

Covariation of the Magnitude of the CNV and P300 as a Function of the Subject's Task

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This paper is concerned with the relationship between the CNV and P300. An opportunity to analyse jointly these two components of the human cortical evoked response was provided by an experiment, reported elsewhere (Donchin *et al.*, 1973b), designed to assess the effects of cognitive complexity on the amplitude of P300. The *Ss* in that experiment were instructed to predict the outcomes of series of Bornoulli trials (trials which can have one of two possible outcomes). In each experimental trial a warning click was followed after 1400 msec by a flash of light illuminating either the letter A or the letter B, the letter defining the outcome of the trial. *S* had to predict the trial's outcome prior to the presentation of the warning click. From one experimental series to another the rule which determined the sequence of outcomes was varied, thereby varying the degree to which *Ss* could utilize information from preceding trials in developing their predictions.

In the paper cited above we focused on P300 elicited by the flash and were able to demonstrate that its amplitude varies systematically with the sequence-generating rule. The experimental arrangement clearly allows a similar study of the effect of the same experimental variables on the CNV. Moreover, we can, by using these data, study conjoint changes in the CNV and in P300. Equally interesting is an analysis of the distribution of both components over the scalp, an analysis made possible by simultaneous recording from 8 electrode locations.

The interrelation between the CNV and P300 has been subject to considerable debate (Donchin and Cohen, 1969; Näätänen, 1969; Donchin and Smith, 1970; Donald and Goff, 1971). At issue is the degree to which the amplitude of the P300 component reflects differential, pre-stimulus, anticipatory processes as has been suggested by Näätänen (1969) and by Karlin (1970) rather than post-stimulus processing as proposed by others (Sutton *et al.*, 1967; Donchin and Cohen, 1967; Hillyard *et al.*, 1971). A different, though related, issue concerns the degree to which the P300 component interacts with the positive-going limb of the CNV. A detailed discussion of these issues appears elsewhere in this volume.

METHOD

The experimental procedures have been described in detail in our previous report. Briefly, 10 *Ss* were each presented with five series of trials, 64 trials per series. Each trial consisted of a warning click followed after 1400 msec by a

flash illuminating the letter A, or the letter B, in an Iconix Tachistoscope. For stimulus parameters and instrumentation details see Donchin *et al.* (1973b).

The experimental series differed in the rule used to determine the sequence of outcomes. We used an *Alternating* series (ALT) in which the As and Bs alternated on successive trials. In the *Learn* series (LRN) *S* was handed prior to the series a sheet on which appeared a 9-element sequence of As and Bs. *S* was told that this sequence would be repeated in the coming series and that he was to memorise the sequence. In the *Pattern* (PAT) series a similar 9-element sequence was used, and *S* was so informed, except that he had to determine the elementary sequence from the presentations. In a series we called *Shifty* (SHF) *S* was again told that the series were generated by repeating an elementary sequence except that no such sequence was used, the series in fact being random. In the *Random* (RAN) series a random sequence of As and Bs was used, and *S* was so informed.

These five series were repeated in a counterbalanced order, under three different experimental régimes, each régime run on a different day. The following régimes were used:

1. *Guess* (GS) *S* was instructed to predict prior to the warning tone what the outcome of each trial would be. Proper care was taken to avoid contaminating the data by movement-generated noise in the EEG. *S* received a financial bonus for guessing correctly on at least 60 per cent of the trials.
2. *Reaction Time* (RT). In this set of sessions *Ss* were instructed to press one of two microswitches following the illumination of the letter. A right hand response followed the presentation of an A, a left hand response followed the presentation of a B. Both speed and accuracy were stressed; slow responses were indicated by repeating the flash; incorrect responses were indicated by a loud buzzer.
3. *Reaction Time with Catch* (RTC). These sessions were identical in all respects to the RT sessions except that catch trials were embedded in the series. On 10 per cent of the trials the warning click was not followed by a flash. *S* was abjured from responding in the absence of a stimulus. Catch trials did not disrupt the sequence generated in a specific series. The stimulus scheduled for the Catch trial was presented on the following trial.

