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THE EFFECTS OF AROUSAL AND ATTENTION ON CENTRAL, AUTONOMIC, AND BEHAVIORAL PROCESSES

by

Linda Motley Dudley

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Approved by

Dissertation Adviser

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of the Graduate School at The University of North Carolina at Greensboro.

Dissertation Adviser: Robert H. Eason

Oral Examination Committee Members: M. Russell Harter

David A. Kelly

Richard H. Klemer

Kendon Smith

May 19, 1971
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The present investigation was conducted primarily to clarify further the dissociative and associative effects of arousal and attention on the evoked cortical potential (ECP), contingent negative variation (CNV), heart rate (HR), and reaction time (RT). A secondary consideration was the evaluation of criticisms directed by Näätänen (1967) to selective attention research.

The experimental paradigm involved a contingency situation. An auditory click (S_1) preceded a light flash (S_2) to which a RT response was required. The time interval between S_1-S_2 and S_2-S_1 was randomly varied from 2 to 3 sec. In some conditions, extraneous stimuli (S_E) were presented randomly at the rate of approximately 1 Hz within the S_1-S_2 and S_2-S_1 intervals. The maximum number of S_E presented in any one interval was three, the minimum zero.

Changes in arousal were experimentally induced by requiring S to make a RT response to light flashes (relevant stimuli, S_2) under conditions of contingent, noncontingent, and no shock. Attention was varied by requiring S to react to S_2 only, react to S_2 while ignoring S_E (light flashes in the opposite field), and react to S_2 while also counting S_E. The ECPs to both S_2 and S_E were obtained; simultaneously, CNV, HR, and RT were recorded for each of four Ss under the nine experimental conditions generated by these major independent variables.

Each S's data were subjected to individual analysis in order to assess consistent treatment effects for each S. Changes in the amplitude of the ECP to S_2 as a function of arousal and shifts in attention were found to be statistically significant for all Ss. The ECPs to S_E

were also found to be significantly affected by changes in arousal and attention for three of the four Ss. In addition, there was a significant within-6-sec-interval effect on the amplitude of the ECP to S_E for two Ss.

The changes in HR for all Ss were found to be significantly dependent upon arousal level and for two Ss upon shifts in attention. The findings also showed that behavioral performance (RT) was significantly altered by the experimental manipulations of arousal and attention, and in the same direction as the ECP data. No statistical analyses were performed on the CNV data due to the extreme variability within each Ss data. Visual inspection of the superimposed tracings of these slow potential shifts suggested the absence of any systematic effects due to the experimental manipulations of arousal and attention.

The results in general favor a selective attention interpretation of changes in the amplitude of the ECP to S_2. That is, the effects of general arousal on the ECP are certainly evident, but the specific effect of directed attention appears more pronounced. The findings of some significant within-interval effects on the amplitude of the ECP to S_E offer some positive support for Näätänen's criticisms of selective attention research. In spite of this, however, the data argue strongly for an interpretation of ECP changes which attributes enhancement to attentional factors in addition to the variation in non-specific arousal. The HR data readily support an interpretation based on activation theory.

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Introduction

During the last decade, the analysis of the relationship between evoked potentials in man and attention has become one of the most actively investigated areas of psychology. This is not surprising, however, since both are thought to be related to information processing in the brain. The findings in this area are interesting and provocative, but incomplete. Generally, an enhancement of the evoked potential has been observed when attention is directed to the source of stimulation, but not always. An attenuation of the evoked potential has usually been observed with distraction, but again there is negative evidence. Some of these inconsistencies may be attributable to altered levels of arousal in addition to the changes in attentional processes. The mere fact that discrepancies exist suggests that more work is needed to further clarify the dissociative as well as the associative effects on evoked potentials of these two separate but related processes.

