Brain-Computer Interaction

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Abstract. Detection and automated interpretation of attention-related or intention-related brain activity carries significant promise for many military and civilian applications. This interpretation of brain activity could provide information about a person's intended movements, imagined movements, or attentional focus, and thus could be valuable for optimizing or replacing traditional motor-based communication between a person and a computer or other output devices. We describe here the objective and preliminary results of our studies in this area.

Keywords: Brain-computer interface, BCI, Neural Engineering, Neural Prosthesis.

1 Introduction

Inquiring a soldier's directional orientation (e.g., direction of attention) is usually either impossible or at least requires motor function. This requirement is often limiting. Directly determining directional orientation from brain signals, not using muscles, would have numerous applications for military use. For example, the locus of attention and/or intended movements could be used to optimize target acquisition or identification. Brain-computer interfaces (BCIs) record signals from the brain and translate them into useful outputs. Recent studies in the rapidly growing field of BCI research provide impressive demonstrations, either with non-invasive [1-15], moderately invasive [16-20], or invasive [21-29] techniques, that BCI technology can allow people to communicate with others using brain signals alone. However, current BCI devices do not readily support large-scale deployment largely because current techniques are either not practical for use in humans [30], require extended user training [31], or function only in particular environments.

Our long-term goal is to develop BCI technologies into a range of practical and useful non-muscular communication, control, and monitoring applications. To work towards this goal, the objective of current efforts is to create a prototype of a system for communication and monitoring of orientation that uses brain signals to provide, in

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real time, an accurate assessment of the direction of the a person's attention, movement intention, and eye gaze.

Its achievement requires that we delineate the brain signal features associated with these variables, determine to which degree these features can be detected using non-invasive sensors, and finally create a system that can translate these features into a set of useful output functions in real time.

2 Methods

In accord with the objective outlined above, we are currently pursuing three avenues in this research. The first avenue is to delineate the brain signal features associated with the direction of attention, intention, and eye gaze. We do this by recording electrical brain signals invasively from the surface of the brain in human subjects. These subjects are asked to engage in tasks that are designed to vary relevant parameters, such the direction of attention. (These subjects are human patients that have electrode grids implanted on the surface of the brain for clinical reasons. Thus, they are not being implanted for the purpose of these research projects.) Analyses relate the brain signals to the parameters of interest described above, and thereby delineate the brain signal features that are most predictive of the particular task. We also plan to determine the relationship of the observed features across time and space to establish a mechanistic understanding of relevant cortical systems.

The second avenue of research is to determine whether these features can be detected non-invasively. To provide information that is critical for practical deployment of such a system, we plan to determine the degree to which these brain signal features and brain systems can also be detected using electrical sensors placed non-invasively on the scalp. To do this, we will use the results gathered using invasive methodologies to guide electrode placement and analyses.

The third avenue of research is to validate the use of brain signals for communication and orientation. To create a prototype of an intuitive communication and orientation system, we will design algorithms that are capable of extracting the features identified above on a single-trial basis, and incorporate these procedures into a real-time software system, called BCI2000 [32], that has been developed in our laboratory over the past decade. The resulting system will allow for a real-time assessment of the direction of the user's attention, intended movements, and eye gaze.

We expect that these efforts will provide the first prototype system that can derive these parameters in humans in real time. These efforts should also contribute fundamental neuroscientific understanding in humans.

3 Preliminary Results

Preliminary results to date provide encouraging evidence that brain signals in humans hold information (which could be extracted in real time) about the direction of attention (Fig. 1) and eye gaze.

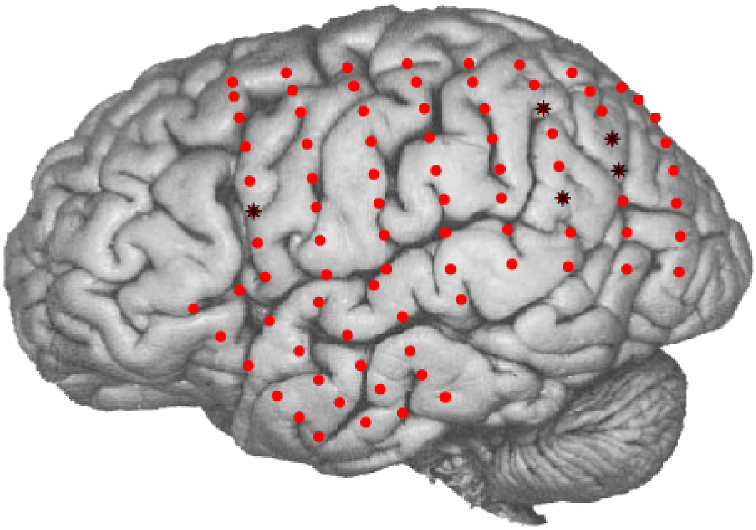

Fig. 1. Information about directional attention in one subject. Red dots indicate all electrode locations. Black stars indicate locations that hold statistically significant ($p<0.001$, Bonferroni corrected) information about whether the subject's attention is focused on the left or right hemisphere of the visual field.

4 Conclusions

Our ongoing studies are addressing the question whether it is possible to derive, in real time, signals from the brain in humans that provide information about a person's directional orientation, i.e., attention, intention, and eye gaze. Preliminary results support this hypothesis.

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