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研究課題名（和文）ブレインマシンインタフェースによる認知課題成績の促進

研究課題名（英文）Enhancing perceptual performance by BMI

研究代表者
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研究成果の概要（和文）：本研究の目標は非侵襲脳計測により、行動を予測する神経プロセスを決定することである。雑音中の音韻判別課題では、音声提示の約 100 ミリ秒前に、運動前野において判別成績を予測出来る脳活動が見られた。飛行操縦実験では、試行の 25 から 5 秒前の自発的な脳活動から、着陸成績を予測出来ることが分かった。この脳活動は適切な行動を選択する注意が反映されていると考えられ、被験者の将来の行動を調節するフィードバックに利用できると考えられる。

研究成果の概要（英文）： The goal of the research proposal was to determine neural processes that predict behavioral performance using non-invasive brain imaging (MEG and fMRI). The results of the combined MEG and fMRI analysis revealed significant activity in premotor cortex that predicted behavioral performance on a speech in noise identification task around 100 msec before stimulus onset. Experiments involved with piloting an airplane while undergoing brain scanning showed that the spontaneous brain activity proceeding each trial by 25 to 5 seconds predicted future glider landing performance. It is hypothesized that this activity reflects attentional preparation in selecting appropriate action plans in the subsequent trial that can be used to give feedback to the subject to modulate future performance.

交付決定額

（金額単位：円）

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2009 年度	1,900,000	570,000	2,470,000
2010 年度	1,300,000	390,000	1,690,000
2011 年度	500,000	150,000	650,000
総　計	3,700,000	1,110,000	4,810,000

研究分野：総合領域
科研費の分科・細目：神経科学、神経科学一般
キーワード：MEG, fMRI, behavioral performance, prediction, decoding, perception, perceptual-motor

１．研究開始当初の背景

(1) The use of articulatory goals to mediate perception was proposed long ago by the motor theory of speech perception (Liberman et al., 1967) and the theory of analysis by synthesis (Stevens and Halle,

1967). I recently reformulated these theories in speech perception in terms of instantiating the use of internal models (Callan et al., 2003; 2004). Studies have shown that regions of the premotor cortex and inferior frontal gyrus known to be involved with action production are also active during action perception ('Mirror Neuron System') (Di Pellegrino et al., 1992; Nishitani et al., 2005). These findings have led to considerable conjecture regarding the neurophysiological mechanisms underlying a variety of abilities ranging from perception to social cognition. A considerable number of my own studies have identified the involvement of speech motor brain regions during speech perception (Callan et al., 2000; 2001; 2003; 2004). I have additionally shown that activity in premotor cortex and Broca's area is related to perceptual learning and performance of second language phonetic contrasts (Callan et al., 2003; 2004; 2006; 2007).

(2) Although these studies demonstrate that premotor cortex and Broca's area, known to be active during speech production, are also active during various speech perception tasks they do not address whether this activity is involved with perceptual performance at the event level. Indeed, more generally, despite the considerable number of studies showing 'Mirror System' activity, its relationship to perceptual performance (for any task) has not been demonstrated. Without such evidence, it may be argued that this activity does not reflect neural properties important for perception at all, but merely reflects covert imitation of the perceived action that is the product of perceptual processing.

(3) Real-time decoding and manipulation of stimulus parameters such as onset time and optimally scheduling trials to maximize performance has not been attempted using MEG. My research attempts to determine methods to make this possible.

(4) It is unclear what types of behavioral tasks will allow for performance to be predicted by brain activity prior to stimulus or trial onset.

２．研究の目的

(1) The purpose of the research proposal was to determine neural processes that predict behavioral performance using non-invasive brain imaging such as magnetoencephalography MEG and functional magnetic resonance imaging fMRI.

(2) An additional purpose of the research proposal was to monitor ongoing oscillatory neural activity localized in specific brain regions in real-time and manipulate the onset of stimulus presentation or optimally schedule trials by using a brain-machine-interface to alter behavioral performance.

３．研究の方法

Speech in Noise Experiment

(1) I used functional magnetic resonance imaging as well as 208 channel MEG for each subject (N=16) to measure brain activity to correct and incorrect trials on an auditory phonetic identification task. The task involved listening to a syllable (/ba/, /bo/, /da/, do/) presented aurally embedded in white noise and selecting the initial phoneme (/b/ or /d/) by button press as quickly and accurately as possible using the left hand.

(2) For fMRI experiments an event-related analysis was employed in which the correct trails were contrasted with incorrect trials. An additional fMRI experiment was conducted in which subjects overtly produced the same syllables as were presented on the auditory speech perception task. This was to determine brain regions that are active for both speech production and speech perception that were the target of this study.

(3) For MEG analysis independent component analysis was used for artifact rejection. The fMRI data on the same task was used as a prior constraint for current source localization on the surface of the cortex using variational Bayesian multimodal encephalography (VBMEG). Time frequency analysis was carried out over the current sources localized on the surface of the cortex. Standard statistical analyses were carried out over the time-frequency plots in various brain regions.