The Arousal Dimension

In recent years the notion of a psychophysiological dimension of activation or arousal (Duffy, 1962; Hebb, 1955; Malmo, 1959) has come into considerable prominence. There are several basic tenets of the theory which are relevant to the present discussion. First, performance is held to be poorer when there is a reduction in activation level. Strong support for this proposition has been derived from vigilance research (Deese, 1955; Jenkins, 1958). Second, the activation effect is thought to manifest itself in a nonspecific manner. It is this particular proposition of arousal theory which makes it hazardous to use the term attention as a synonym for arousal as some writers do (Berlyne, 1970). One may be activated or highly aroused with or without being attentive to the primary stimulus, and relevant changes in arousal may not necessarily be reflected in the measure of attentiveness (Jerison, 1967). Third, performance is held to be maximal under optimally activated conditions. Nevertheless, caution must be exercised in adhering to an inverted U-shaped relation between activation and performance. Studies (Eason & Branks, 1963; Malmo, 1966) have shown that in order to predict what happens to performance as activation level changes, one must also have knowledge of the S's attentional state.

Activation theorists such as Duffy (1957, 1962), Lindsley (1960) and Malmo (1959) have stressed that behavioral arousal can be indicated by a variety of measures, and that arousal is a continuum, varying from deep sleep to excited states. The measures which have figured most prominently in relation to activation theory are muscular tension (MT), skin resistance (SR), heart rate (HR) and the evoked cortical potential (ECP). A number of studies have demonstrated that general arousal varies along a continuum and is reflected in changes in a variety of peripheral and central physiological events (Duffy, 1951; Eason, 1959; Eason, 1963; Eason & Dudley, 1971; Eason, Harter, & Storm, 1964; Eason & White, 1961; Malmo, 1959, 1966; Schlosberg, 1954; Stennett, 1957; Surwillo, 1956).

Some of the difficulties with activation theory have been recently reviewed by Lacey (1967). Lacey (1959, 1963, 1967), in particular, has questioned the usefulness of the concept of general arousal based on his findings that cortical activation, autonomic activation, and behavioral activation may occur quite independently of one another. That is, under some circumstances, heart rate shows a decrease that is paradoxical because it is accompanied by an increase in other autonomic variables such as skin conductance. A recent study by Eason and Dudley (1971), however, showed that general changes in activation manifested themselves even in the presence of dissociative physiological activity. Nevertheless, the relationship among autonomic responses, attention, and arousal deserves further empirical consideration.

Arousal, Attention, and the ECP

Since the advent of the averaging computer, considerable evidence has been obtained which indicates that the ECP changes systematically with experimental variations in activation level. For example, several studies have shown that the ECP obtained from a drowsy subject is attenuated compared with the ECP of an alert subject, alertness being indicated by such measures as reaction time (Haider, Spong, & Lindsley, 1964; Callaway, 1966; Donchin & Lindsley, 1966; Morrell & Morrell, 1965; Wilkinson & Morlock, 1967). Experiments reported by Eason et al. (1964) clearly demonstrate that any stimulus situation leading to a directly observable increase in behavioral activity, i.e., exerting a sustained force on a hand-grip device, is accompanied by an increase in amplitude of summated ECP's to a flashing light. Similarly, such amplitude increases were found to accompany covert increases in arousal or alertness induced by voluntary mental tasks, such as memorizing digits or adding by 13's. A number of other investigators have also attributed changes in the evoked cortical potential to altered states of general arousal (Sutton, Teuting, Zubin, & John, 1967; Näätänen, 1967).

Changes in the evoked cortical potential have been related not only to altered levels of arousal but also to shifts in attention. For example, Garcia-Austt and colleagues (1961, 1962, 1964) report that counting repetitive light flashes enhanced the evoked cortical potential. Using a paired-flash technique, Ciganek (1964) found the visual ECP to the second of two flashes presented 200 msec apart to be elevated by the counting procedure. Donhin and Cohen (1967) presented light flashes (figure) superimposed on fluctuating geometric designs (ground) and found the ECP to be larger to figure or ground, whichever was being counted. Generally, then, in studies in which the subject is instructed to attend to one stimulus (relevant) and ignore another (irrelevant), an enhancement of the ECP to the relevant stimulus occurs (Satterfield, 1965; Spong, Haider, & Lindsley, 1965; Ritter & Vaughan, 1969; Eason, Harter, & White, 1969; Karlin, 1970). Distraction by tones, clicks, light flashes, or mental tasks has usually been found to reduce the amplitude of the ECP (Garcia-Austt, 1963; Garcia-Austt, Bogacz, & Vanzulli, 1964; Chapman & Bragdon, 1964; Haider et al., 1964; Spong et al., 1965; Donchin & Cohen, 1967). For example, Courjon (1958) reported a decrease in the ECP from memorization; reduction was also observed with nociceptive and proprioceptive stimulation as distractions.

