Can brain activity be used to evaluate the usability of smartphone devices?

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***Abstract*—Usability is a critical area of concern in the development of smartphone devices. In the present study, we aimed to determine whether changes in oxyhemoglobin concentration, as measured via functional near-infrared spectroscopy (fNIRS), are associated with the usability of touchscreen devices. Our findings indicate that interface usability can be predicted based on brain activity, as measured via fNIRS. Thus, our results may aid in redefining usability based on objective measurements of brain activity.**

I. Introduction

Product development strategies should focus on advancements regarding usability. Previous researchers have investigated how touchscreen devices have affected the usability of interactive consumer products[1]. However, such studies have relied on subjective assessments, which do not accurately reflect the user's mental state. Near-infrared spectroscopy (NIRS) is widely utilized in the study of brain activity, which is measured based on changes in oxyhemoglobin (Oxy-Hb) concentration obtained using optical topography. Ozawa et al. [2] reported that NIRS can be used to investigate neural processing during emotional control. Furthermore, Hu et al. [3] compared mental representations of taste in the human prefrontal cortex (PFC) between pleasant and aversive stimuli, using functional NIRS (fNIRS), with the aim of elucidating the mechanisms underlying taste preference. However, research focused on the association between usability and brain activity has been scarce.

In the present preliminary study, we aimed to predict the usability of smartphone interfaces based on brain activity.

II. Experimental method

Sixteen adults (11 men, five women; age range: 21-24 years) were recruited for the present study. Participants were asked to evaluate the usability of a smartphone screen. Fifteen multiple-choice questions regarding the prefectural capital were presented to the participants on the screen. Each question had four possible responses. After responding to each of the 15 questions, participants were asked to rate the usability of the device from +1 to +5. The subjective assessment was performed in a dark room for one participant at a time, with two experimenters in the room. The questionnaire was completed on a 27-inch monitor, with a resolution of 1920×1080. Participants completed the assessment using two different user interfaces: checkbox (all checked), and checkbox (all unchecked). The NIRS device was equipped to the participant's forehead. The experimental tasks were conducted as follows:

1) participant rests for ten-seconds (rest).
2) participant completes one task.
3) participant evaluates the usability of the device.

Participants repeated tasks 1 through 3 until all questions had been completed, resting for 10 seconds between each evaluation.

TABLE I
EXPERIMENTAL CONDITIONS FOR MEASUREMENT OF BRAIN ACTIVITY.

Measuring device	Spectratech OEG-16
Task device	smartphone
Number of task	ten question
Experiment environment	Darkroom
Number of participants	Adult sixteen people

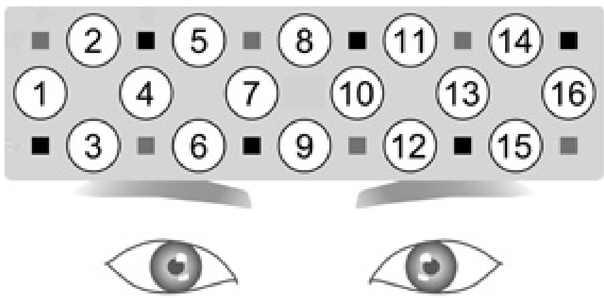

Fig. 1. NIRS settings.

III. Experimental condition

TABLE I describes the experimental conditions for NIRS measurements. NIRS can measure changes in Oxy-Hb concentration based on the optical topography of the brain. Fig.1 depicts the NIRS settings used in the present study.

978-1-5090-4045-2/17/$31.00 ©2017 IEEE

TABLE II
DISCRIMINANT ACCURACY OF USABILITY.

participant	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
closed data	0.6	1	0.7	0.7	0.6	0.6	1	1	0.7	0.8	1	0.6	1	1	0.8	1
open data	0	0.2	0.4	0.3	0	0.3	0.4	0.1	0.2	0.5	0.9	0.2	0.3	0.9	0.3	0.1

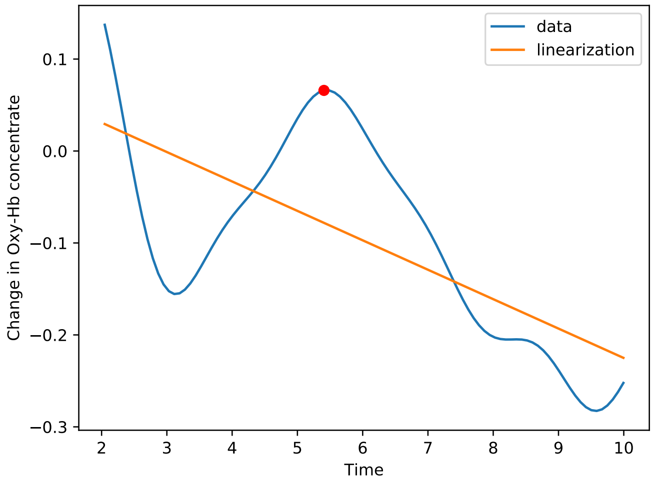

Fig. 2. Change in Oxy-Hb concentration in participant A.

IV. Experimental Results

A. Analysis of brain activity

Changes in Oxy-Hb concentration are delayed following increases in brain activation. Therefore, we evaluated NIRS data obtained 8 s after the participants had completed each question. A low-pass filter with a cut-off frequency of 0.68 was used to remove noise from the NIRS data (mainly at 10 Ch). This channel is suitable for evaluating preferences and levels of stress. We analyzed NIRS data from each of the 16 participants.

B. Support vector machine

In the present study, we aimed to predict the usability of a smartphone device based on brain activity, as measured via fNIRS. Usability was estimated based on the support vector machine (SVM), which requires parameters of C and γ. These parameters were obtained using Gridsearch.TABLE III lists the SVM conditions.

We predicted differences between user interfaces composed of all-checked and all-unchecked checkboxes.

SVM predicts usability based on two features: peak time and slope of linearization. Fig.2 shows the peak and linearization of Oxy-Hb concentration. Oxy-Hb concentration is represented on the x-axis, while time is represented on the y-axis.

TABLE II shows the discriminant accuracy of usability estimates. Ten-fold cross-validation via the leave-one-out method was used to examine usability estimates for open data.

TABLE III
CONDITIONS FOR SVM.

Cross-validation	leave-one-out Cross-validation
kernel function	RBF kernel
Parameter	$C = \{10^1 \sim 10^5\}$ $\gamma = \{10^{-5} \sim 10^3\}$

V. Discussion

Research focused on the association between usability and brain activity has been scarce. In the present study, we aimed to obtain estimates of device usability based on brain activity, as measured via fNIRS. In this study, accurate usability estimates were obtained using only two features of brain activity (peak time and slope of linearization). As the accuracy of predictions for closed and open data was high among the 16 participants in the present study, our findings suggest that usability can be predicted based on brain activation.

For closed data, accuracy verification was performed using supervised learning, while accuracy verification for open data was performed using unsupervised learning. Our results indicated that accuracy was higher for closed data than for open data. That is, when there are differences in the propensity for overall brain activation, the accuracy of closed data increases, while the accuracy of open data remains low. However, if associations are observed between a specific interface and brain activation, the accuracy of both open and closed data increases.

However, further studies are required to more fully elucidate whether usability can be predicted based on brain activation.

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