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HUMAN SCALP POTENTIALS ASSOCIATED WITH PREPARATORY AND MOVEMENT-RELATED PROCESSES

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The ontogenetic aspects and the spatial, temporal organization of movement-related brain macropotentials recorded during the execution of a skilled performance task are reviewed. The skilled performance task is a self-paced, voluntary, interactive, bimanual, goal-directed task, that requires bimanual coordination, adaptive self-programming, learning a correct time interval, improvement of performance and provides on-line knowledge of results. The cerebral potentials associated with this task are: the Bereitschafts-potential related to the preparatory processes before the movement; the motor cortex potential related to the execution of the task and the skilled performance positivity related to evaluation and knowledge of results after the movement. Normative data and clinical applications are also described.

KEY WORDS: Bereitschaftspotential, goal-directed behaviour, movement-related potentials, skilled task.

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INTRODUCTION

From the very first month of life, the parents' attention is focused on detecting the first motor behaviour of their child as a signal of an initial social interaction. Grasping objects, crawling, walking and talking are indicated as fundamental steps in a child's psychomotor development. The scope is obviously the wish to match a motor event with a psychic meaning. This mental meaning becomes transparent when the child's action changes into voluntary and finalized action and becomes the expression of his thought.

The psychological studies of this century have studied this argument extensively, whereas physiological studies on animals and man have described all the physical and kinematic aspects of the movement itself. It is known that a simple voluntary movement is the result of a complex integration between the central nervous system, the autonomous and the peripheric.

Only recently, thanks to the technological development of computers, has it been possible to investigate all these aspects in close temporal relationship with the behaviour of man and subsequently give a psychological interpretation of the cerebral modifications that take place during a motor action.

The discipline that studies these aspects is Psychophysiology which initiated originally in the studies carried out by the Russian school of Pavlov, Luria, Bernstein and more recently in the anglo-saxon and american school of Grey Walter, Kornhuber and Sutton. Initially, the electric cerebral phenomena that accompanied simple behavioural answer were described, such as, the simple movement of a finger as an answer to a stimulus or self initiated; subsequently, human behaviours seen as the result of an interaction between the subject and his environment have been studied with more complex paradigms. By the term subject-environment interaction Papakostopoulos (1) means "a situation in which the individual's plan and action towards a goal can be continuously updated on the basis of the results achieved after each attempt. In such a behavioural sequence individual attempts are interlinked because the preceding ones influence subsequent ones. After each attempt new information is available to be used, provided that the subject choose to do so".

The paradigm employed to study interactive behaviour is the self-paced, goal directed, interactive task introduced by Papakostopoulos in the 1978 (2). It allows the quantification of the interaction between subject and environment in terms of performances and strategies of performances simultaneously to the quantification of the brain signals, of the involved muscles and of the autonomous nervous system. In brief, the subjects were requested to perform a self-paced left hand button-press which had as a result the initiation of the sweep of an oscilloscope. The sweep had to be stopped by a right hand press within 40-60ms from its initiation. It is apparent from the short time allowed for the right hand press that both initiation and arrest of the sweep had to be prepared before the execution. The subject was informed of his degree of accuracy in preparing and executing the whole sequence by on-line information provided by the end point position on the screen of the oscilloscope trace. The brain electrical activity accompanying the performance of this task is defined as movement related brain macropotentials (MRBMs). Observation of the myographic and brain electrical activity allows us to distinguish four periods: a premotor period; a motor-sensory period; a motor completion period, and a postmotor period (3). Figure 1 shows a detailed diagram of the sequence of the electrical brain events accompanying the execution of this task.

The premotor period is characterized by the steady, tonic muscular activity, the deceleration of heart rate and the presence on the scalp of a phasic negative potential lasting 800 to 1200 ms: the Bereitschafts-potential (4), or readiness potential (5), that is absent during passive movements. Its amplitude is proportional to the complexity of the task both in adults (3) and in children (6). It is mainly recorded in the frontal and central regions. The Bereitschafts-potential (BP) is believed to reflect the processes of organization and selection of the strategy needed to carry out the task and has been proposed as an electrophysiological index of cerebral efficiency during the premotor period.

The sensory-motor period begins at the onset of phasic electromyographic activity and lasts about 200 ms. It is during this period that behaviour becomes manifest. It coincides with the appearance on the scalp of the motor cortex potential (MCP), and N100. Motor cortex potential is a negative potential that follows the Bereitschafts-potential; it is absent during passive movements, present in simple voluntary motor actions, and increases in amplitude during ballistic and sustained motor actions (2,7). Scalp and cortical recordings have shown that motor cortex potential is mainly present in the precentral and central regions and is absent from the parietal regions (8,9). The motor cortex potential is proposed as an index of response generated reafferent activity from the muscle, skin and tendon receptors (10). It is present in both children and adults, its amplitude decreasing with senescence (11). N100 is a negative potential with a latency of 100 ms that follows the motor cortex potential and represents the response evoked by the appearance of the oscilloscope trace and is normally inhibited in the

