Chapter 29
Evaluation of Pleasure-Displeasure Induced by Use of Lipsticks with Near-Infrared Spectroscopy (NIRS): Usefulness of 2-Channel NIRS in Neuromarketing

M. Tanida, M. Okabe, K. Tagai, and K. Sakatani

Abstract In order to examine whether near-infrared spectroscopy (NIRS) would be a useful neuromarketing tool, we employed NIRS to evaluate the difference of pleasure-displeasure in women, induced by the use of different types of lipsticks. The subjects used lipsticks A and B; A is softer than B. Concentration changes of oxy-Hb were measured in the bilateral prefrontal cortex (PFC) during use of lipsticks A and B. We evaluated the right and left dominancy of PFC activity by calculating the Laterality Index (LI) (LI = leftΔoxy-Hb - rightΔoxy-Hb); positive LI indicates left-dominant activity while negative LI indicate right-dominant activity. We found a significant interaction between the use of lipsticks A and B, using a two-way factorial analysis of variance [$F(1,13) = 9.63$, $p < 0.01$]; Δoxy-Hb in the left PFC was larger than that in the right PFC during the use of lipstick A, while Δoxy-Hb in the right PFC tended to be larger than that in the left PFC during the use of lipstick B ($p < 0.1$). The LI of lipstick A was larger than that of lipstick B (paired T-test, $p = 0.0083$). We suggest that lipstick A caused a more positive emotional response than lipstick B, since greater left than right frontal cortical activity is associated with positive affect. These results suggest that 2-channel NIRS may be a useful neuromarketing tool, since it allows objective assessment of pleasure-unpleasure.

Keywords Prefrontal asymmetry • TRS-NIRS • Lipstick • Comfort

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1 Introduction

Neuromarketing is a field of study that involves application of neuroscientific methods, such as neuroimaging techniques, to analyze and understand human behavior related to markets and marketing exchanges [1]. Magneto-encephalography (MEG), functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) have been used as neuroimaging techniques in neuromarketing research [2]. However, these techniques are not suitable for over-the-counter use.

Near-infrared spectroscopy (NIRS) appears to be an attractive alternative method, since NIRS is compact and less stressful during measurements. Although 2-channel NIRS provides limited information about brain function, we can evaluate emotional responses based on the prefrontal cortex (PFC) activity measured by 2-channel NIRS [3–7]. In the present study, we investigate whether 2-channel NIRS allows us to objectively evaluate customer preferences for lipsticks.

2 Methods

2.1 Subjects

We studied 14 women (aged 22.7 ± 1.6 years), all of whom were deemed right-handed according to the laterality quotient questionnaire of the Edinburgh Handedness Inventory. All subjects provided written informed consent as required by the Human Subjects Committee of the Shiseido Life Science Institute, Japan.

2.2 Experimental Protocol

The subjects used two kinds of lipsticks (i.e. lipsticks A and B); lipstick A is softer than lipstick B, but there is no difference in color or flavor between them.

We evaluated the feeling associated with use of the lipsticks using our original Visual Analog Scale (VAS) with four items, i.e., softness, comfort, liking, and melting texture; each item was scored from 0 to 100). In order to avoid possible effects of the VAS feeling evaluation on the PFC activity measured by NIRS, we evaluated the VAS after the NIRS measurement. In addition, the subject was not allowed to obtain any prior information about which lipstick they are using before the NIRS measurement. During the experiment, a photoelectric sensor (Tsuyama Mfg Co., Tokyo, Japan) was used to continuously monitor heart rate (HR).

We employed quantitative, near-infrared time-resolved spectroscopy (TRS: Hamamatsu Photonics K.K, Hamamatsu, Japan) for measurement of the PFC activity evoked by the use of lipsticks A and B. Details of this system have been described previously [8–11]. Briefly, it consists of three pulsed laser diodes with different

wavelengths (761, 791, and 836 nm) having a pulse duration of 100 ps at a repetition frequency of 5 MHz, a photomultiplier tube, and a circuit for time-resolved measurement based on the time-correlated single photon counting method. The observed temporal profiles were fitted to the photon diffusion TRSequation using the nonlinear least-squares fitting method. The reduced scattering and absorption coefficients for the three wavelengths were calculated. The concentrations of oxy-Hb, deoxy-Hb, and total Hb (=oxy-Hb + deoxy-Hb; t-Hb) were then calculated using the least-squares method. The concentrations of Hb were expressed in μM.

2.3 Data Analysis

The evoked CBO changes in the bilateral PFC were continuously monitored by TRS and were averaged every second during: (1) baseline conditions for 30 s; (2) use of lipstick A or B for 30 s; and (3) recovery for 30 s. To analyze PFC activity in response to the use of lipsticks, we calculated changes in oxy-Hb concentration during lipstick use. The mean baseline values (measured during 30 s) were subtracted from the mean activation values (measured during the first 30 s of lipstick use).

We evaluated the right and left dominancy of the PFC activity by calculating the Laterality Index (LI) (i.e., LI = leftΔoxy-Hb – rightΔoxy-Hb); a positive LI indicates left-dominant activity while a negative LI indicates right-dominant activity. .

