fNIRS Survey of Brain Function at the Moment of Winning

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Abstract

Critical positions in gaming have been defined as a moment when one senses the Information of Game Outcome prior to the game final outcome. (Iida 2010). The authors have set out to find a significant isolated cerebral signal during the critical moment when one realizes s/he is going to win (lose) a game. We devised a simple one-player game and obtained data of 11 players' brain oxygen activity using functional Near Infrared Spectroscopy (fNIRS). Our preliminary result is mixed, with a slight proclivity to decreasing oxygenation on the left side of the brain, increasing oxygenation on the right side of the brain and frontopolar areas.

Introduction

The theory of Game Information Dynamics proposed by Iida et al. (2010) shows that game information flows adhere to the same physical laws of nature as liquid flows. The model provides for aspects of gaming such as elemental game progress patterns, winning rates, the safety lead curve, and certainty and uncertainty of game outcome [1,2]. The Certainty of Game Outcome is defined as $\xi = \eta^n$ where ξ is the non-dimensional information of game outcome, η the non-dimensional game length or time, and n a positive real number parameter depending on the fairness of the game, strength of the player(s), and the difference in the strength of the teams. It is evident that the Information of Game Outcome is sometimes complete at a critical position prior to the end of normalized game play η=1, even if only by a few seconds. The authors of this paper set out to identify a simple instance of that critical position, which for convenience sake we call The Wakatta Moment. At the same time, we measured brain functioning associated with the Wakatta Moment, as evidenced by the marginal oxygenation in the outer cerebral cortex of subjects in a five second period, 2.5 seconds pre- and 2.5 seconds post-Wakatta Moment.

Design

Functional Near Infrared Spectroscopy (fNIRS) uses light in from the near-infrared electromagnetic spectrum to measure hemodynamic activity. Keenan et al. (2001) showed that fNIRS is a reliable tool for the measurement of neural activity in the brain. Supported by fMRI and EEG measurements, event-related hemodynamic responses in the cortex were demonstrated by fNIRS with accuracy [2]. We used an fNIRS Hitachi Wearable Optical Topography model WOT-220 technology to measure participants' brain oxygen changes across 22 channels around the prefrontal cortex. The machine is mobile and easy to use, painless and safe.

For a game conducive to data collection we sought the game with the following characteristics:

1) one player alone can play
2) has a time limit for completion
3) has an incentive for winning
4) is fun or interesting to play
5) has never been played by the subject

We chose a puzzle from Professor Iida's collection. The puzzle is a cube which unfolds, and inside of which is a star-shape. The two forms are mirror-images of each other, and the object of the game is to change the shape of the two forms so that the one which was outside can be put inside of the other within three minutes. It has been considered that to encourage mental involvement of the subjects we would apply both time pressure in the form of a three minute limit, and a modest prize for subjects who could solve the puzzle correctly. Although subjects were told they would be "failed" after the three-minute buzzer, no clock was visible to subjects, and no buzzer sounded after 3 minutes. This way, even for subjects who went "over" time by a few seconds, or even a minute, we could collect uniform data for the critical position of winning.

Participants

We used data gained from 11 Volunteers (6 male, 5 female) chosen from among 5 JAIST students and 6 Nomi Shi area citizens. 10 were right-handed, and one was left-handed. Their average age was 26.5 in a range from 8 to 41. Originally 14 volunteers participated in our study, however three data sets proved unusable for the following reasons: One 6 year-old volunteer's head was too small for the headset, and produced data with a large amount of artifact. Another data set was rendered ineffective due to a recording error, and one participant moved erratically, causing the headset, and therefore the light sensors to slip, creating a large amount of artifact.

Experiment

Participants were greeted in the University Commons and escorted to the fNIRS laboratory for briefing. Participants consented to having their cerebral hemodynamic data recorded and used as part of a cognitive science experiment in accordance with JAIST privacy policy for personal information. Participants were instructed that while wearing the fNIRS headset, they would become subjects in two control experiments of 3 to 5 minutes length, followed by a puzzle game experiment. For control experiment part one, participants were asked to sit quietly in a dimly lit room for 5 minutes and just relax without thinking about anything very much in particular. For part two, they would sit in the same comfortable position and shuffle a deck of cards for 3 to 4 minutes. In the final part of the experiment they would play the puzzle game. In this game they would race against the clock to solution within 3 minutes. If they could solve within the allotted time, they would win a very modest prize. In the case of the children, we described the puzzle for them and gave them hints for how to solve it. Participants were not allowed to touch the cube until the start of the experiment.