<u>Cognitive vs Noncognitive Interpretations of ECP Changes</u>

Näätänen (1967) has argued that "the ECP research on attentive behavior has not revealed electrophysiological correlates of the psychologically valid phenomenon of selective attention" (Näätänen, 1967, p. 179). Rather, he suggests that the changes taking place in the central nervous system during selective attention reflect only the increased non-specific arousal connected with attentive states and not the aspect of selectivity or the direction of these states. Several experiments have been performed by Näätänen (1967) to elucidate the problem of the selective-attention interpretation of enhanced potentials elicited by the relevant stimulus. His main criticism of the selective-attention research has been that the activation of the subject is not strictly controlled. Thus, in situations in which the presentation of the relevant and irrelevant stimuli are regularly alternated, the presentation order of the stimuli make possible different anticipatory and preparatory alertness reactions to the relevant stimulus; alertness and activation will be high when the subject knows that a relevant stimulus will be immediately presented and low between the relevant stimuli, when the irrelevant stimuli are presented. Data of a substantive nature are presented by Näätänen (1967) for these assertions.

The implication of Näätänen's position is that evoked potential enhancement will occur only when differential preparation for the relevant stimulus is possible. He (Näätänen, 1967) reports a cross-modality experiment in which sequences of clicks and flashes were randomly mixed and the interstimulus interval randomly varied. No significant differences in evoked potential amplitude between relevant and irrelevant clicks were found. This finding, however, is clearly discrepant with the one reported recently by Eason et al. (1969) which.

supports the hypothesis that when attention is effectively manipulated within a sense modality, the amplitude of the ECP varies according to whether or not the subject is attending to the stimulus. In their study (Eason, Harter, & White, 1969) an attempt was made to factor out the differential effects of general arousal and specific attention on the amplitude of the ECP. Arousal was manipulated by the presence or absence of shock when light flashes were presented. Attention was varied by having the subject make a reaction time response to flashes appearing in either his left or right visual field while ignoring those appearing in the opposite field. Potentials obtained under high arousal were found to be much greater than those under low arousal for the relevant stimulus but not the irrelevant stimulus. It was also reported that potentials evoked by the relevant stimuli were found to be significantly larger than those evoked by irrelevant stimuli. These attentional effects are clearly contradictory to the findings reported by Näätänen (1967). It appears that additional research is needed to clarify the nature of these discrepancies.

<u>Attention, Arousal and Contingent Negative Variation</u>

Contingent negative variation (CNV), originally described by Walter, Cooper, Aldridge, McCallum, and Winter (1964), refers to a potential change mainly in the frontal cortex during which the surface of the brain becomes electronegative with respect to deeper structures. Evidence that these negative electric fields at the vertex are mainly cortical in origin has been provided by Walter (1965) who recorded CNV directly from cortical tissue in patients with chronically implanted gold electrodes. Effects similar to human CNV's have been observed during conditioning in cats by Rowland and Goldstone (1963). Low, Borda, Frost, and Kellaway (1966) have found surface negative slow-potential shifts in the rhesus monkey during operant conditioning and regard these as identical with human CNV's.

The situation which appears most favorable for CNV development is one involving a regular presentation of stimulus pairs in which the first member of the pair (S_1) precedes the second (S_2) by a fixed interval and a manual response is required to S_2. The basic morphology of CNV can be described as an initial negative shift in EEG baseline beginning after the evoked potential to S_1, a gradual rise to maximum negativity within the S_1-S_2 interval, and a quick return of CNV to baseline upon response to S_2 (Walter et al., 1964). The appearance and maintenance of this effect is contingent on the significance of an association, and its amplitude (or the magnitude of negativity) is thought to reflect the degree of "subjective probability" felt by the subject (Walter et al., 1964). Walter (1965) has since renamed the negative shift the expectancy wave (E wave), expectancy being defined as the subjective probability or relative certainty that S_2 will follow S_1. There is some evidence that CNV amplitude is reduced when S_2 is partly or entirely omitted without warning to the subject (Walter et al., 1964).