3 Results

The VAS score of the melting texture for lipstick A was significantly higher than that for lipstick B (Fig. 29.1a). There was no significant difference in heart rate changes between lipstick A and B (Fig. 29.1b).

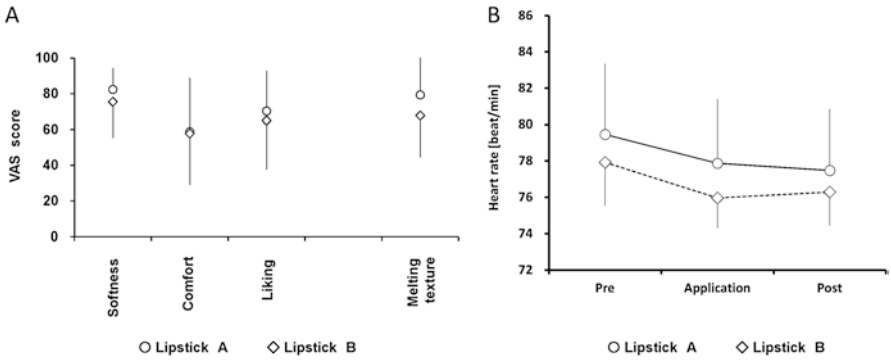

Fig. 29.1 (**a**) Differences of VAS score between lipstick A (*circles*) and lipstick B (*diamonds*) (**b**) Changes of heart rate during the course of experiment (symbols as in (*A*))

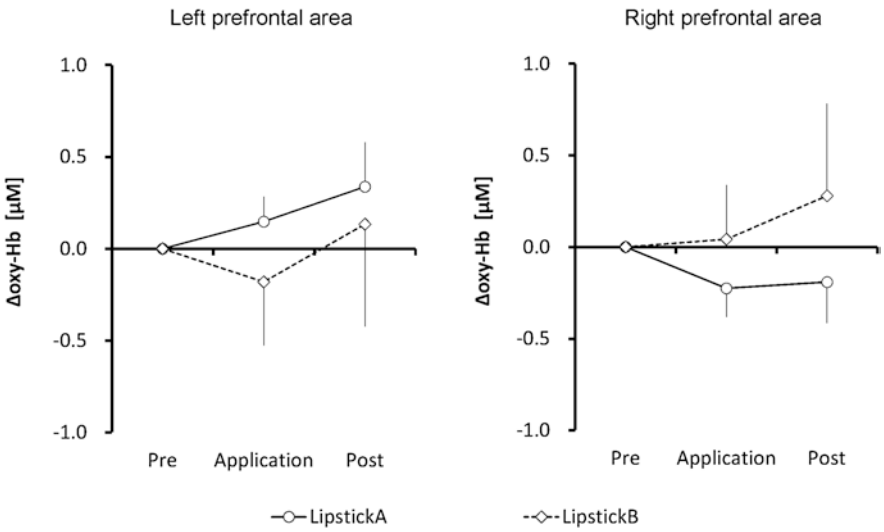

Fig. 29.2 Changes of oxy-Hb in the *right* and *left* prefrontal cortex during use of lipsticks A and B

TRS demonstrated different patterns of oxy-Hb changes between lipsticks A and B (Fig. 29.2). That is, lipstick A induced an increase of oxy-Hb in the left PFC associated with a decrease in the right PFC (LeftΔoxy-Hb = 0.15 ± 0.14, RightΔoxy-Hb = −0.22 ± 0.16), resulting in a left-dominant pattern. In contrast, lipstick B induced only small changes of oxy-Hb (LeftΔoxy-Hb = −0.18 ± 0.35, RightΔoxy-Hb = 0.043 ± 0.30).

We found a significant interaction between the use of lipsticks A and B, using a two-way factorial analysis of variance [$F(1,13) = 9.63$, $p < 0.01$]; Δoxy-Hb in the left PFC was larger than that in the right PFC during the use of lipstick A, while Δoxy-Hb in the right PFC tended to be larger than that in the left PFC during the use of lipstick B ($p < 0.1$) (Fig. 29.3a). In addition, the LI of lipstick A was larger than that of lipstick B (paired t-test, $p = 0.0083$) (Fig. 29.3b).