We asked participants to signify by saying "Wakatta" or "I got it" when they felt they were close to solving the puzzle and winning the game. To separate cognitive signals from motor and/or language signals, participants were asked to pause for a few seconds between cognizing the moment in which they felt sure to "win," and signaling the cognition with the word "Wakatta" or "I got it!" Of the 11, the fastest solution time was 18 seconds, the longest time was 4:15, and the average solution time was 2:05. Most participants solved the puzzle before signaling "Wakatta." Video review reveals that in all cases, participants appeared to arrive at the solution of the puzzle suddenly. In the post-questionnaire, many said they had finished before they realized it.

Only one participant actually signaled "Wakatta." The subject solved four seconds later. For the other subjects, a Wakatta Moment was selected for them by video analysis, which we judged by spontaneous utterances other than "Wakatta," facial expressions, or visible and abrupt changes in physical activity. A total of six participants revealed no discernible "wakatta" behavior. For those six we selected the moment of solution as their Wakatta Moment. In no case was there more than 10 seconds of separation from "Wakatta" to solution. The average was 5.2 seconds from "Wakatta" to solution, except when the "Wakatta" moment was the same as the moment of solution.

WOT-220 is managed by a laptop PC running Hitachi fNIRS software. The device takes five oxygen measurements per second. After "start" the computer takes a few seconds to find the subject's brain's "zero" line during a pre-scan, after which the marginal oxygenation, de-oxygenation and total oxygen recording is made. Furthermore, we allowed 30 seconds prior to starting each experiment and control, to allow subjects to acclimate to the situation and to collect at-rest data from each outset. Although de-oxygenation and total oxygenation are useful for some purposes, we are primarily interested in the oxygenation record for the purpose of this study.

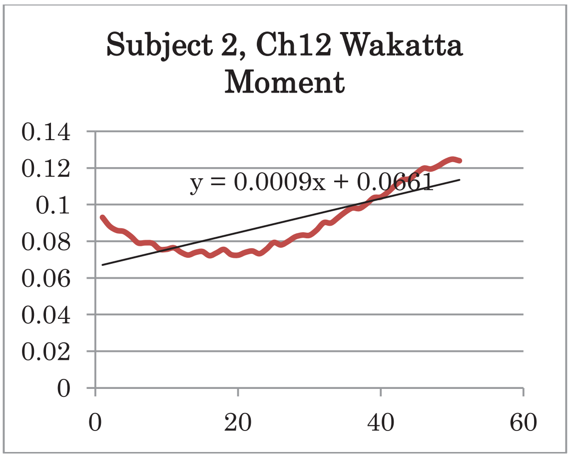
Data Analysis

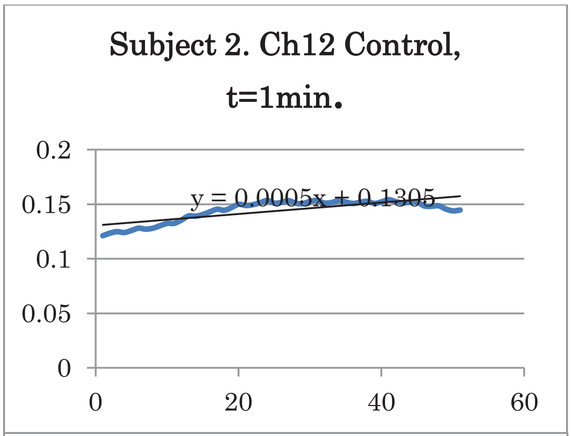
Data was selected from the 2.5 seconds prior, until 2.5 seconds after the Wakatta Moment or solution moment. For all 22 channels, inter-channel distance is 3cm, and the depth is approximately 1.5cm. We selected Channels 11 and 12 for closer scrutiny. Channels 11 and 12 cover an area over the long fissure between two cerebral hemispheres around parts of the left and right superior frontal gyri, corresponding roughly to Brodmann area 10.