The majority of studies on CNV have focused upon the concepts of expectancy, conation, motivation or arousal, and attention, since all of these conditions seem to favor CNV production. The importance of "conative" factors in CNV development has been emphasized in the work of Low et al., (1966). By "conative" is meant the intention, conscious drive, or mental preparation to make some response. Their position is based on the finding that when S_1 is a cue to how much muscular effort would be required to depress a plunger in response to S_2, higher levels of anticipatory muscular effort were related to higher magnitudes of CNV development (Low et al., 1966). These results were interpreted as showing that CNV is related to preparation to perform an action. However, as noted by Tecce (1969), it is possible that greater attention to S_2 accompanied increasing muscular force; if so, attentional processes might account for the CNV magnitude. A second finding reported by Low et al. (1966) was also interpreted in terms of conative factors. It was observed that when it was necessary to substract numbers after presentation of S_1 to determine the force of response to S_2, a weakened CNV-force relationship was obtained. One might speculate that the mental arithmetic between S_1-S_2 served as a distraction and interfered with attention to S_2.

McAdam, Irwin, Rebert, and Knott (1966) have reported a study of CNV in which the results were also interpreted in terms of conative factors. These experimenters demonstrated that they could at will increase or decrease CNV amplitude by thinking high and low CNV. To achieve this control, however, they reported altering their vigilance to S_2, i.e., in the think high CNV condition they imagined S_2 to be difficult to detect. Hence, fluctuation in attention to S_2 might account for the changes in CNV amplitude.

Evidence has also been obtained which indicates that CNV amplitude may be related to arousal level. For example, Rebert, McAdam, Knott, and Irwin (1967) have reported a larger CNV amplitude when high muscular effort is anticipated for a response to S_2 compared to a low effort condition. Similarly, Irwin et al. (1966) have found a larger CNV amplitude when a response is required to S_2 compared to when no response is required and when S_2 is an anticipated strong painful shock compared to a weak one. Although these findings seem to indicate a relationship between CNV amplitude and arousal level, it is possible that accompanying the heightened arousal was a concomitant increase in attention to S_2 which might be related to elevated CNV amplitude.

Experiments on directed attention and distraction seem to bear out a relationship between attention and CNV. In a recent study by Tecce and Scheff (1969) CNV amplitude was found to be smaller when the subject had to divide his attention between responses to S_2 and listening to distracting numbers compared to a control condition when only responses to S_2 were required. In addition, in the distraction condition, there was a slowing of both motor responses to S_2 (reaction time) and the time for maximal CNV negativity to occur within the S_1-S_2 interval (latency to CNV peak). They also presented evidence to suggest that CNV reduction during distraction was not due to lowered arousal level.

Many investigators have attested to the complexity of the CNV phenomenon (Irwin et al., 1966; Low et al., 1966; Walter et al., 1964) about which there seems to be little general agreement regarding its psychophysiological significance. Probably the most serious methodological problem in recording CNV is the possibility of eye movement artifacts, which may introduce significant contaminants into the records of the slow activity (Cohen, 1969).

Purpose of the Investigation

Numerous studies have now been cited which, in one way or another, have related to the significance of changes in central, autonomic, and behavioral processes. These data appeared sufficiently controversial to warrant the present investigation, the purpose of which was threefold: (a) to further elucidate the relative contributions of arousal and attentional processes to evoked potential changes, and, in addition, to evaluate the criticisms directed by Näätänen to selective-attention research; (b) to examine further the relationship of CNV to expectancy, arousal, and attention; and (c) to clarify the relationship between autonomic responses (specifically heart rate), arousal and attention.

Specific Statement of the Problem

The experimental paradigm involved a contingency situation. An auditory click (S_1) preceded a light flash (S_2) to which a reaction time response was required. The time intervals between S_1-S_2 and S_2-S_1 were randomly varied from 2 to 3 sec. In some conditions, extraneous stimuli (S_E) were presented randomly at the rate of approximately 1 Hz within the S_1-S_2 and S_2-S_1 intervals. The maximum number of extraneous stimuli presented in any one interval was three, the minimum zero.

"Attention" was manipulated by instructing the subject to: (a) make a reaction time response to flashes appearing in one visual field (relevant or S_2) while ignoring extraneous flashes (S_E) appearing in the other field (Distraction Condition, D); (b) react to flashes appearing in the relevant field while also counting the extraneous flashes appearing in the other field (Divided Attention Condition, DA);

and (c) reacting to flashes appearing in the relevant field when the extraneous flashes were not present (No Distraction Condition, ND).

