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Cerebral Evoked Potential Correlates in Forced-paced Tasks

CEREBRAL evoked potentials can be monitored by averaging scalp records in subjects performing psychological tasks. The waveform is affected not only by the physical features of the sensory stimulus but also by cognitive and motivational parameters¹⁻⁷. These can be manipulated through verbal instructions given to the subject and several studies have shown that a slow positive component of about 300 ms peak latency (P_{300}) can be elicited by stimuli to which perceptual significance is attached^{2,5-8}. We have examined the evoked potential correlates of sensory overload in forced-paced auditory tasks and find that the cerebral "decision" potential can reveal intermittency in the perceptual channel.

Fifteen young adult volunteers with normal hearing served in one or more sessions. Each sat in an easy chair in a sound-proof air-conditioned room. Binaural clicks were delivered through Permoflux PDR-10 earphones at a regular interval which is the same throughout any run, chosen from 1,000 to

200 ms for successive runs. Each such run included a random sequence of 50% signal clicks (80 dB above subjective threshold) and 50% non-signal clicks of lower intensity (see below).

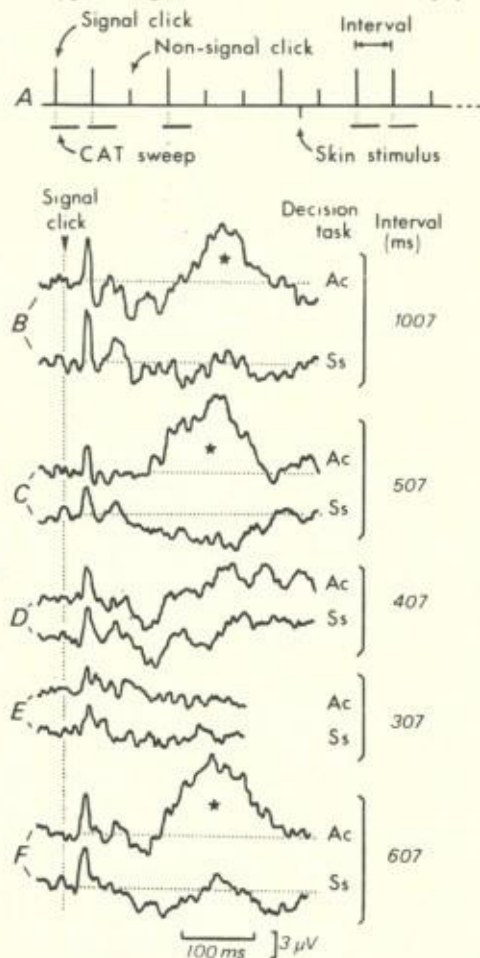


Fig. 1 *A*, Sample diagram of the stimulation program with a random sequence of signal and non-signal acoustic clicks, and skin stimuli. *B-F*, Records of cerebral potentials evoked by the signal clicks during decision tasks involving either the acoustic (Ac) or the somatosensory (Ss) stimuli. The intervals between successive clicks in the different runs vary from 1,007 to 307 ms. The runs were recorded in the order given. The differentiation between signal and non-signal clicks is difficult as their intensity difference is only 5 dB. The "decision" potentials are identified by a star.

The subject was asked to count mentally the signal clicks in the sequence, to avoid key-pressing or vocalizing which might induce so-called readiness or motor potentials^{9,10}. The cerebral potentials evoked by the signal clicks were recorded between vertex (Cz) and mid-frontal skin electrodes, stored on

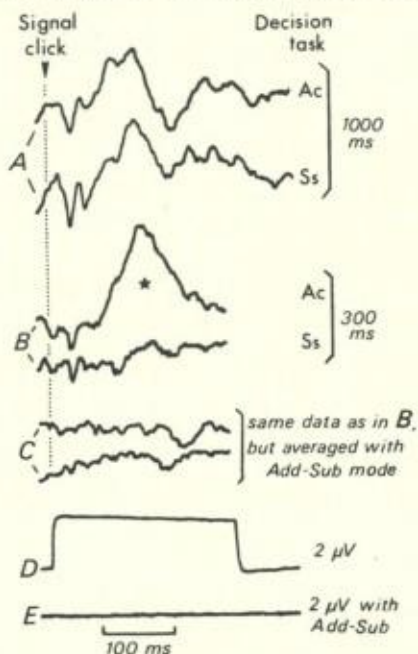


Fig. 2 Records of cerebral potentials evoked by the signal clicks during runs similar to those of Fig. 1, except that the intensity difference between signal and non-signal clicks is here 30 dB. The interval between acoustic stimuli is 1,000 ms in A and 300 ms in B.