(4) Decoding of correct versus incorrect performance was decoded using sparce logistic regression using features from the time frequency analyses in different brain regions as well as hierarchically across the brain regions both 1 second before and 1 second after stimulus onset.

Glider Landing Experiment
(1) Both fMRI and MEG were used to collect brain imaging data from pilots (N=14) performing a difficult glider landing task.

(2) The flying task was to land a glider (ASK-21) as close to a red + on the runway as possible to the left or right as instructed while keeping alignment with the runway and proper pitch, yaw, and roll on landing. Subjects utilized 4 degrees of freedom to fly the glider including a joystick used with right hand (aileron controlling roll and elevator controlling pitch), pedals used with both feet (rudder controlling yaw), and a dive break used with the left hand (air break controlling increased drag and increased steepness of glide slope). There was also a baseline condition where the subject rested looking straight and did not move. Glider landing performance was assessed by the distance to the red +. Each of the trials lasted 20 seconds with approximately 3 seconds between to present instructions for the next trial.

(3) For the fMRI analysis parametric modulation of each trials landing performance with brain activity was assessed for the trial in which the task was accomplished as well as for the spontaneous activity in the proceeding baseline rest trial.

(4) For MEG analysis independent component analysis was used for artifact rejection. The fMRI data on the same task was used as a prior constraint for current source localization on the surface of the cortex using variational Bayesian multimodal encephalography (VBMEG). Time frequency analysis was carried out over the current sources localized on the surface of the cortex.

(5) Decoding of performance using sparse regression over features of the cortical activity results of VBMEG analysis was used for both spontaneous activity before the task as well as activity during the task.

４．研究成果

Speech in Noise Experiment
(1) The results of the experiments conducted in this study strongly suggest that the ventral PMC including the opercular part of Broca's area identified as having Mirror System properties is an influential part of the perceptual system that is involved in facilitating performance. Both the fMRI and MEG results (Fig. 1) indicate significant differential activity for correct over incorrect trials within the ventral PMC/Broca's area. This region was found by conjunction analysis to be present during speech production, active speech perception in which a button response was required for phonetic identification, and during passive speech perception of the same phonemes. The presence of neural activity during action observation and action execution are hallmarks of the Mirror System (Iacaboni 2005; Iacaboni and Dapretto 2006; Rizzolatti & Craighero, 2004).

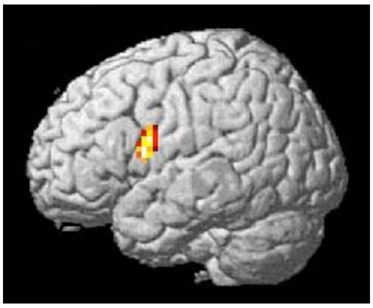

Fig. 1. Brain Activity in ventral PMC/Broca's area that predicts speech perception performance for both fMRI and MEG analyses that is active for both speech perception and production tasks.

(2) These results are highly relevant in that they dispel concerns that the activity found in brain regions involved with motor planning and execution during perception are merely a result of covert imitation of the perceived action arising from a perceptual system upon which no influence is exerted. Additionally the results have ramifications with respect to predictions made by direct realist and constructivist theories of speech perception.

(3) Results of decoding analysis across the entire brain using sparse logistic regression revealed that correct and incorrect trials could be predicted prior to stimulus onset with an average of around 90% across subjects. These results are important in that they demonstrate that it may be possible to manipulate stimulus onset time to enhance behavioral performance.

Glider Landing Experiment

(1) The results of the glider landing experiment show that brain activity on a complex real-world task can be identified that parametrically relates to behavioral landing performance (Fig 2).

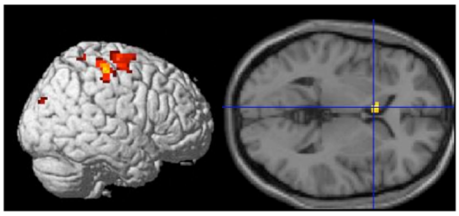

Fig. 2. Brain Activity that is parametrically modulated with glider landing performance during the task. The same regions were found to be negatively modulated with landing performance in the spontaneous activity just prior to the start of the trial. Brain regions include premotor cortex, motor cortex, supplementary motor area, and basal ganglia.

(2) It was further shown that activity in these same regions that had greater activity with better landing performance had reduced spontaneous activity in the rest condition prior to onset of the landing task. It is hypothesized that this activity reflects attentional preparation in selecting appropriate action plans in the subsequent trial.

(3) MEG analysis is still underway. The ability to detect future landing performance from spontaneous brain activity several seconds before the task suggests that it can be used to give feedback to enhance performance.

５．主な発表論文等

〔雑誌論文〕（計２件）

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〔その他〕
ホームページ
http://www.cns.atr.jp/~dcallan/index.html

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