A DIRECT BRAIN INTERFACE BASED UPON DETECTION OF EVENT RELATED POTENTIALS IN AN ELECTROCORTICOGRAM

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The goal of this project is the development of a direct brain interface based on detection of event-related potentials (ERPs) within electrocorticogram (ECoG) obtained from the surface of the cortex. The initial study in this effort involved the identification of averaged ERP templates to be used for cross correlation based detection. Ten epilepsy surgery patients, undergoing monitoring with subdural electrode strips and -rid arrays, participated in this study. ECoGs were continuously recorded while subjects performed multiple repetitions for each of several motor actions. ERP templates were identified from action-triggered ECoG averages using amplitude criterion. At least one ERP template was identified for all ten subjects and in 56% of all electrode recording sets resulting from a subject performing an action. These results were obtained even though electrodes were placed solely for clinical purposes and not for research needs. Eighty-two percent of the identified ERPs be-an prior to the trigger, indicating the presence of premovement ERP components. The recording locations for multiple ERPs arising from the performance of a specific action were usually found on close-by electrodes. ERPs associated with different actions were occasionally identified from the same recording site but often had noticeably different characteristics. The ease with which ERP templates were identified for subjects and the differences apparent in the location or shape of valid ERPs related to different actions supported the use of subdurally recorded ERPs as a basis for a direct brain interface

Ongoing, work to develop a direct brain interface is now focused on the detection of individual ERPs within the ECoG using cross-correlation between an averaged ERP template (as described above) and the continuous ECoG from the same electrode recording site. Each point where the cross-correlation value exceeds an experimentally determined detection threshold is considered a detection point. Each detection point is considered to be a valid "hit" if it occurs between one second before and a quarter second after the recorded time of a voluntary action. The difference between the hit and false positive percentages (HF-difference) is used as a metric of detection accuracy. To date, 15 subjects have been studied. HF-differences greater than 75 were found for 8 of the 15 subjects. Four subjects had HF-differences in the range 50 to 75. The subjects with low detection accuracy either performed only one action or had electrode locations not well suited for recording movement-related ERPs. The best HF-differences were 96 (96% hits - 0% false positives), 96 (100%-4%), and 93 (100%-7%).

In all of these studies electrodes were placed solely to meet clinical needs and not for research purposes. The number of subjects for whom accurate detection of ERPs was possible even without custom placement of the electrodes over sensory-motor cortex indicates that a direct brain interface that can accept a command directly from the brain (without requiring any physical movement) and produce a single switch closure is quite feasible. Such an interface would enable people with severe disability (i.e. locked-in syndrome) to communicate and to participate in society. Results further indicate the strong feasibility of multiple control channels using this approach.

The actual provision of this direct brain will require chronic subdural implantation of electrodes, an extremely invasive procedure. Before this step is considered, additional studies are being performed with epilepsy surgery subjects to 1) confirm that improved electrode placement will produce higher percentages of accurately detectable ERPs and 2) demonstrate the use of the direct brain interface for communication or other functional tasks.

Concurrently, other studies are underway which include: 1) improved methods to predict the accuracy possible with a particular ERP template; 2) template optimization through data preprocessing and/or selection of average constituents; 3) methods for ERP detection when there is no associated physical motion, 4) exploration of the ability of subjects to control or modify ERP quality given appropriate feedback; 5) optimization of the detection methods through alternative methods for analysis of the cross-correlelogram; and 6) examination of multiple-electrode detection algorithms.

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