4 Discussion

The present results indicate that use of lipstick A induced more left-dominant PFC activity than use of lipstick B. In addition, lipstick A showed a significantly higher score for melting texture than lipstick B. These findings are consistent with the valence-asymmetry hypothesis, which asserts that the left/right asymmetry of PFC activity is correlated with specific emotional responses to mental stress and personality traits [12–14]. More precisely, Davidson reported that the asymmetry of prefrontal electrical signals recorded from the surface of the scalp

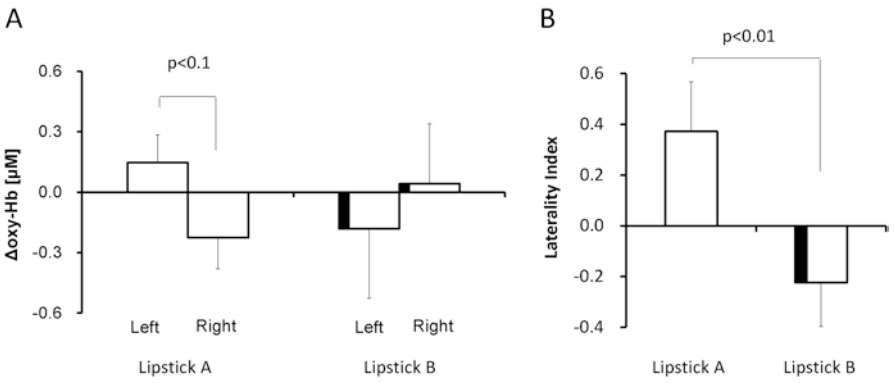

Fig. 29.3 (**a**) Changes of oxy-Hb during use of lipsticks A and B in the *right* and *left* PFC (**b**) Laterality index of lipsticks A and B

were related to emotional processes, insofar as there is relatively more left-frontal activity associated with positive emotion, whereas there is relatively more right-frontal activity associated with negative emotion [12]. This hypothesis has been confirmed in several studies using a variety of methods, including EEG, fMRI, PET, and NIRS.

In contrast to neuroimaging techniques such as fMRI, PET, and multi-channel NIRS (so-called Optical Topography), 2-channel NIRS provides limited information about brain function. However, 2-channel NIRS allows us to evaluate positive and negative emotions induced by sensory stimulations based on the left/right asymmetry of PFC (i.e. the valence-asymmetry hypothesis). Thus, our present results indicate that 2-channel NIRS may be useful in neuromarketing, particularly in evaluation of customer preferences in the over-the-counter situation.

Finally, it should be noted that we used time-resolved NIRS for measurements of PFC activity in the present study. In contrast to continuous-wave NIRS, time-resolved NIRS allows quantitative measurements of Hb concentration changes [8, 10, 11]. Thus, we could perform statistical analysis using the absolute values of Hb concentration changes induced by lipsticks A and B in the subjects, who might have had different values of optical pathlength [9].

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References

1. Lee N, Broderick AJ, Chamberlain L (2007) What is “neuromarketing”? A discussion and agenda for future research. Int J Psychophysiol 63:199–204
2. Vecchiato G, Astolfi L, De Vico FF et al (2011) On the use of EEG or MEG brain imaging tools in neuromarketing research. Comput Intell Neurosci 2011:643489
3. Tanida M, Sakatani K, Takano R et al (2004) Relation between asymmetry of prefrontal cortex activities and the autonomic nervous system during a mental arithmetic task: Near infrared spectroscopy study. Neurosci Lett 369:69–74
4. Tanida M, Katsuyama M, Sakatani K (2007) Relation between mental stress-induced prefrontal cortex activity and skin conditions: a near infrared spectroscopy study. Brain Res 1184:210–216
5. Tanida M, Katsuyama M, Sakatani K (2008) Effects of fragrance administration on stress-induced prefrontal cortex activity and sebum secretion in the facial skin. Neurosci Lett 432:157–161
6. Sakatani K (2012) Optical diagnosis of mental stress: review. Adv Exp Med Biol 737:89–95
7. Ishikawa W, Sato M, Fukuda Y, Matsumoto T, Takemura N, Sakatani K (2014) Correlation between asymmetry of spontaneous oscillation of hemodynamic changes in the prefrontal cortex and anxiety levels: a near-infrared spectroscopy study. J Biomed Opt 19:027005
8. Yokose N, Sakatani K, Murata Y et al (2010) Bedside monitoring of cerebral blood oxygenation and hemodynamics after aneurysmal subarachnoid hemorrhage by quantitative time-resolved near-infrared spectroscopy. World Neurosurg 73:508–513
9. Katagiri A, Dan I, Tuzuki D et al (2010) Mapping of optical pathlength of human adult head at multi-wavelengths in near infrared spectroscopy. Adv Exp Med Biol 662:205–212
10. Tanida M, Sakatani K, Tsujii T (2012) Relation between working memory performance and evoked cerebral blood oxygenation changes in the prefrontal cortex evaluated by quantitative time-resolved near-infrared spectroscopy. Neurol Res 34:114–119
11. Machida A, Shirato M, Tanida M et al (2016) Effects of cosmetic therapy on cognitive function in elderly women evaluated by time-resolved spectroscopy study. Adv Exp Med Biol 876:289–295
12. Davidson RJ (1993) Cerebral asymmetry and emotion: conceptual and methodological conundrums. Cognit Emot 7:115–138
13. Davidson RJ, Irwin W (1999) The functional neuroanatomy of emotion and affective style. Trends Cogn Sci 3:11–21
14. Davidson RJ, Jackson DC, Kalin NH (2000) Emotion, plasticity, cortex, and regulation: perspectives from affective neuroscience. Psychol Bull 126:890–909