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by

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TITLE

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NEGATIVE VARIATION PHENOMENON

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Attention, Intention, and the Contingent Negative Variation Phenomenon

One characteristic of neural tissue is that an electrical potential exists between it and nonneural tissue. This electrical potential is not stable but fluctuates in time. Such fluctuations can be recorded from either single cells or groups of cells. The voltage fluctuations from cell bodies in close proximity interact to produce a summated voltage which when the cells are numerous can be readily detected (through bone and overlying tissue) at some distance from the cell bodies. Fluctuations in brain potentials occur over periods ranging from milliseconds to hours for a single oscillation.

Recently, attention has been focused upon a brain electrical phenomenon of diffuse spatial distribution and of relatively slow time course, called the "contingent negative variation," or CNV. The CNV is a slow negative shift (up to several seconds in duration) of the cortex with respect to deeper structures or a remote reference electrode. It was first described by Walter _et al_. (1964), who observed it to occur over the entire head, but to be maximal over the frontal region in the adult. Low _et al_. (1966a) reported that the response is maximal anteriorly and medially. Walter _et al_. (1964) stated that "... it is almost synchronous over a very wide extent of the frontal cortex...", and has a mean amplitude of about 20 μV. The phenomenon is believed to originate as polarization of the apical dendrites in the outer layers of the cortical mantle (Walter _et al_., 1964). The effect is best seen during the time interval between two stimuli which are paired in a regular temporal relationship, and develops gradually with

repeated pairings. It is facilitated by having the S perform some overt response to the second stimulus of the pair. The phenomenon terminates abruptly at the instant the response is performed. More recently, Walter et al. (1967) have shown that the CNV is a normal accompaniment of everyday tasks and not restricted to a conditional relation between stimulus and response. An illustration of a fully developed CNV is shown in Fig. 1.

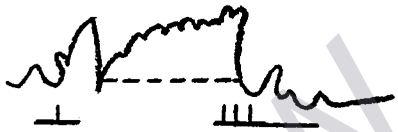

Figure 1. A CNV developed in the classical paradigm (Walter et al., 1964).

Reports suggest that at least three classes of factors, associative, attentional, and intentional (response set, preparation to respond, conation), influence the CNV:

1. Evidence of the effects of associative factors (Low et al., 1966a,b; McAdam, 1966; Walter 1965b; Walter et al., 1964).

   (a) The CNV develops gradually when two stimuli are paired.

   (b) The CNV extinguishes gradually when the second stimulus is omitted.

   (c) Partial pairing reduces the size of the CNV.

   (d) CNV development parallels performance level during the early and middle stages of learning to estimate an interval.

(e) The CNV occurs in classical, operant, or escape conditioning situations.

(f) The CNV is maintained to only the reinforced stimulus in a discrimination learning situation.

2. Evidence of the effects of attentional factors (Cohen _et al_., 1966; Low _et al_., 1967a; McCallum and Walter, 1968; Rebert _et al_., 1967; Tecce and Scheff, 1969; Walter, 1965a).

(a) The CNV occurs in anticipation of stimulus configurations when light flux is constant.

(b) The CNV is of greater amplitude when the second stimulus is varied in form than when it is not.

(c) The CNV is of greater amplitude and is less variable when the second stimulus is near threshold value.

(d) Distraction from a CNV relevent task is associated with suppressed slow potentials and retarded reaction times.

(e) Highly anxious patients show a greater reduction in CNV amplitude during distraction than do normals.

(f) Voluntary concentration on a task increases the amplitude of the CNV and produces a more rapid change in potential at the onset of the negative variation.

3. Evidence of the effects of intention (Irwin _et al_., 1966; Low _et al_., 1967b; McAdam _et al_., 1966; Rebert _et al_., 1967).

(a) Sophisticated _Ss_ are able to control the amplitudes of their CNVs "at will."

(b) The CNV amplitude is greater when an overt response is required than when none is required.

(c) Larger CNV amplitude accompanies overt responses requiring greater muscular effort.

(d) When two tasks are required, CNV amplitude is larger than when either task is required alone.

The present research program is aimed at elucidating the relations between attention, intention, and the CNV. Two experiments were done. The first to be described deals with the relationship between the CNV and selective attention. The second deals with the intensive aspects of attention and intention and with their relationship to the CNV.

