CC/NUMBER 10
MARCH 8, 1982

This Week's Citation Classic

Vaughan H G, Jr., Costa L D & Ritter W. Topography of the human motor potential. *Electroencephalogr. Clin. Neuro.* 25:1-10, 1968.
[Dept. Neurology, Albert Einstein Coll. Med., Bronx, NY]

The scalp topography of cortical potentials associated with voluntary movements of the face, tongue, hand, and foot was maximum in amplitude over the contralateral precentral cortex and exhibited distributions consistent with the known arrangement of body parts within the motor cortex. [The *Science Citation Index*® (*SCI*®) and the *Social Sciences Citation Index*® (*SSCI*®) indicate that this paper has been cited over 140 times since 1968.]

Herbert G. Vaughan, Jr.
Rose Fitzgerald Kennedy Center for
Research in Mental Retardation
and Human Development
Albert Einstein College of Medicine
Bronx, NY 10461

January 11, 1982

"In 1961 our laboratory began a systematic study of the cortical electrical activity associated with human information processing, using computer averaging techniques to extract the tiny signals specifically related to sensorimotor processes from the random activity that predominates in the scalp-recorded electroencephalogram. Although cortical potentials elicited by external stimulation had begun to be widely studied, no brain activity related to the initiation of voluntary movements had been observed, either in man or in experimental animals. Such activity should, in principle, be detectable by signal averaging methods if the brain activity related to movement could be adequately synchronized.

"We initially observed movement-related potentials from scalp recordings overlying the motor cortex when brisk responses of the hand or foot were made in response to visual or auditory stimulation.[1] Similar 'motor potentials' were recorded when movements were self-initiated, but in contrast to the stimulus-triggered condition, activity preceded the movements by one second or more.[2] These 'readiness potentials,' concurrently reported by Kornhuber and Deecke,[3] provided evidence that preparatory neural mechanisms were volitionally activated long before the phasic discharge of corticospinal neurons reflected in the potentials that immediately preceded movement initiation. The next step in our investigation involved the detailed mapping of the motor potentials in an effort to identify the cortical regions that generated them. Our findings, reported in this paper, indicated a somatotopic distribution of potentials preceding face, hand, and foot movements consistent with the spatial organization of motor cortex which Penfield and Boldrey had demonstrated by direct electrical stimulation in the 1930s.[4] Subsequent work from several laboratories[5-7] has further examined the configuration and scalp topography of movement-related potentials in both normal subjects and in patients with motility disorders.

"Although some issues regarding the specific neural structures that generate the complex sequence of potentials associated with voluntary movement remain to be empirically resolved, the motor potentials provide a non-invasive index of cortical mechanisms involved in the initiation and control of human voluntary movement. Following the discovery of the scalp-recorded movement-related potentials in man, studies of single neurons in monkeys trained to perform specific movements have contributed a substantial amount of information on the brain mechanisms underlying motor control. There is a close relationship between firing patterns of neurons within the motor cortex and the motor potentials of monkeys. Furthermore, the human and simian movement-related potentials closely resemble one another, both in waveform and topography.[8] Thus, these potentials provide a bridge between the analysis of motor mechanisms in experimental animals and the study of cerebral processes related to movement in man.

"This report has presumably been frequently cited because it was the first effort to relate the scalp distribution of human movement-related potentials to the underlying somatotopic organization of sensorimotor cortex."

1. **Vaughan H G, Jr., Costa L D, Gilden L & Schimmel H.** Identification of sensory and motor components of cerebral activity in simple reaction-time tasks. *Proceedings of the 73rd Annual Convention of the American Psychological Association, 1965.* Washington, DC: American Psychological Association, 1965. p. 179-80.
2. **Gilden L, Vaughan H G, Jr. & Costa L D.** Summated human EEG potentials with voluntary movement. *Electroencephalogr. Clin. Neuro.* 20:433-8, 1966.
3. **Kornhuber H H & Deecke L.** Hirnpotentialänderungen bei Willkurbewegungen und passiven Bewegungen des Menschen: Bereitschaftspotential und reafferente Potentiale. *Pflügers Arch. Ges. Physiol.* 284:1-17, 1965.
4. **Penfield W & Boldrey E.** Somatic motor and sensory representation in the cerebral cortex of man as studied by electrical stimulation. *Brain* 60:389-443, 1937.
5. **Deecke L, Scheid P & Kornhuber H H.** Distribution of readiness potential pre-motion positivity, and motor potential of the human cerebral cortex preceding voluntary finger movements. *Exp. Brain Res.* 7:158-68, 1969.
6. **Shibasaki H, Barrett G, Halliday E & Halliday A M.** Components of the movement-related cortical potential and their scalp topography. *Electroencephalogr. Clin. Neuro.* 49:213-26, 1980.
7. **Deecke L, Engltz H G, Kornhuber H H & Schmitt G.** Cerebral potentials preceding voluntary movement in patients with bilateral or unilateral Parkinson akinesia. (Desmedt J E, ed.) *Attention, voluntary contraction, and event-related cerebral potentials.* Basel: Karger, 1977. p. 151-63.
8. **Arezzo J C & Vaughan H G, Jr.** Intracortical sources and surface topography of the motor potential and somatosensory evoked potential in the monkey. (Kornhuber H H & Deecke L, eds.) *Motivation, motor and sensory processes of the brain: electrical potentials, behaviour, and clinical use.* Amsterdam: Elsevier/North-Holland Biomedical Press, 1980. p. 77-83.