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Abstract

The aim of our paper is to present a neuroeconomic study of the social cognition that emerges from the recognition of two kinds of "nudge" as small graphic symbols representing social approval and criticism. Investigating mainly the function of the frontal cortex, we obtain the following two results. First, the neural activation is observed in the frontal cortex, when the subjects recognize a happy face as the nudge to represent other people's approval that has been already told and understood. Even if the information is not new, it receives much attention from the subjects in the experiment. We are not only rational economic agents. This is a counter example for the fictitious assumption of rational agents who are sharply different from the reality of our human beings. Second, we observe different effects of a sad face on the neural activation from those of the happy face. The sad face represents other people's doubt and criticism. The neural activation in the frontal cortex is sensitively changed by the shift from the happy face to the sad face. The result implies that we always pay much attention to the change in others' reaction to our behavior to search for the change in the meaning of our existence in the society. We will present several reasons for the changes in the neural activation in the brain, when the nudge is changed.

Introduction

Many philosophers have claimed that we human beings need the meanings of life to live our own life to the fullest. Understanding the meanings makes us aware of the value and purpose of our life. *1

Meanings are different from the value of information. The value of information is a problem of whether or not new and useful information is conveyed. The value is measured by an increase in profits obtained by an individual agent who uses the new information for his profit maximizing behavior. However, meanings are produced in social interrelationship among people. They are not decided separately by individual decision makings and actions. Even if an individual agent independently get new and valuable information, the information may not be useful to develop the relationship between him and his colleague. Individual valuable information is not always meaningful in social context. On the other hand, if the information has not any value because it has been already known to him, the information may be still necessary and worth receiving much attention in the social context. This statement is especially difficult to be understood by the traditional social scientists who believe the effectiveness of the assumption that agents are always rational and individualistic. They will instantaneously criticize by asking why such valueless information should receive much attention. However, you should remember that we human beings are fully complex living creature, i.e., we are not only rational individualistic utility maximizers. As is claimed by the philosophers, we are social agents who are searching for the meanings of our existence with paying attention to others' behavior as well as to the relationship between ourselves and other people. It is because that other people are good "mirrors" where we ourselves are reflected. It makes us understand deeply and confirm the characteristics of ourselves to carefully observe other peoples' reaction to our behavior in the mirrors. Direct understanding of ourselves without using mirrors is difficult. This is the very reason for the fact that meanings are different from the value of information.

In this paper, we demonstrate an important experimental case where the already known information still receive much attention for being meaningful from the subjects who are strongly conscious of social context. The neural activation in the brain is strongly affected by receiving attention, even when the information is old and has already been known.

As is mentioned above, the implication of this experiment may be difficult to be understood by the traditional economists who believe the effectiveness of the assumption on rational and individualistic economic agents. Because if all of us were rational economic agents, we would consider that only new and directly useful information does matter because it increases our profits (or utility). If it ware the case, already known information would not receive any attention from the subjects. Our experimental study presents an important counter example to deny the effectiveness of the neoclassical assumption on individualistic and rational economic agents. It is demonstrated that we are in social existence.

Our study uses the functional Near-Infrared Spectroscopy (fNIRS) that is a simpler and more convenient tool for examining brain activation than the functional Magnetic Resonance Imaging (fMRI) system. It gives subjects minimal stress to enable performing lengthy and complex tasks. The benefit of using fNIRS is demonstrated by the valuable work of Strangman et al. (2002) which examines fNIRS data to correspond to BOLD fMRI data, the standard now adopted in neuroeconomic experiments. *2

As in our previous neuroeconomic study (2011b), we also use a "nudge" as social norm in this study. Thaler-Sunstein (2008) introduce the "nudge" that is a graphic symbol to represent other people's approval (or doubt and criticism) to our behavior. Fig.1 illustrates the examples of the nudge, a happy face and a sad one. When the subjects notice the appearance of the nudge on the monitor in the experimental tasks, they understand how their choices are judged by other people who are expected to watch them as viewing audience. Their decision making and the neural activation will be much affected by their cognition of the nudge that represents other people's approval (or doubt and criticism) to their behavior.