General "arousal" was experimentally manipulated by requiring the subject to: (a) react to relevant flashes under conditions in which shock could be avoided if reaction times were fast enough (Contingent Shock Condition, CS); (b) react to flashes under intermittent or unavoidable shock (Noncontingent Shock Condition, NCS); and (c) react to flashes under no threat of shock (No Shock Condition, NS).

Nine experimental conditions were generated by these independent variables. A tenth condition was included in which no shock was administered and the subject was not required to make a behavioral response (reaction time); this condition served essentially as a baseline, resting condition and was not subjected to statistical analyses. The entire experiment, then, consisted of ten experimental conditions. In sum, there were Shock/Distraction, Shock/Divided Attention, Shock/No Distraction, Noncontingent Shock/Distraction, Noncontingent Shock/Divided Attention, Noncontingent Shock/No Distraction, No Shock/Distraction, No Shock/Divided Attention, No Shock/No Distraction, and No Shock/No Response. The primary dependent variables under investigation were the evoked cortical potential (ECP), contingent negative variation (CNV), heart rate (HR), and reaction time (RT). Additional dependent variables monitored were muscle tension (MT) and skin resistance (SR).

As a matter of convenience the terms "arousal" and "attention" (in quotes) will be used in a descriptive manner through the results section to refer to the above experimental manipulations; it is recognized, however, that "arousal" and "attention" may be confounded within the experimental manipulations themselves. In the discussion and concluding sections, the changes in the dependent variables will be interpreted as supporting attentional or arousal processes or both as defined in the introduction.

Method

Subjects

Four graduate students (three males, one female) from the University of North Carolina at Greensboro served as subjects. Each had participated in evoked potential research on several other occasions. All were between the ages of 24 and 30 years.

Experimental Design

Due to the large number of experimental conditions, Ss were required to participate in two sessions in order to complete one replication of the experiment. A session lasted approximately 2 hr and consisted of five experimental conditions. Each S participated in eight experimental sessions, one session per day for eight days. By the end of the study, therefore, each experimental condition had been administered four times with each S serving as his own control.

Experimental conditions in which extraneous stimuli occurred lasted approximately 20 min; those in which no extraneous stimuli were presented, approximately 10 min. A 5-min rest followed each 20-min condition, a 2-min rest followed the shorter conditions. The order in which the Ss were exposed to the experimental conditions was randomly determined within and across sessions. The order of presentation of relevant flashes in the right and left visual fields was counterbalanced over each condition.

Procedure, Apparatus, and Data Recording

The subjects were placed in an electrically shielded, semi-darkened room during the recording session. A Grass Model 7 Polygraph equipped with the necessary preamplifiers was used to record the various physiological events.

ECPs. Evoked cortical potentials were recorded monopolarly with commerical silver disc electrodes. The scalp electrode was placed one inch above the inion on the midline. The reference electrode, a commerical silver clip, was placed on the right earlobe. The potentials were amplified with a Grass 7P5 preamplifier and recorded on one channel of an Ampex FM tape recorder (Model SP 300). The potentials evoked by the relevant and extraneous stimuli were later separately averaged (N of 42) with a TMC 400-B Computer of Average Transients (CAT). This was accomplished by triggering the CAT with synchronous pulses previously recorded on tape each time the photostimulators flashed. Permanent records of the averaged potentials were obtained with a Moseley X-Y Plotter (Model 2 D-2). The CAT analysis time was 0.5 sec.

The evoked potential data were quantified by calculating an average amplitude score for the summated evoked potentials of each S by measuring the vertical peak-to-trough distance (in mm) covered by the major deflection and computing an average.

CNV. The slow potential DC shift was recorded with chlorided silver electrodes. The active lead was placed on the vertex; the reference electrode on the left ear. CNVs were amplified with a DC preamplifier (Grass 7P1) and recorded on one channel of the Ampex FM tape recorder. These were later averaged (N of 42) by triggering the

CAT with synchronous pulses previously recorded with the FM tape recorder each time an S_1-S_2 or S_2-S_1 interval occurred. Permanent records of the CNVs were obtained with a Moseley X-Y Plotter. The CAT analysis time was always 4 sec.

