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This Week's Citation Classic®

Picton T W, Hillyard S A, Krausz H I & Galambos R. Human auditory evoked potentials. I: evaluation of components. *Electroencephalogr. Clin. Neuro.* 36:179-90, 1974; and **Picton T W & Hillyard S A.** Human auditory evoked potentials. II: effects of attention. *Electroencephalogr. Clin. Neuro.* 36:191-200, 1974.

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The first paper identified 15 distinct components in the auditory evoked potential recorded from the human scalp: early potentials originating from the cochlea and brainstem, middle-latency potentials from the auditory thalamus and cortex, and long-latency potentials. The second paper found no significant effect of attention on these measurements until the long-latency potentials. [The *SCI*® and *SSCI*® indicate that these papers have been cited in over 350 and 290 publications, respectively.]

Between Reality and Prophecy

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The studies that led to my doctoral thesis with Bob Galambos followed two main principles—that cognition should be studied in relation to the brain and that human brains would provide the best access to cognition. Since the idea of human neuroscience ran somewhat counter to the tenor of the times, I placed an explanatory sign above my desk—"The more we know about the workings of the human brain, the easier it will be to understand the abdominal ganglion of the *Aplysia*."

Steve Hillyard and I became fascinated by the possibility of studying the processes of human attention with the auditory evoked potentials—small electrical patterns that can be recorded from the human scalp in response to a sound. I reviewed these responses for the weekly laboratory seminar, a wonderful session where enthusiasm and criticism talked to one another, and presented a sequence of early, middle-latency, and long-latency auditory evoked potentials, with each potential having particular characteristics. I remember Bob getting very excited about how this could organize our experiments on the human auditory system and figuring out how to display the whole sequence on a logarithmic time-scale. The classification system is probably the main reason the first paper has been so frequently quoted.

However, our main intent was to investigate the intracerebral generators of these scalp-recorded potentials. We would only find out more about the neurophysiology of attention if we knew the origins of our waveforms. Our main approach was to evaluate the scalp-distribution of the different waves in the evoked potential. Analyzing the sources for scalp-recorded evoked potentials has progressed greatly since those early days, and some of our original ideas are no longer valid. We had concluded that the long-latency evoked potentials were generated by the widespread activation of the frontal cortex, in opposition to an earlier proposal by H.G. Vaughan and W. Ritter that they were generated in the auditory cortex of the temporal lobe.[1] Recent evidence suggests that they were correct[2] and convinces me that being able to disprove one's PhD thesis is the hallmark of a good scientist.

The second paper evaluated the sequence of auditory evoked potentials when a subject attended to the sounds. Our findings suggested that auditory information is initially processed (through the early and middle-latency potentials) without regard to attention. This remains the generally accepted finding,[3] although, under certain conditions, there may be some attentional changes in the middle-latency response.[4]

The long-latency potentials showed two main effects of attention—an enhancement of the response to attended stimuli and the addition of a late negative-positive complex when the subject detected a target. A similar complex occurred alone (without any sensory evoked potential) when the subject detected occasional omissions in a regular train of stimuli. The human brain analyzes incoming information independently of attention, compares this information with what is expected, and initiates action on the basis of the comparison. I tried to express these ideas in the statement that "between the reality and the prophecy there rests the judgement of perception." However, my colleagues thought it too pompous, and, although it was translated into Russian,[5] this represents its first publication in English (now that middle age has dissolved some of my youthful inhibitions).

The evoked potentials still contribute to the study of attention.[6,7] Present research is concerned more with demonstrating the different cerebral processes that occur during attention than with trying to prove that attention does not affect particular processes—an endeavour that easily runs aground on the limitations of the measuring technique.[8] The evoked potentials cannot record everything that occurs in the human brain, but whatever they record must be considered in any formulation of how the brain works.

1. **Vaughan H G & Ritter W.** The sources of auditory evoked responses recorded from the human scalp. *Electroencephalogr. Clin. Neuro.* 28:360-7. 1970. (Cited 235 times.)
2. **Scherg M, Vajsar J & Picton T W.** A source analysis of the late human auditory evoked potentials. *J. Cognitive Neurosci.* 1:336-55. 1989.
3. **Connolly J F, Aubry K, McGillivary N & Scott D W.** Human brainstem auditory evoked potentials fail to provide evidence of efferent modulation of auditory input during attentional tasks. *Psychophysiology* 26:292-303, 1989.
4. **Woldorff M, Hansen J C & Hillyard S A.** Evidence for effects of selective attention in the mid-latency range of the human auditory event-related potential. *Electroencephalogr. Clin. Neuro.* (Supp. 40):146-54, 1987.
5. **Picton T W, Hillyard S A & Galambos R.** Evoked responses to omitted stimuli. (Livanov M N, ed.) *Basic problems of brain electrophysiology*. Moscow, USSR: Nauka, 1974. p. 302-11. (In Russian.)
6. **Hillyard S A & Picton T W.** Electrophysiology of cognition. (Plum F, ed.) *Handbook of physiology. Section 1. The nervous system. Volume V. Higher functions of the nervous system*. Bethesda, MD: American Physiological Society, 1987. p. 519-84. (Cited 10 times.)
7. **Näätänen R.** Implications of ERP data for psychological theories of attention. *Biol. Psychol.* 26:117-63, 1988.
8. **Donald M W.** Limits on current theories of transient evoked potentials. *Prog. Clin. Neurophysiol.* 6:187-99, 1979.

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