(Fig.1) The Examples of the Nudge, a Happy Face and a Sad Face

Schultz et al (2007) represents an interesting result of their experiment that is conducted in San Marcos, California. In their experiment, a happy face (or a sad face) is written as nudge in a consumers' receipt issued by an electric power company, when their electric energy conservation is larger (or smaller) than expected. The happy (sad) face is a symbol that represents the consumers' conservation behavior to be desirable (undesirable) in their society with a severe electricity consumption restriction. The nudge's result is unexpectedly large. The electric energy conservation is remarkably promoted, when the nudge is written in the receipt. It is especially worthy to note that the boomerang (or backfire) effect remarkably decreases even after the desirable result. The boomerang effect is usually observed as a going back movement to bad behavior after agents have attained satisfactory result. However, recognizing the happy face written in the receipt , many consumers do not react to increase their electric consumption even after attaining sufficiently large energy conservation. This is an anomaly that cannot be explained by agents' rational and individualistic behavior that has been assumed by the traditional mainstream economic theory.

The aim of our paper is to present a neuroeconomic study of the social cognition that emerges from the recognition of the nudge. Investigating mainly the function of the frontal cortex, we obtain the following two results. First, we demonstrate that the neural activation is observed in the frontal cortex, when the subjects recognize the happy face as the nudge to represent other people's approval that has already been explained and understood. Even if the information is not new, it receives much attention from the subjects in the experiment. Second, we demonstrate the different effect of the sad face on the neural activation from that of the happy face. The sad face represents other people's doubt and criticism, while the happy face represents the approval. The neural activation in the frontal cortex is sensitively changed by the shift from the happy face to the sad face. This result implies that we always pay much attention to the change in others' reaction to our behavior to search for the change in the meaning of our existence in the society. We will present several reasons for the changes in the neural activation in the brain, when the nudge is changed.

Methods

The experimental games are played by eight healthy right-handed subjects, four males and four females aged 18-27. *3 The subjects are prohibited from eating within two hours before executing the games. In order to execute the experimental games, each subject enters a shielded tent in a quiet room protected from electromagnetic interference (EMI) and noises.

We use the convenient and low-stress fNIRS tool to scan primarily the frontal cortex of the brain. *4 As illustratied by Fig.2, fNIRS uses lightweight, small-sized and multi-channel digital sensors with a headband in order to obtain the event-related fNIRS data through a high-sensitivity optical signal that changes dynamically reflecting how the in vivo hemoglobin is combined with oxygen in the blood vessels with high or low cortical activation.

(Fig.2) FNIRS Multi-channel Digital Sensors with Headband

The location of the 16 channels are illustrated in Fig.3 provided by NIRS-SPM software for statistical analysis of fNIRS signals. We obtain the event-related high-sensitivity optical signal from these channels. The 8th and 9th channels are placed at the center of each subject's forehead.

(Fig.3) Locations of the 16 fNIRS Channels

Two experimental games are presented to the subjects. The first game is the AB type game composed of two kinds of tasks A and B. The subjects execute task A repeatedly in the baseline period, then the task changes from A to B for the experimental period. The subjects execute task B repeatedly in the next experimental period. As illustrated by Fig.4, the randomization test requires that the subjects are randomly allocated to the games having different task compositions. Specifically before executing the games, each subject is randomly allocated to the i-th game (i = 1,2, ... 8) which is composed of the (4 x i) rounds of task A and the (36 - 4 x i) rounds of task B, where 36 is the total number of task executions. Each task requires 10 seconds to execute, and the total time to complete the experimental game is 6 minutes.

(Fig.4) Experimental Design for Randomization Test

Task A is a simple and stress-free game. Before investigating the effect of the nudge in task B, we conduct the simple preliminary task A as a reference point. The content of the short task A is illustrated by Fig.5. In the task, the subject notices only the 850Hz tone as the stimulus S1 and presses any button after hearing the 850Hz long tone as the stimulus S2. It takes 10 seconds to execute task A, and as the randomization test requires, the simple task is repeated (4 x i) rounds in the baseline period.

(Fig.5) Task A in Game AB

Next, the content of task B is illustrated in Fig.6. Task B is the same as task A except for an introduction of the nudge. After the first screen with 850Hz tone, a happy face as a symbol appears on the next screen. The subjects recognize the happy face as the nudge to understand that their next action of pressing a button after hearing the 850Hz long tone is approved in the experimental game. It also takes 10 seconds to execute task B, and as the randomization test requires, the task with the nudge is repeated (36 - 4 x i) rounds in the experimental period.