SELECTIVE ATTENTION

The literature has included the suggestion of a relationship between the CNV and attention since 1964, the year in which the first reports on the CNV were published. Recent work attempting to verify this relationship has focused on the effects of concentration and distraction (McCallum and Walter, 1968), attention reduction (Tecce and Scheff, 1969), and alertness (Low et al., 1967) upon the amplitude of the CNV. The results of these studies have been consistent with the hypothesis that attention and CNV amplitude are positively correlated. However, clarification of the meaning and usage of the term attention is required before much more progress in understanding of this relationship can be made.

Hillyard and Galambos (1967) suggest that, "the CNV could be an electrical component of the attentional process, ..." They conceptualize attention "... as an intermediary focusing response between initial suggestive cues and the subsequent flow of events ...." A focusing response preparing the organism for stimulus reception is synonymous with the traditional concept of selective attention.

Berlyne (1960) notes that selective attention has two parts: "the intensification of the process on which attention is being concentrated, and the holding in check of other, distracting processes." It is important to note that attention can be focused not only upon external stimuli but upon internal processes as well. The following discussion will be limited to studies manipulating external stimuli but it is assumed that the attentional process operates similarly for both classes of focusing objects. Recent neurophysiological research was confirmed

that an O has both facilitative and inhibitory efferent control over some, and presumably all, afferent systems. The state of attention has been shown to affect the amplitude of evoked potentials (transient voltage fluctuations time-locked to stimulus input and with characteristic waveform and latency) recorded from electrodes implanted in specfic sensory pathways in animals (Hernández-Peón et al., 1956; Hernández-Peón et al., 1957; Jouvet and Hernández-Peón, 1957) and in man (Jouvet et al., 1959; Hernández-Peón and Donoso, 1959). Similar effects have been demonstrated on the cortical evoked potentials (EPs) in animals (Hernández-Peón et al., 1957; Shaw and Thompson, 1964) and in man (Donchin and Cohen, 1967; Eason et al., 1969; Garcia-Austt et al., 1964; Haider et al., 1964; Satterfield, 1965; Shevrin and Rennick, 1967; Wilkinson et al., 1966; Wilkinson, 1967; Wilkinson and Morlock, 1967). In general, these studies have consistently shown: (1) EPs to arbitrary neutral stimuli in man and animals which occur in the primary subcortical pathways are attenuated when the organism is simultaneously distracted (e.g., when the S is being simultaneously stimulated with a UCS or the S is involved in some task such as eating, thinking, or focusing on another stimulus), (2) those occurring in the primary subcortical pathways and primary cortices are accentuated when the stimulus is made significant (e.g., through classical conditioning or verbal instructions), and (3) those occurring in primary cortical areas are of higher amplitude when the S's arousal level is high as demonstrated by performance in vigilance tasks or associating stimuli with shock.

In addition, EPs occurring in nonspecific cortical projection areas in man are greater in amplitude when the S is instructed to attend

to that particular stimulus; and in animals EPs occurring in nonspecific projection areas are decreased during simultaneous novel stimulation and bodily activity. In most of these experiments the control data were obtained from an awake resting animal, a human with no specific attentional instructions, or an appropriate opposite condition (e.g., alerted vs bored; attending to the stimulus eliciting the EP vs attending to an other stimulus source). More refined analysis of some of the human data demonstrate that the changes observed in the EP are due to changes in the long latency components only, i.e., after 100 msec. Changes in EPs associated with attention and distraction have been demonstrated intramodally in the visual system.

These results indicate that the EP is sensitive to central nervous system modification of sensory input. Moreover, when the data across species and including both cortical and subcortical recordings are considered, the amplitude of the EP appears to be sensitive to both parts of the selective attentional process. Specifically, the amplitude of the EP to an object of concentration is enhanced, whereas its amplitude *to a distracting stimulus is attentuated.* The implication of these results is that the EP could be used under certain conditions as a quantitative index of the functioning of selective attention. Although, in man, the data are unclear as to whether during distraction the cortical EP is attentuated as compared with that elicited during the resting state, it is a reasonable inference based on evidence obtained from animals. Thus using the EP as an index of selective attention, it is possible to test the hypothesis that the CNV is an electrical component of the attentional process.

The general procedure for testing this hypothesis was to look at the cortical response evoked by a stimulus in the presence and in the absence of the CNV. The CNV was developed and maintained by presenting a "cue" stimulus of 1000 msec duration and instructing the S to make a thumb press response to the offset of that stimulus. A shorter duration "test" stimulus was then superimposed upon the cue signal to evoke the response of interest. In the control condition the CNV was eliminated by instructing the S to not respond to the cue stimulus, and then the EP was obtained from the same S receiving the same stimulus combination, in the absence of the CNV.

