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Dual functional near-infrared spectroscopy (1): Technical consideration

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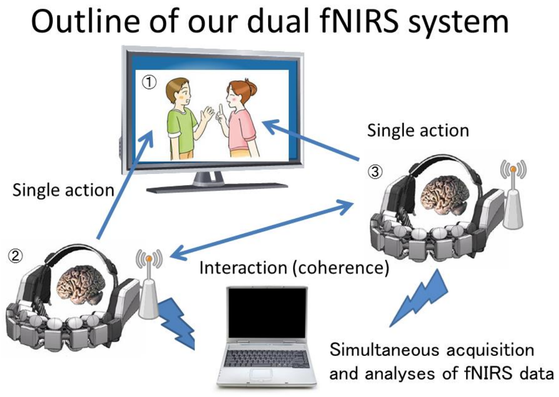
Background

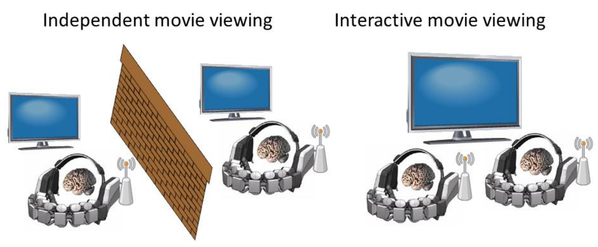
Human behavior such as conversation can be assessed properly using ecologically valid experiments in which multiple subjects participate. Unconstraint and portable near-infrared spectroscopy (NIRS) have a potential to do that but have not been studied well.

Thus we have developed a dual functional NIRS system where hemodynamic responses are simultaneously recorded from two subjects with identical two NIRS instruments and started to apply to psychological and psychiatric conditions.

Outline of our dual fNIRS system



An example of the application



Is unconscious and automatic empathy formation through a shared experience (e.g. movie viewing) associated with cortical synchrony or coherence?

Objective

Is there significant variation of the channel positions among subjects? (i.e. variation of the cortical regions measured by NIRS probes attached on the foreheads).

Is there significant effect of the head motion when two subjects interact with each other? (e.g. nodding or gesture during conversation).

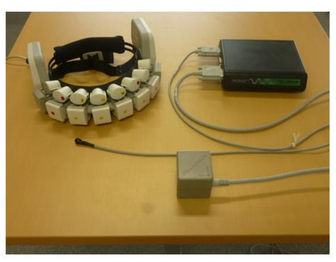
Participants & Methods

The NIRS instruments used here were two sets of WOT-100 (HITACHI) with 16 channels that covered prefrontal cortex. Data sampled at 5Hz were transmitted to a PC through wireless LAN. Room temperature and relative humidity were kept 22-25 centigrade and 40-43%.

Study 1: cortical regions corresponding to the individual channels were examined using a magnetic digitizer and virtual spatial registration technique for 10 participants.

Study 2: head motion was measured using a small acceleration sensor attached on the WOT-100 headset and its effect on NIRS signals was assessed in a single participant.

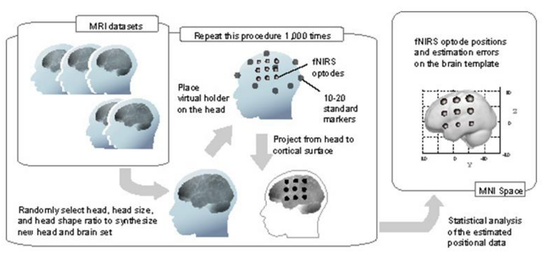
Study 1: Localizing NIRS channel positions with 3D-magnetic digitizer



A digitizer (PATRIOT™) provided real-time measurements of position (X, Y and Z Cartesian coordinates) and orientation (azimuth, elevation and roll). X, Y and Z coordinates corresponding to the 16 channels, nasion, inion, Cz, and pre-auricular points were used as input data for the individual spatial analysis script running on Matlab (http://www.jichi.ac.jp/brainlab/index_de.html)

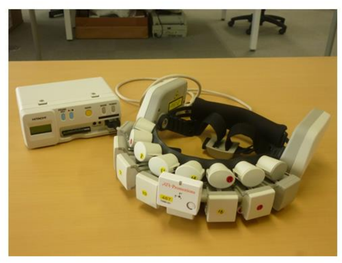
Technical and theoretical details of virtual spatial registration

http://www.jichi.ac.jp/brainlab/virtual_regE.html



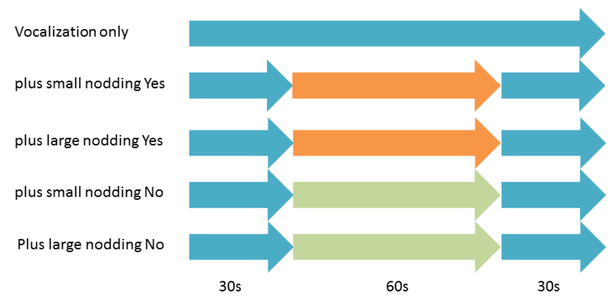
Tsuzuki, D. et al. Virtual spatial registration of stand-alone functional NIRS data to MNI space. NeuroImage 34, 1506-1518 (2007)

Study 2: An acceleration sensor attached on the NIRS headset



This sensor (TSND121, ATR-Promotions) was developed to measure the movement of the human body part. Data stored in internal memory were A/D-converted and transmitted to PC for analysis via Bluetooth connection. Both acceleration and angular velocity information were used for the study 2.