(Fig.6) Task B in Game AB

The second experimental game is presented to the subjects, after they finish the first game. The second game is the AC game composed of two kinds of tasks A and C. The subjects execute task A repeatedly in the baseline period. Then the task changes from A to C for the experimental period. The subjects execute task C repeatedly in the next experimental period.

As explained in Fig.7, The difference between task C and task B is only an introduction of a sad face instead of the happy face into the experimental task. After the first screen with 850Hz tone, the sad face appears on the next screen. The subject recognizes the emergence of the sad face that represents a change in the experimental situation caused by others' doubt and criticism to his behavior of pressing a button after hearing the long tone.

After the games conclude, an interview survey is conducted. The subjects are asked to answer the following questions. Explain your different perception about playing the experimental games AB and AC. What is the strength of your psychological stress while executing the two games?

(Fig.7) Task C in Game AC

Results

The two experimental games AB and AC are executed. In these games, the task changes from A to B or from A to C. We investigate the effects of the task change on the event-related fNIRS data which reflect how the in vivo hemoglobin is combined with oxygen in the blood vessels with high or low cortical activation. As is already mentioned, the fNIRS data of the changes in oxy-Hg levels are demonstrated by Strangman et al. (2002) to correspond to the changes in the BOLD data of the fMRI, a standard now adopted in neuroeconomic experiments.

Our results are shown in Tables 1,2,3 and Figures 8 and 9. Tables 1 and 2 show respectively the p-values of all channels obtained by the randomization test of games AB and AC. The method for calculating the p-value by the randomization test is provided by Wampold-Worsham (1986) and Yamada (1998). Use of the randomization test is justified because our experimental study is a repeated-task study where the fNIRS data are expected to have strong time series correlation. Table 1 implies that the change in data at channel 14 is statistically significant at the 10% level in game AB. Fig.8 indicates an increase in the average values of the event-related fNIRS data at channel 14 for all the subjects. The neural activation at channel 14 is judged to increase in game AB with the happy face as the nudge.

On the other hand, Table 2 implies that the changes in data at channels 2,3,4,9,10,11 and 12 are statistically significant at the 5% level in game AC. In game AC with the sad face, the neural activation changes in many areas of the frontal cortex. In order to examine the directions of changes, we show Table 3 that indicates the average values of the event-related fNIRS data at all of the statistically significant channels 2,3,4,9,10,11 and 12 before and after the task change form A to C. At the channels 2,3,4,10,11 and 12 except for 9, the average values increase. We can judge that the neural activation in many areas of the frontal cortex increases with the change from task A to C. The result at channel 12 is interpreted that a decrease in the value come from the deprivation of Hg by an increase in neural activation in the neighboring many areas of frontal cortex. Therefore the fundamental conclusion is kept and we can conclude that the sad face as the nudge increases more the neural activation of the frontal cortex than the happy face, when the subjects are strongly conscious of social context. Fig.9 illustrates the increases in the average values of the event-related fNIRS data at channels 2,3,4,10,11 and 12 where the neural activation is observed.

(Table 1) The P-values of the Channels in Game AB
(Table 2) The P-values of the Channels in Game AC
(Table 3) The Average Values of the fNIRS Data at All Statistically Significant Channels in Game AC

Discussion and Interpretation

We conduct the experimental games AB and AC using the nudge as symbols, a happy face and a sad face. From the experimental study, we obtain the following theoretical and philosophical implications. First, the subjects are not only rational economic agents. They pay much attention to the happy face as the nudge, and their neural activation increases in their frontal cortex. As is shown in the previous section, the change in data at channel 14 is statistically significant at the 10% level in game AB. And Fig.8 illustrates the increase in the neural activation of the frontal cortex. The happy face is a simple symbol only to imply that their behavior of choice and pushing the button as a subject is approved in the experimental game. This is already known information for them, because they are obtained an explanation for the subjects' role before executing the experimental game. However, they pay much attention to the nudge that coveys only the already known message. If they were rational economic agents who only try to maximize their profits, they would not pay any attention to the valueless symbol. The first implication obtained in our study is a fundamental criticism to the fictitious assumption of the rational economic agents who are sharply different from the reality of our human beings.