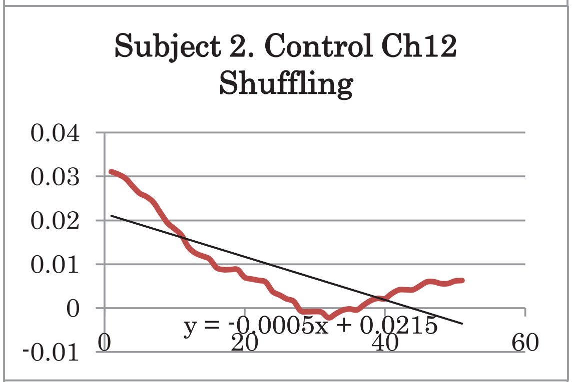
We analyzed the numerical waveform data using the linear least-squares method. Marginal oxygenation values from 2.5 seconds prior until 2.5 seconds after the moment of winning was acquired. First we determined a coefficient that is the sum of squares of a remainder the minimum, or such so a function as to serve as good approximation to measured value. Assuming we the equation set y = ax + b,

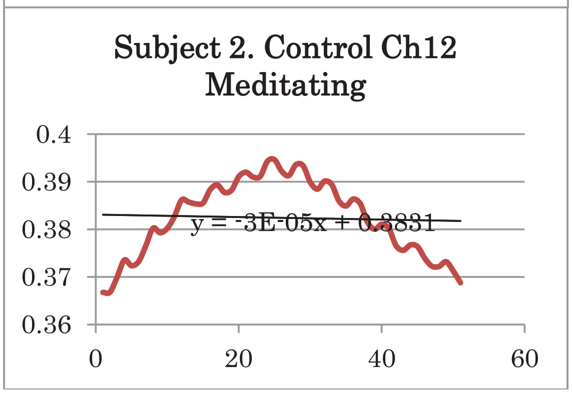
$$a = \frac{n\sum_{k=1}^{n} x_k y_k - \sum_{k=1}^{n} x_k \sum_{k=1}^{n} y_k}{n\sum_{k=1}^{n} x_k^2 - \left(\sum_{k=1}^{n} x_k\right)^2}$$

This method was applied to each of the data sets, as shown in the following examples:









The units shown are in Mol/L (y) and seconds (x).

For both channels 11 and 12, six subjects exhibited decreasing oxygenation at the Wakatta Moment or moment of winning, and 5 subjects exhibited increasing oxygenation. Our preliminary result also shows a slight general tendency for increasing oxygenation on the right hemisphere, and decreasing oxygenation in the left at the critical position in gaming.

In the control experiments, using the same channels 11 and 12, we found the following values:

Control Group:

	Ch 11	Ch 12
Subject data:	Shuffling	Shuffling
rising ↗	7	5
falling ↘	4	6

Control Group:

	Ch 11	Ch 12
Subject data:	Meditating	Meditating
rising ↗	2	6
falling ↘	9	5

Control Group:

	Ch 11	Ch 12
Subject data:	At t=1 min.	At t= 1min.
rising ↗	6	7
falling ↘	5	4

Future Work

At the time of this writing, further analysis of the present data is required in order to provide a definitive result. It has recently come to light, such as in studies by Kirilina et al. [5], that physiological noise e.g. from hemodynamic fluctuations in the scalp, are a greater impairment to fNIRS measurements than had been previously believed. We also need to implement artifact noise-reduction processing to improve the value of our data. We recognize it is important to verify that one is measuring what one thinks s/he is measuring. Further, we acknowledge that an fNIRS survey may not provide the precision of, say, fMRI, CT or PET measurements for example.

The design of the game itself was perhaps not the most appropriate for eliciting the desired Wakatta Moment in the study's participants, either. As we continue these studies, changes will be made in the specific instructions to participants, as well as administration of the game, or possibly changing to another game with a mind to elicit the Wakatta Moments more clearly.

References

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