frequent deceiving and frequent deceiving could cause different prefrontal cortical responses. In the left prefrontal cortex, non-frequent deceiving would lead to greater neural activation than telling the truth, while frequent deceiving would not have such a pattern. These results suggested that fNIRS has the ability to detect deception under different situations.

ACKNOWLEDGMENT

This work was supported by Guangdong Innovative Research Team Program (No. 2010 01D0104799 318), the Natural Science Foundation of Guangdong province (2014A030310502).

REFERENCES

1. Leff, D. R., F. Orihuela-Espina, C. E. Elwell, et al., "Assessment of the cerebral cortex during motor task behaviours in adults: A systematic review of functional near infrared spectroscopy (fNIRS) studies," *Neuroimage*, Vol. 54, No. 4, 2922–2936, 2011.
2. Pouliot, P., T. P. Y. Tran, V. Birca, et al., "Hemodynamic changes during posterior epilepsies: An EEG-fNIRS study," *Epilepsy Research*, Vol. 108, No. 5, 883–890, 2014.
3. Elwell, C., "Shedding light on brain development," *NIR News*, Vol. 25, No. 8, 25–27, 2014.
4. Gálvez-Cerón, A., E. Serrano, J. Bartolomé, et al., "Predicting seasonal and spatial variations in diet quality of Pyrenean chamois (Rupicapra pyrenaica pyrenaica) using near infrared reflectance spectroscopy," *European Journal of Wildlife Research*, Vol. 59, No. 1, 115–121, 2013.
5. Zhu, H., Y. Fan, H. Guo, et al., "Reduced interhemispheric functional connectivity of children with autism spectrum disorder: Evidence from functional near infrared spectroscopy studies," *Biomedical Optics Express*, Vol. 5, No. 4, 1262–1274, 2014.
6. Vartanian, O., P. J. Kwantes, D. R. Mandel, et al., "Right inferior frontal gyrus activation as a neural marker of successful lying," *Frontiers in Human Neuroscience*, Vol. 7, 616, 2013.
7. Sai, L., X. Zhou, X. P. Ding, et al., "Detecting concealed information using functional near-infrared spectroscopy," *Brain Topography*, Vol. 27, No. 5, 652–662, 2014.
8. Ding, X. P., X. Gao, G. Fu, et al., "Neural correlates of spontaneous deception: A functional near-infrared spectroscopy (fNIRS) study," *Neuropsychologia*, Vol. 51, No. 4, 704–712, 2013.
9. Verschuere, B., A. Spruyt, E. H. Meijer, et al., "The ease of lying," *Consciousness and Cognition*, Vol. 20, No. 3, 908–911, 2011.
10. Greene, J. D. and J. M. Paxton, "Patterns of neural activity associated with honest and dishonest moral decisions," *Proceedings of the National Academy of Sciences*, Vol. 106, No. 30, 12506–12511, 2009.
11. Jiang, W., H. Liu, J. Liao, et al., "A functional MRI study of deception among offenders with antisocial personality disorders," *Neuroscience*, Vol. 244, 90–98, 2013.
12. Marchewka, A., K. Jednorog, M. Falkiewicz, et al., "Sex, lies and fMRI — Gender differences in neural basis of deception," *PloS One*, Vol. 7, No. 8, e43076, 2012.
13. Ganis, G., R. R. Morris, and S. M. Kosslyn, "Neural processes underlying self-and other-related lies: An individual difference approach using fMRI," *Social Neuroscience*, Vol. 4, No. 6, 539–553, 2009.
14. Koessler, L., L. Maillard, A. Benhadid, et al., "Automated cortical projection of EEG sensors: Anatomical correlation via the international 10-10 system," *Neuroimage*, Vol. 46, No. 1, 64–72, 2009.
15. Tak, S., S. J. Yoon, J. Jang, et al., "Quantitative analysis of hemodynamic and metabolic changes in subcortical vascular dementia using simultaneous near-infrared spectroscopy and fMRI measurements," *Neuroimage*, Vol. 55, No. 1, 176–184, 2011.
16. Ding, X. P., L. Sai, G. Fu, et al., "Neural correlates of second-order verbal deception: A functional near-infrared spectroscopy (fNIRS) study," *Neuroimage*, Vol. 87, 505–514, 2014.