The second implication is a possibility of an increase in the agents' attention to the nudge. As is investigated in our experiment, the changes in data at channels 2,3,4,9,10,11 and 12 are statistically significant at the 5% level in game AC. And as Fig.9 illustrates, in game AC with the sad face, the neural activation increases in many areas of the frontal cortex. Our experimental result suggests that the negative meaning of the nudge gets more and stronger subjects' attention than the positive meaning. However another interpretation is possible. The unexpected meaning may get their much attention than the expected meaning. The former interpretation is explained by the fact that the nudge to represent others' doubt and criticism to them increases the neural activation in almost all areas of frontal cortex. People keenly pay much attention to the signs and indications that suggest the meaning of crisis in the social existence in order to evade their social isolation. On the other hand, the latter interpretation is explained by the fact that the fundamental cognition to the nudge increases by an additional value of information coming from the surprise and the doubt of why their behavior is criticized. It may be difficult for them to understand the reason of the appearance of the sad face on the monitor in the experimental task. The above alternative interpretations are different each other, however, the both of them show the possible explanations for an increase in the effect of the nudge in the social context. We human beings are in the social existence, and this fundamental characteristics of our existence increases the effect of the small and simple nudge on our attention and cognition.

Notes

*1 In the postmodern context, after Friedrich W.Nietzsche, philosophers, sociologists and psychologists have examined and described human cognition accompanied by a sense of loss over identity and the meanings of life but searching for the meanings in our complicated and uncertain society. For example, see Maurice Merleau-Ponty (1945, 1948), Michel Foucault (1966), J-F. Lyotard (1984), Norbert Bolz (1997) et al.

*2 Strangman et al. (2002) finds a strong correlation between fMRI variables and fNIRS measures with oxyhemoglobin providing the strongest correlation.

*3 The number of subjects may seem small. However when the number of subjects is eight, the randomization test requires, as Wampold-Worsham (1986) and Yamada (1998) explains, 8! (= 40320) repeated calculations of the statistical data to obtain the p-value that determines whether to reject the null hypothesis to claim no difference between the dynamic processing of risk and ambiguity in the brain. The number of subjects and that of statistical calculation are thus sufficiently large for our randomization test to obtain the p-value in the non-parametric method.

*4 Our fNIRS is the Spectratech OEG-16 model. This model has previously been installed and used for scientific research such as Kita et al (2011).

(Table 1) The P-values of the Channels in Game AB

Channel	1	2	3	4	5	6	7	8
P-value	0.2338	0.191	0.196	0.2894	0.1534	0.5673	0.4382	0.7452
Channel	9	10	11	12	13	14	15	16
P-value	0.4676	0.5833	0.1496	0.3108	0.1523	0.0752	0.4289	0.3281

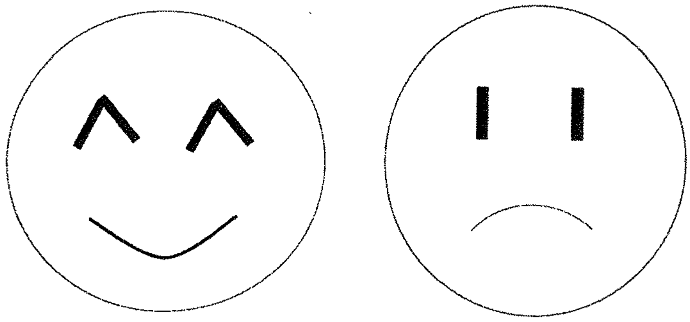
(Table 2) The P-values of the Channels in Game AC

Channel	1	2	3	4	5	6	7	8
P-value	0.2376	0.0444	0.0132	0.0088	0.2733	0.2823	0.3094	0.5177
Channel	9	10	11	12	13	14	15	16
P-value	0.041	0.0285	0.0182	0.0318	0.2873	0.3351	0.5371	0.7037