Eight Beckman silver-silver chloride electrodes were referred to linked ear electrodes. Electrodes were placed at Fp₂, F₂, T₃, C₃, C_z, C₄, T₄, O₂. EOGs were recorded from a pair of electrodes placed above, and to the right of, *S*'s left eye. The EEG was amplified using Brush amplifiers (13-4218-00) and recorded on FM magnetic tape (Hewlett-Packard 3955). The system's bandwidth was 0.01-30 Hz.

All processing was performed off-line using an IBM 1800 computer. All averages considered here were obtained by averaging together the data from all *Ss*. A detailed analysis of the data obtained from individual *Ss* is reported by Donchin *et al.* for the GS and the RTC condition. This analysis revealed a large measure of intersubject homogeneity which suggests that the overall averages used in this report are valid. We computed for each trace the area under the CNV and the P300 portions of the record. Integration was performed with respect to a base line defined as the Midmean of the 500 msec epoch immediately preceding the warning stimulus. (The Midmean, a statistic recently proposed by Tukey, is the arithmetic mean of the data falling into the inter-quartile range.)

RESULTS

In Fig. 1 we plot the area of the CNV and P300. Panels A and B present the areas for the Vertex electrode plotted as a function of the sequence generating rule (SGR) for each of the three experimental régimes. The other six panels plot the areas for all SGRs and experimental régimes (tasks) as a function of the location of the electrodes.

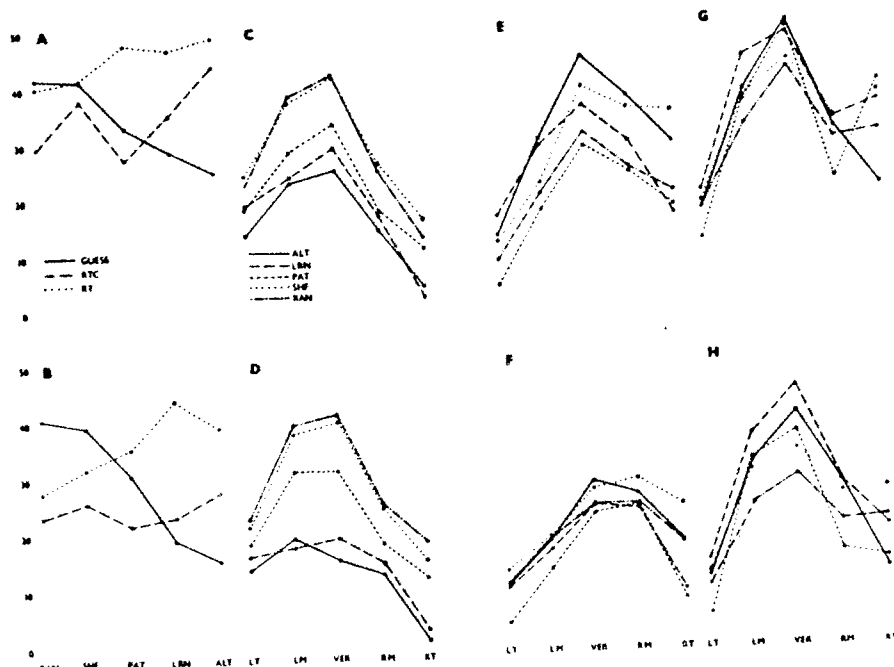


Fig. 1. The area of either the CNV or P300 at different locations on the scalp are plotted for different tasks and different series. Each point represents an area calculated by integration over a baseline defined as the midmean of the 500 msec preceding the warning stimulus.

Panels A and B plot the areas of the CNV and P300 respectively as a function of the sequence generating rules, for each of the three tasks (GS, RT and RTC) for the Vertex electrode.

The remaining panels present the distribution of CNV (C, E, G) and P300 (D, F, H) areas along the interaural line. The five lines in each panel represent the five sequence generating rules. Panels C, D represent the GS condition, E, F the RTC and G, H the RT conditions. Further details in text.

The data presented in Panel B, for the GS and the RTC task repeat in a condensed form the data presented in detail by Donchin *et al.* (1973b). The area of P300 is clearly a monotonic function of the SGR, from a minimum at ALT to a maximum at RAN. At the same time, when a motor response is required of the *S*, with catch trials included in the series, P300 area does not vary with the SGR. The values for the RAN and ALT series are virtually identical. When catch trials are eliminated from the series the relation between P300 and the SGR is different from that in the other two tasks. In the RT condition the area of P300 during an ALT series is larger than during the RAN series. In fact, P300 area for ALT during an RT condition is quite similar to the area of P300 for the RAN series during the GS régime. (A full report of these

data, including the levels of statistical significance, are to be published elsewhere.)