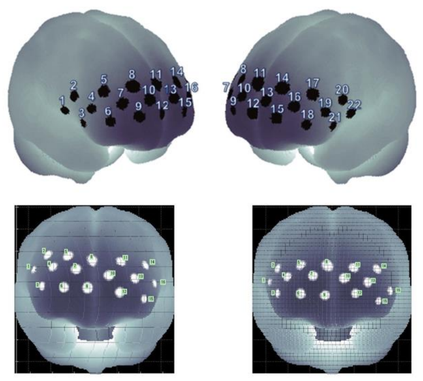
Generating periodic head motion



The participant generated vocalization and nodding once per 2 seconds during 60s (Yes, orange arrow; No, light green arrow), while did vocalization only during blue arrow periods (Upper, entire 120s; Others, pre-30s plus post-30s). In this study, small nodding rapidly moved the chin about 1-2 cm and large one did it about 5-6 cm vertically (Yes) or horizontally (No), considering the observed real conversation.

Results of study 1

Virtual registration to brain cortices



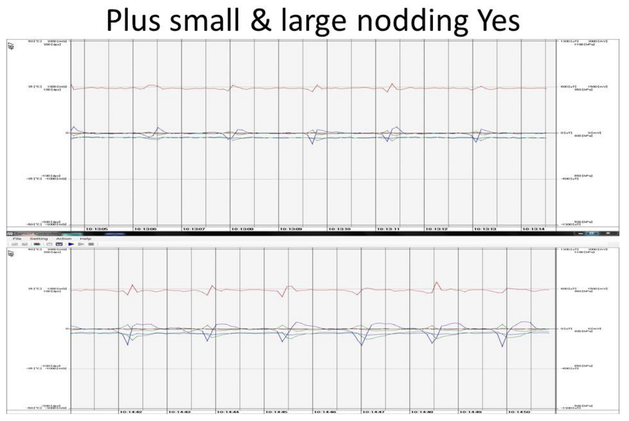
Mean and standard deviation (SD) of channel positions for 10 participants

Channel	Row	Side	X mm (SD)	Y mm (SD)	Z mm (SD)
2	upper	right	46.6 (6.7)	45.5 (8.5)	27.1 (8.2)
5	upper	right	24.5 (8.8)	57.7 (7.7)	29.2 (8.6)
8	upper	midline	4.4 (8.6)	64.6 (7.6)	31.4 (7.9)
11	upper	left	-20.7 (6.9)	62.6 (8.4)	30.0 (7.7)
14	upper	left	-45.5 (6.4)	46.5 (8.5)	25.4 (7.6)
1	middle	right	54.4 (6.5)	39.5 (8.8)	13.8 (6.9)
4	middle	right	37.7 (8.2)	59.2 (7.2)	15.5 (9.1)
7	middle	right	17.1 (7.3)	70.5 (5.5)	18.8 (9.4)
10	middle	left	-12.0 (6.6)	69.8 (6.9)	17.6 (9.5)
13	middle	left	-33.5 (6.5)	62.0 (6.7)	15.2 (8.1)
16	middle	left	-51.7 (6.1)	39.6 (7.1)	9.1 (7.6)
3	low	right	46.8 (6.9)	53.9 (8.4)	1.8 (9.6)
6	low	right	28.4 (7.7)	70.1 (6.8)	5.4 (8.9)
9	low	midline	4.0 (7.4)	70.0 (5.6)	6.2 (9.1)
12	low	left	-22.0 (7.0)	69.7 (5.4)	4.3 (8.9)
15	low	left	-44.1 (6.8)	55.9 (6.9)	-0.9 (7.2)

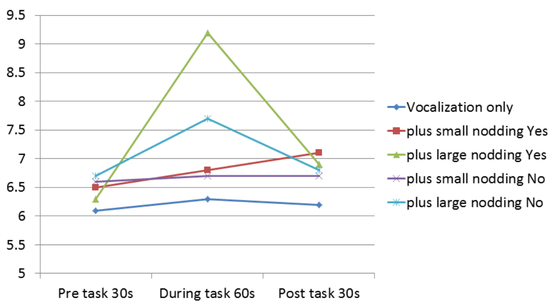
Left upper row, the measurement positions averaged among the 12 participants in a prior study by Funane et al (2011); Left lower row, the measurement positions in two participants in the present study on a standard brain in the MNI coordinate system.

Results of study 2

Head motion: Plus small & large nodding Yes



Variation (%) of [Oxy-Hb] levels



Left upper row, a smaller amplitude of the velocity; Left lower row, a larger amplitude of the velocity, the other recordings (vocalization only, plus small & large nodding No) are not shown; Right, an increase in variation during task 60s is clear in the condition of plus large nodding Yes.

Conclusions

By using virtual registration technique, 16 channels of the WOT-100 used in our dual fNIRS system were found to be localized at specific prefrontal cortical regions, which was comparable with a prior study using the same instrument.

By using a wireless small motion sensor, NIRS signals were found robust for a small (1-2 cm) vertical or horizontal head motion. However, a large (5-6 cm) vertical head motion had a possible adverse effect on the signal level.

We should be cautious for this when applying the dual fNIRS system to interactive human behaviors such as conversation with non-verbal communication (e.g. gesture) in natural condition.