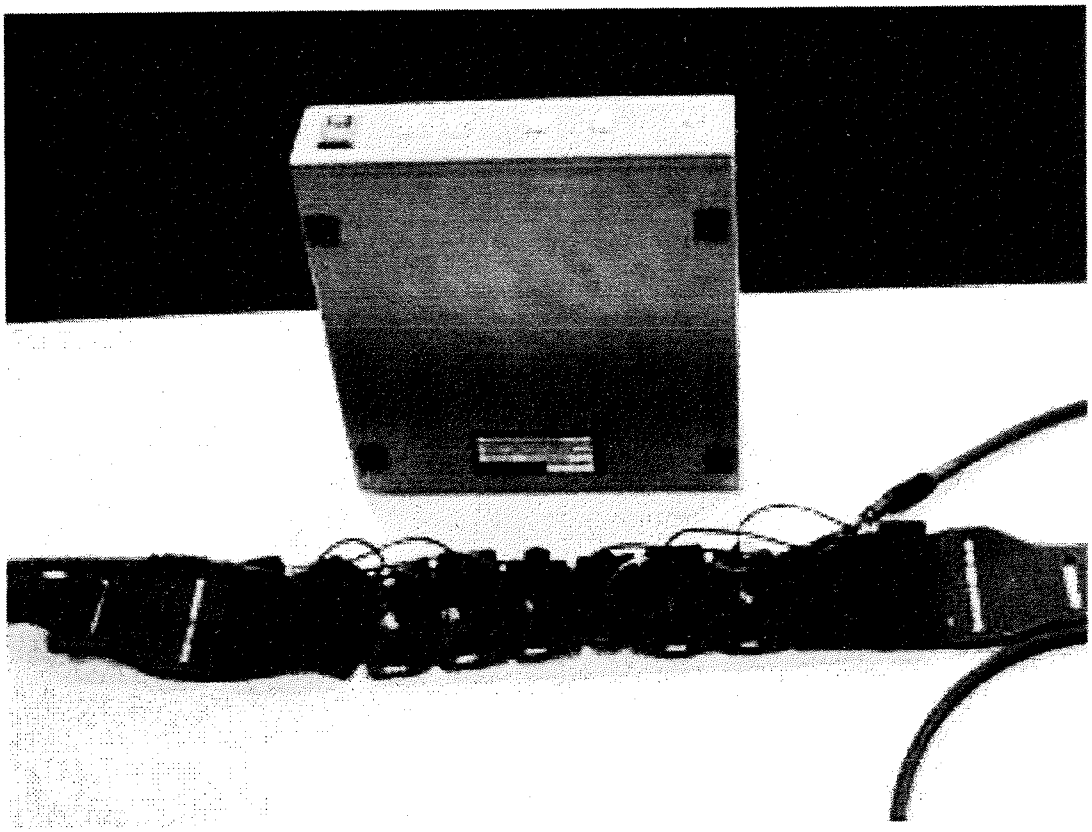
(Table 3) The Average Values of the fNIRS Data at All Statistically Significant Channels in Game AC

	baseline period	experimental period
ch.2	0.015815238	0.025827969
ch.3	0.010591644	0.016808384
ch.4	0.013461103	0.022059399
ch.9	0.029044533	0.026518392
ch.10	0.0509766	0.051905116
ch.11	0.024839761	0.034834075
ch.12	0.040574021	0.0415237