The hypotheses are that if CNV is an electrical component of the attentional process then:

(1) The amplitude of the evoked cortical potential in man to the stimulus of concentration will be enhanced in the presence of a CNV as compared with the amplitude of the EP to the same stimulus in the absence of a CNV.

(2) The amplitude of the EP in man to a distracting stimulus in the same modality as the stimulus of concentration will be attentuated or unchanged in the presence of a CNV as compared with the amplitude of the EP to the same stimulus in the absence of a CNV.

(3) The amplitude of the EP to a distracting stimulus which is in a modality different from the stimulus of concentration will be attenuated or unchanged in the presence of a CNV as compared with the amplitude of the EP to the same stimulus in the absence of a CNV.

Recently, Stoyva and Kamiya (1968) have argued that a combination of verbal report and physiological measures can be successfully used as converging operations in studying conscious processes. A working assumption in the present experiment was that the process of attention has conscious components (discriminable mental events) which are associated with changes in quantitative physiological events (i.e., that an S's judgments of his level of attention will be correlated with his CNV amplitude). In the present experiment the S was asked to quantify his level of attention by use of a rating scale under the CNV and no-CNV conditions. It was hypothesized:

(4) That the S would rate his level of attention to be higher in the presence of the CNV than in its absence.

(5) That the difference between the S's ratings of his attention level in the CNV and no-CNV conditions would be positively correlated with the concomitant amplitude change in the CNV.

In a recent review on the EP and reaction time, Wilkinson (1967) concludes that the amplitude of certain components of the EP correlates positively with response speed. In addition, several investigators (Hillyard and Galambos, 1967; McAdam et al., 1969; Rebert et al., 1967; Tecce and Scheff, 1969; Walter, 1964; Waszak and Obrist, 1969) have shown a positive correlation between response speed and amplitude of the CNV. The correlation between the EP and the response speed has generally been attributed to a common influence of attentional factors upon the two responses. In contrast, an alternative explanation of a response set has generally been invoked to explain the relationship between the CNV and response speed. It appears that the latter phenomenon can be

explained equally well by attentional influences but differential evidence favoring one of these explanations is lacking.

Triesman (1964) referred to evidence leading her to the conclusion that shifting attention takes a finite amount of time. In the method proposed for this experiment if a test stimulus were to attract attention, (i.e., produce a shift in attention) then attention would have to be shifted back to the cue stimulus before a response could be made to it and a consequent lag in response time should be noted. The test stimuli in this study have been specifically selected because of their relationships to the cue stimulus leading to differential predictions concerning their "attention getting" value. With Berlyne's concept in mind (see page 5) it is expected that the response to a test stimulus of identical quality to the stimulus of concentration will be intensified, (i.e., that this test stimulus will have high attention getting value) and that the attentional mechanism will hold in check other distracting processes (i.e., test stimuli differing in quality from the stimulus of concentration will not attract the S's attention). It is consequently hypothesized:

(6) Ss receiving a test stimulus identical in quality to the stimulus of concentration will have a significantly longer reaction time than will Ss receiving different quality test stimuli.

(7) If, as predicted in hypotheses 1 and 6, the same mechanism of attention produces an increase in EP amplitude to the identical quality test stimulus and a decrease in response speed, then these effects will be proportional, and a negative correlation will be found between them for this test stimulus group.

(8) If the CNV indexes the same mechanism of attention, then there will be a negative correlation between CNV amplitude and response speed for the group receiving a test stimulus of identical quality to the stimulus of concentration.

Method

Experimental design

These 8 hypotheses were tested in a 3 X 2 factorial design with repeated measures on one factor (Winer, 1962) in which three treatment groups were subjected to two experimental conditions. The treatment of the groups differed only in the nature of the test stimulus used to evoke a response as recorded by a vertex scalp electrode. The test stimuli were: (1) qualitatively identical to the stimulus controlling the CNV (T500 group), (2) qualitatively different from, but in the same modality as, the stimulus controlling the CNV (T6000 group), (3) in a different modality from that of the stimulus controlling the CNV (Flash group). The test stimuli were presented under two levels of CNV amplitude. An outline combining the essential design and procedural elements is presented in Fig. 2.

Subjects

The Ss were 18 right handed, experimentally naive male university students. They were randomly assigned to one of the 3 treatment groups of 6 Ss each.

Stimulating and Recording System

The Ss were seated in a reclining chair in an electrically shielded, sound attenuated room (Industrial Acoustics Company 403A). They were thus isolated from possible distractions of movements of the E and noises associated with operation of the stimulating and recording system.

Reference to the block diagram (Fig. 3) will be helpful in understanding the following discussion. The E initiated each event with a hand