an Ampex FR-1300 magnetic recorder and averaged by a CAT mnemotron computer whose sweep was triggered by the stimulus program (Fig. 1A). An accessory random program delivered occasionally a juxta-threshold electric pulse to the skin of one finger, and the CAT sweep was automatically disabled for the adjacent signal clicks to avoid trivial heterosensory interactions in the data. In each run an identical program of stimuli (about fifty signal clicks altogether) was delivered several times with brief periods of rest in between: the subject was asked to count mentally either the skin stimuli (somatosensory decision, Ss) or the signal clicks (acoustic decision, Ac), while the cerebral responses to the signal clicks

were recorded. This provided control sequences of click evoked potentials elicited while the subject was not attending to the auditory input^{6,8}. Subsequently the taped data corresponding to four or eight such sequences with alternate tasks were averaged together so that any trend in the experimental conditions during the run was minimized. In agreement with previous results^{2,6,8} the potentials evoked by identical binaural clicks presented at the easy frequency of 1/s differed characteristically according to task condition (Fig. 1*B*). In this experiment the auditory task was made difficult by having an intensity difference of only 5 dB between signal and non-signal clicks, and a large surface-negative component of about 120 ms latency appeared at the vertex (Fig. 1*B*, upper trace). The component was not present in the control potential recorded in the alternate sequences involving a somatosensory task (lower trace). Other runs with a higher frequency of click presentation are illustrated for the same experiment. The component associated with acoustic decision still appeared up to 2.0/s (Fig. 1*C* and *F*) but was not present at 2.5 and 3.3/s (Fig. 1*D* and *E*). The loss of the "decision" component was not related to fatigue, for it was readily elicited at the end of the session in a run at 1.7/s (Fig. 1*F*). It depended rather on the speed overload, which disrupted the performance of the subject. This is shown by the next experiment in which the auditory decision was made much easier by augmenting to 30 dB the intensity difference between the signal and the non-signal clicks. The decision was so easy that, in a run at 1/s (Fig. 2*A*), no difference appeared between the click evoked potentials recorded either with the acoustic or the somatosensory task⁶. When the pace was forced to 3.3/s in *B*, a prominent component of 75 ms peak latency was elicited by the signal clicks in the acoustic task (upper trace). As a routine test we averaged the same taped data with the add-sub mode, that is by alternate addition and subtraction of the samples, to estimate the noise which was superimposed on the stimulus-locked responses¹¹. Fig. 2*C* shows that the noise was quite similar for the two sequences compared, which shows that the large "decision" component in the upper trace of *B* is not related to the background activity. That the waveform is genuine is further indicated by the small distortion of a calibrating square function of 2 μ V averaged in the same way (Fig. 2*D*). Averaging this function in the add-sub mode results of course in a straight line (Fig. 2*E*). Other controls indicate that the component cannot be ascribed to non-specific systemic changes nor to variations in the level of arousal of the subject; indeed in alternate bi-sensory tasks the enhancement only involves the potential evoked by the cueing stimulus^{5,6,8}.

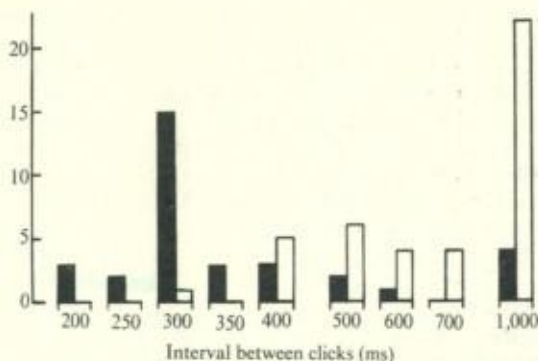


Fig. 3 Histogram of the incidence of a "decision" component in the cerebral potentials evoked by the signal clicks in seventy-five runs carried out at various frequencies. Abscissa, interval between clicks in any run. Black columns, decision component present.

A total of seventy-five runs at frequencies from 1/s to 5/s were carried out in sixteen sessions on fourteen subjects. The frequencies were chosen at random for the successive runs in any subjects, to avoid effects of possibly associated fatigue or task familiarity. The intensity difference between signal and non-signal clicks was 20-30 dB. Fig. 3 discloses a consistent trend although the number of runs performed at each frequency was different. A "decision" component was present in only four of the twenty-six runs at 1/s, and this occurred generally with naive subjects who were "trying too hard". All runs except one gave positive results at 3-5/s. The frequency of 2.5/s seems critical, with three positive results in eight runs, which is suggestive in view of our psychological experiments with identical sequences of signal and non-signal clicks (20-30 dB difference) in which subjects had to press a key for each signal click: in forced-paced conditions the rate of correct decisions did not exceed a ceiling of about $2.45/s^{12}$.

These results disclose rapid dynamics for the evoked potential "decision" components and indicate that rapid sequential tasks represent a cognitive load adequate to trigger this mechanism. At slow rates of presentation the signal stimuli only evoked a "decision" component if they involved a difficult discrimination task. Such difficult tasks cannot be performed correctly at rates exceeding about 2/s, at which the characteristic cerebral component disappears (Fig. 1). By contrast when the stimuli presented to the subject are very easy to discriminate the signal stimuli fail to elicit a "decision" component unless the stimuli are presented at a frequency

exceeding about 2.5/s (Figs. 2 and 3). To some extent the intrinsic difficulty of a discrimination and the speed at which it has to be made can be traded. We think that further studies along this line may provide an approach to the neural switching processes which organize information¹³.

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