(Fig.1) The Examples of the Nudge, a Happy Face and a Sad Face

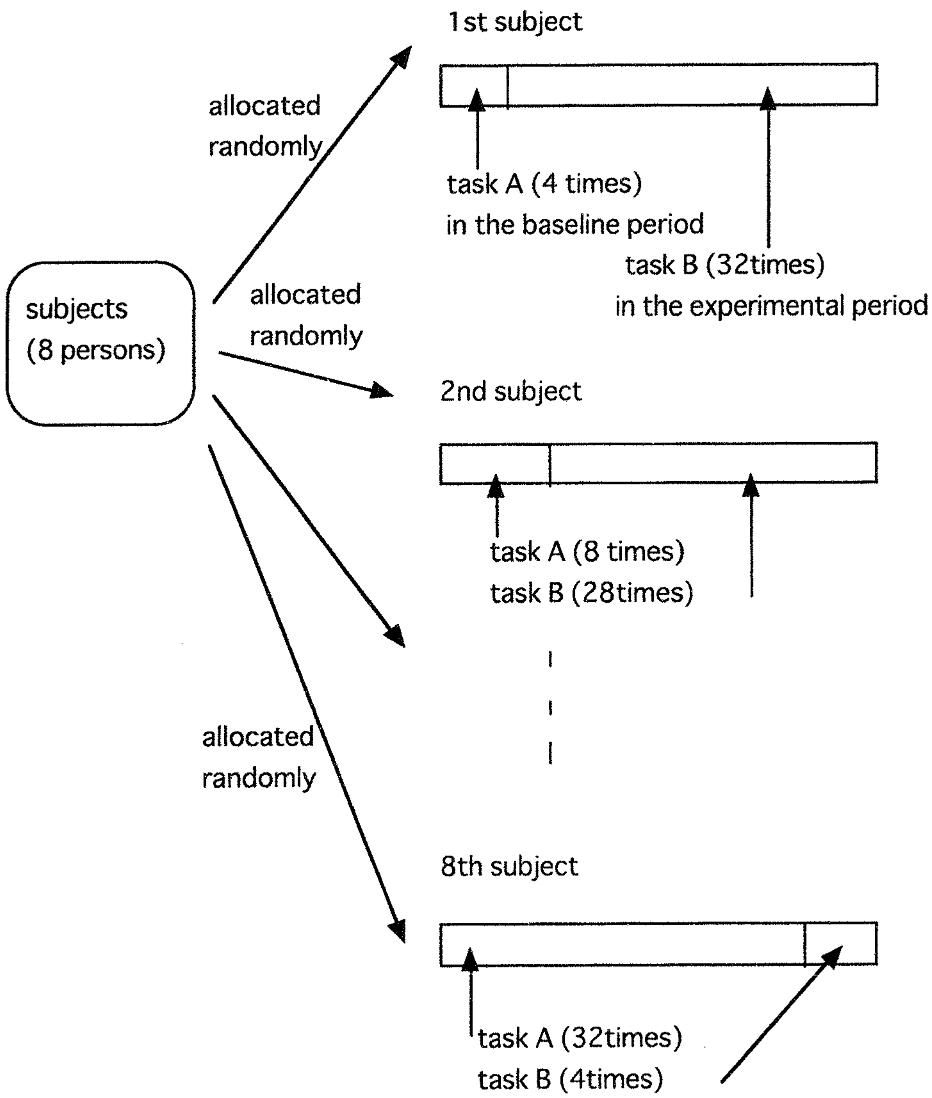


(Fig.2) FNIRS Multi-channel Digital Sensors with Headband



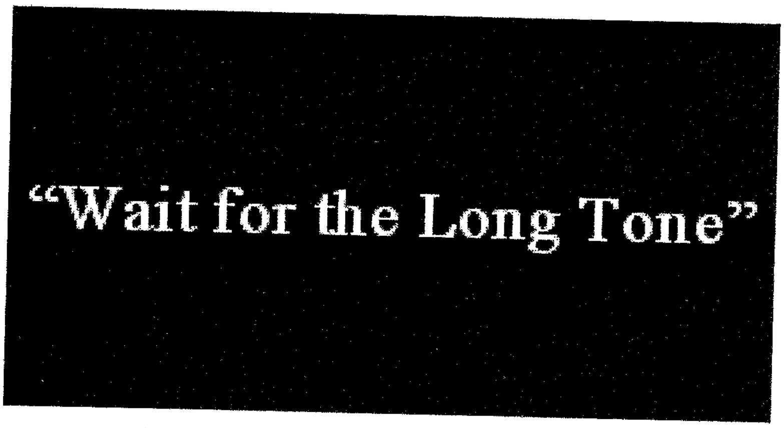
(Fig.3) Locations of the 16 fNIRS Channels

(Fig.4) Experimental Design for Randomization Test



(Fig.5) Task A in Game AB

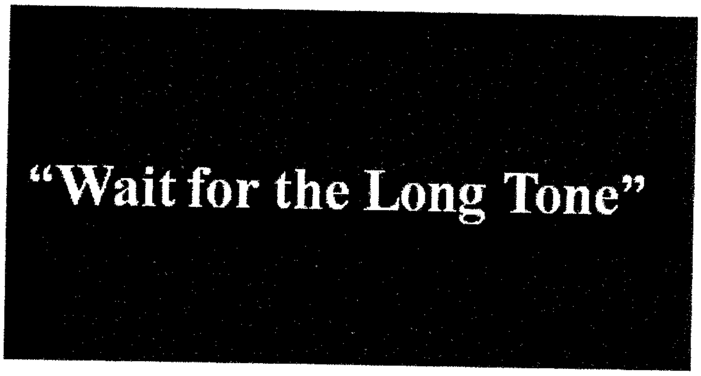
(The First Screen with 850kHz Tone)...The stimulus S1