Panel A presents the corresponding areas of the CNV. Interestingly the CNV areas vary as a function of the various experimental variables in much the same fashion as do the areas of P300. CNV area increases with the complexity of the SGR in the GS condition. It shows an inverse relationship in the RT condition and seems to fluctuate in the RTC condition. In general CNV areas obtained during the RT series are larger than CNV areas obtained in the other two régimes except for the RAN series, where the GS and RT areas converge.

The correlation between the CNV and the P300 areas is indicated by the behaviour of these two measures along the interaural line as shown by the remaining six panels of this figure. Two aspects of these plots are worthy of note. The distribution of the areas within any of these panels seems to be quite homogeneous. That is, while there are clear differences *between* the distributions in the different panels, within each panel the relative magnitude of the CNV at each of the five electrode locations is similar. In other words, the tasks (GS-RT-RTC) affect the distribution of the CNV and P300 along the interaural line. The SGRs appear to modulate the amplitude of this distribution without affecting its shape.

Of particular interest is the fact that, while in most cases the area recorded at the Vertex electrode is larger than that recorded at the more lateral positions, there is a substantial difference in the amplitude at the lateral electrodes between the data recorded at the GS and the two RT conditions. In the GS condition the left electrodes yield a larger area than the right electrodes. This relationship is reversed during the two RT conditions. It is important to note that the above statement is equally correct for the P300 areas. The distribution of P300 and the CNV, at least along the interaural line, seems positively correlated.

The effect of the SGR on the overall amplitude of both the CNV and P300 varies among the six panels. There is very little difference between the P300 areas recorded during the RTC condition. On the other hand for the CNV the areas are least variable during the RT condition. The areas of the CNV recorded during the RT condition are consistently higher than those obtained during the RTC and GS conditions.

DISCUSSION

The above results indicate that by varying *S*'s task it is possible to manipulate the distribution over the scalp of both the CNV and the P300 as well as the overall amplitude of these two components. Within each task, the magnitude of the components, though not their scalp distribution, is modulated by conditions under which the *S* is performing the task. In two tasks requiring a motor response we find right-hemisphere potentials exceeding the left-hemisphere potentials. In one task, not requiring a motor response, this relationship is reversed. However, in all tasks we find that the amplitude of the distribution can be shifted up or down as a function of the complexity of the sequence generating rule used to determine the succession of trial outcomes. In any event, P300 and CNV areas appear to be affected in a similar manner by all these manipulations.

We speculated about the implications of the effects of the sequence on P300 amplitude in our previous report (Donchin *et al.*, 1973b). For the present it is noteworthy that similar considerations might apply to the CNV. This of course

revives the possibility that there is a strong relationship between these two components of the human evoked response. Needless to say, the demonstration of such a correlation does not imply a common causal source.

It is difficult to see why we should find the different tasks affecting the laterality of the CNV and P300. We are quite confident that this result is not due to any imbalances in our electrodes, amplifiers or recording system. That this is the case is attested by the fact that the evoked responses elicited by the warning click are virtually identical on the left and right hemispheres in all conditions. Had we changed in any way the parameters of our recording system between tasks, we should have seen a change in the relative amplitude of these evoked responses.

Why are the potentials recorded during the RT and RTC condition so different? The overall reduction in amplitudes during RTC is of course consistent with previous reports that diluting a series of RT trials leads to a reduction in CNV amplitude. Yet the dilution was only of the order of 10 per cent, far less than is required to obtain 'dilution' effects. It seems to us more likely that the differences in CNV amplitude are due to the relative usability of temporal information by the *S* in performing his task. Consider for example the ALI condition during the RT task. In this case the *S* can successfully perform the task by estimating the interval between the warning and the imperative stimuli. As he can well predict which hand will respond, the stimulus in itself is less critical. In the RTC series such temporal information is less relevant in that the *S* cannot be sure that he will indeed have to respond. Similar considerations can be applied to the other combinations of RT by series used. What we are proposing is that CNV amplitude is strongly affected by the degree to which the information about the interval between the warning and the imperative stimulus can be utilized by the *S* in optimizing his task performance.

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