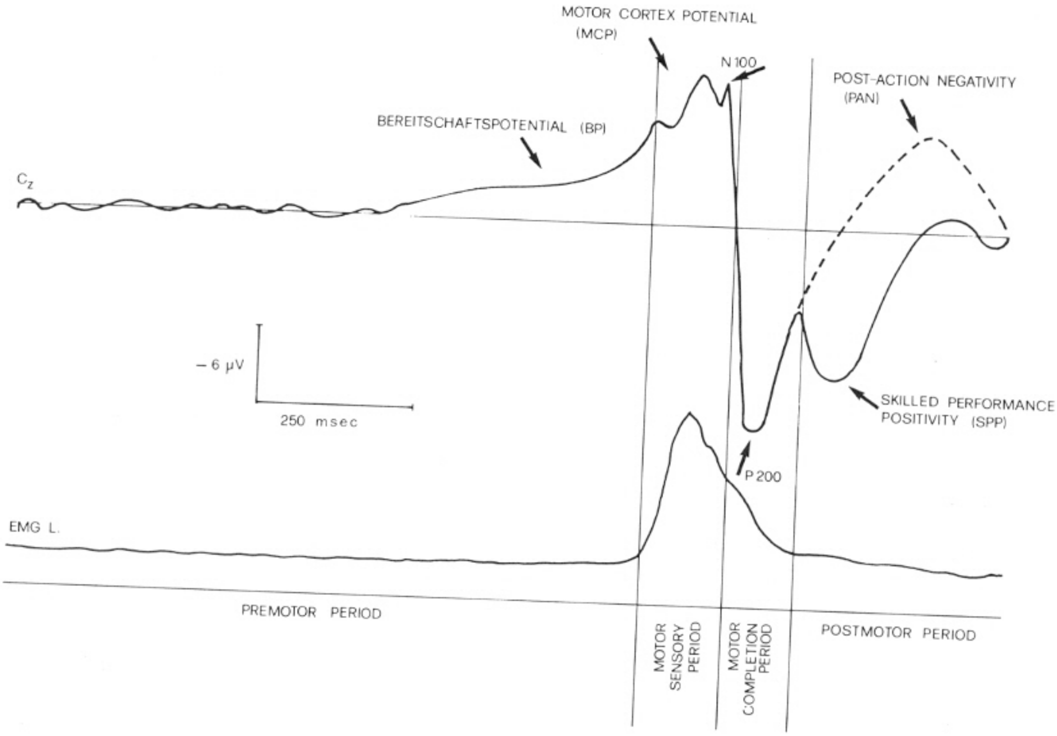

Fig. 1 - Schematic diagram of movement related brain macropotentials during goal-directed behaviour.

frontal and postcentral areas during movement.

The motor completion period is characterized by the completion of the electromyographic phasic activity and the presence of a positive potential defined as P200 that follows N100 with a latency of about 200 ms from the beginning of the light stimulus (5). This potential is present during passive an active movements, both simple and complex and is believed to be one of the components of the reafferent somatosensory potential on the basis of its developmental course (12).

The postmotor period is characterized by the electromyographic tonic activity similar to the premotor period, the acceleration of heart rate, the development of Galvanic skin response (GSR) and the appearance on the scalp of a positive potential with a latency of about 450 ms called skilled performance positivity (SPP) (2), and by a slow negative potential defined as post-action negativity, with a latency of about 600 ms (12). The skilled performance positivity, in the adults, has a higher amplitude in the centro-parietal regions. Scalp and cortical recordings have shown that skilled performance positivity is present only when the subject can evaluate the result of his performance (8,13). This potential is independent of the motor action and the presence of any exteroceptive stimulation; it coincides with the subject's awareness of success or failure in the performance (8,14).

Post-action negativity has a specific spatial distribution, mainly recorded in the fronto-central regions, and decreases in amplitude with age disappearing around the tenth year (12). Like the skilled performance positivity, post-action negativity is independent of the motor act and seems to be related to analysis and evaluation strategies different from those generating skilled performance positivity (15). The presence of these positive and negative potentials following the performance of a skilled action has been confirmed by other authors, each time a voluntary goal-directed motor task is employed (7,16-21).

Direct electrical (8) and magnetic recordings (22) form the human cortex, developmental studies (12) and variations in experimental procedures provide firm experience for the area of generation of the BP, MCP and SPP together with the processing function which is associated with each one of them.

Clinical studies, Parkinson's desease, Down's Syndrome, schizophrenia, dyslexia and other psychiatric conditions (23-26) are characterized by different profiles which are relevant both in further understanding and treating those conditions.

Parkinsonian subjects, for example, have been discriminated on the basis of the BP amplitude, between three subgroups of patients with different symptoms and responses to drug treatment: 1) low BP amplitude - symptoms dominated by rigidity, good response to drug treatment; 2) normal BP amplitude - symptoms dominated by tremor, poor response to treatment; 3) high BP amplitude, symptoms dominated by akinesia, very good response to treatment. This division of patients into subgroups may have relevant clinical implications vis-à-vis the drug therapy to use, i.e. L-dopa or anticholinergic drugs or a combination of both (26).

Down syndrome subjects are known to be very slow in carrying out motor perceptive tasks; they are known to age precociously and Alzheimer-type tangles are observed in the frontal and precentral cortex. Their psychophysiological profile is characterized by the absence of BP and MCP. Down syndrome subjects, besides having few or no preparation processes, lack the ability to process the response-generated sensory reafferent information. These subjects like old people, they do not learn new motor ability tasks rapidly: lack of MCP may be considered as a contributing factor (27).

This approach together with the comprehension of higher nervous functions which regulated and organise the movement in its innermost sophisticated aspects, as a subject-enviroment interaction, could be usefully employed to develop further diagnostic criteria and methods for the evaluation of pharmacological and rehabilitation treatments.

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