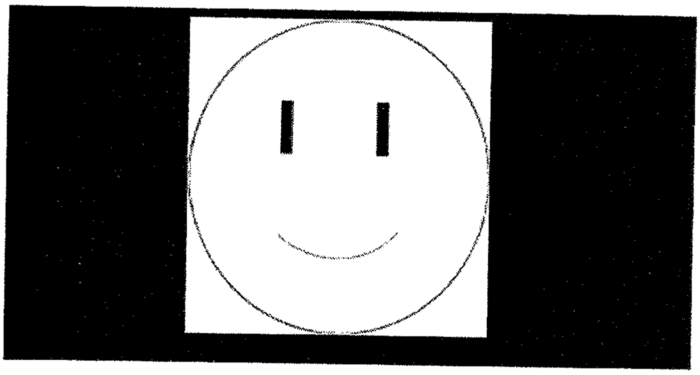
(The Second Screen with 850kHz Tone)...The stimulus S2

(Fig.6) Task B in Game AB

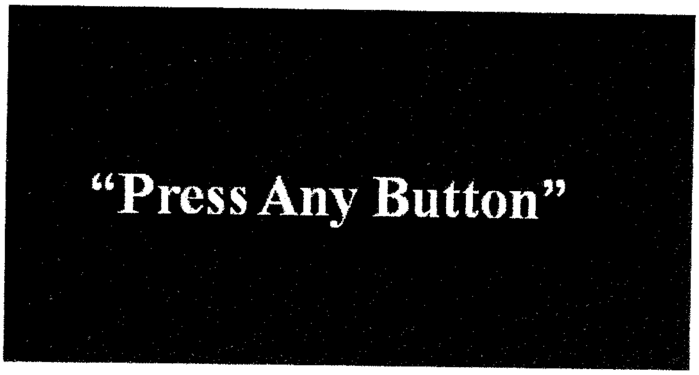
(The First Screen with 850Hz Tone)...The stimulus S1



(The Second Screen with A Happy Face as the Nudge)



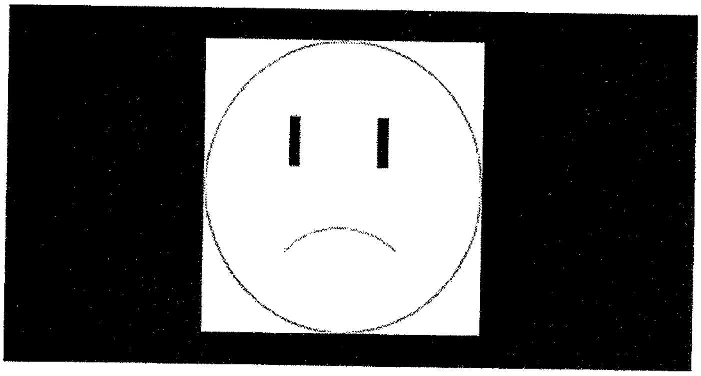
(The Third Screen with 850Hz Tone)...The stimulus S2



(Fig.7) Task C in Game AC

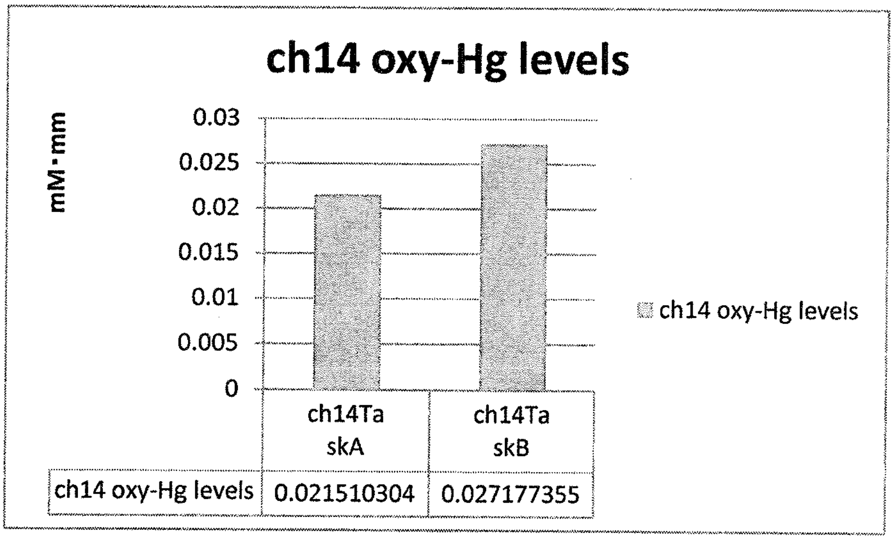
(The First Screen with 850Hz Tone)...The stimulus S1

(The Second Screen with A Sad Face as the Nudge)

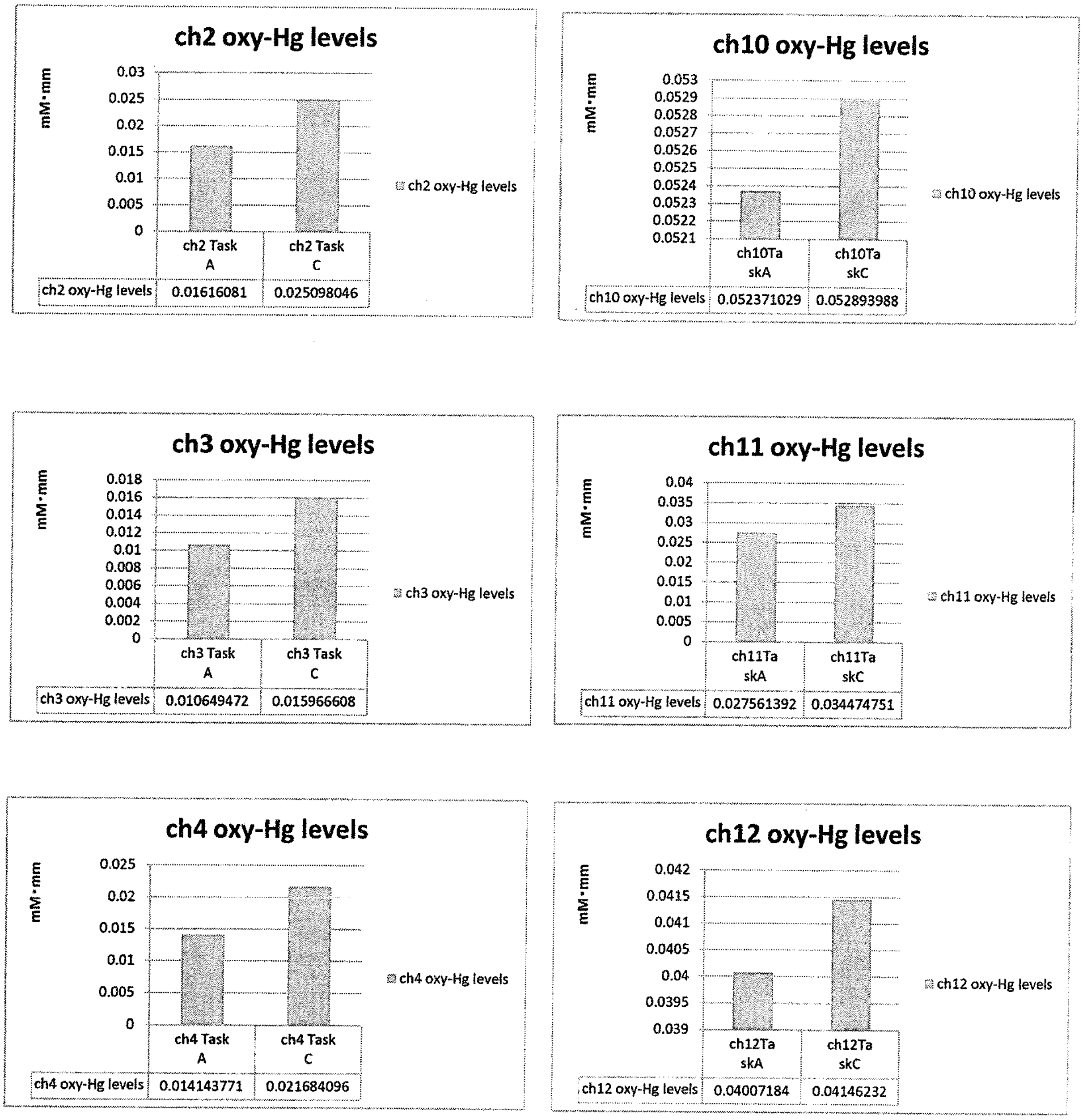


(The Third Screen with 850Hz Tone)...The stimulus S2

(Fig.8) The Average Values of fNIRS Data at Channel 14 in Game AB



(Fig.9) The Average Values of fNIRS Data at Channels with Increased Neural Activation in Game AC



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