HR. A Grass 7P4 Tachograph preamplifier was used to record heart rate on a beat-by-beat basis. The active lead was attached to the left wrist with the right earlobe serving as ground. Heart rate was monitored online with the CAT as well as recorded on one channel of the FM tape recorder. Heart rate changes over the S_1-S_2 and S_2-S_1 intervals were later averaged (N of 42) by triggering the CAT with synchronous pulses previously recorded with the tape recorder each time a S_1-S_2 and S_2-S_1 interval occurred. Permanent records of the changes in heart rate were obtained with a Moseley X-Y Plotter. The CAT analysis time was always 4 sec.

SR. Skin resistance was recorded with silver chlorided electrodes attached to the volar surface of the first and third fingers of the left hand. A Grass 7P1 preamplifier was used to amplify resistance changes and to balance the resistance bridge. The polygraph channel was calibrated in such a manner that the S's resistance could be read directly in ohms from the oscillogram. Skin resistance changes were averaged (N of 42) online with the CAT; the analysis time was 4 sec.

MT. Muscle tension was recorded from the forearm flexor muscles of the active arm (right) with silver disc electrodes mounted two inches apart in a plastic adaptor. The potentials were integrated by a Grass Model 7P3 preamplifier. Muscular tension was also averaged online by the CAT for 42 3-sec S_1-S_2 intervals. The CAT analysis time was 4 sec.

RT. Reaction times were measured in msec with a Hewlett-Packard Universal Counter (Model 5325B) and printed out with a Hewlett-Packard Digital Recorder (Model 562 A). Upon giving a verbal ready signal, S pressed down on the lever of a microswitch. When a light flash was presented the counter was automatically triggered and S raised his finger as quickly as possible from the lever. The response time was displayed on the digital recorder and automatically printed out.

Visual stimulus apparatus. The visual stimuli consisted of two semicircles containing checkerboard patterns composed of 8.0 mm black and white checks; the individual checks of the semicircular patterns subtended a visual angle of approximately 46 min. The stimulus patterns were attached to a translucent screen located approximately 60 cm from S. Each semicircular stimulus had a radius of approximately 11 cm. When recording, S binocularly fixated a point located midway between the two semicircles. Thus one semicircular stimulus appeared in the left visual field; the other in the right. The flashes were of moderate brightness, being approximately 3 log units above the dark surround which was less than 0.5 millilamberts. The duration of each flash was 10 microseconds.

Two photostimulators (Grass PS-2) were independently programmed to present flashes concomitantly but never simultaneously within each visual field. Relevant flashes were generated approximately once per 6 sec; extraneous flashes were randomly presented at the rate of approximately 1 Hz during the 3-sec S_1-S_2 and S_2-S_1 intervals. The maximum number of extraneous flashes occurring in any one interval was three, the minimum zero.

<u>Shock apparatus</u>. The shock apparatus consisted of a Grass S-8 stimulator wired through a Grass Stimulus Isolation Unit (Model SIU-4678) to electrodes attached to the <u>S</u>'s right leg just above the ankle. The voltage level was adjusted for each <u>S</u> to a level which he indicated was unpleasant and would be avoided if possible; the duration of the shock was 50 msec. Prior to beginning the experiment proper, <u>S</u> was asked to make 50 RT responses to the light flashes. From these responses the three longest were selected and the shortest of these was used as a criterion for the presentation of shock. In the shock/divided attention condition, however, the criterion for the administration of shock was lengthened by 50 msec due to the complexity of the task. In the shock avoidance conditions, shock was administered automatically when a solid state timer timed out and closed a relay. In the unavoidable shock situations, <u>E</u> administered the shock randomly by manually pressing a switch on the S-8 stimulator. <u>S</u>s seldom received more than three shocks during a given condition.

<u>Quantification of the data</u>. Only the 3-sec interval data for S_1-S_2 and S_2-S_1 were quantified and subjected to statistical analyses. The primary purpose for varying the time interval between S_1 and S_2 from 2 to 3 sec was to introduce some uncertainty into the experimental situation as to when S_2 would occur. This precaution, it was felt, would reduce to some extent any tendency on the part of <u>S</u> to alternately attend and not attend.

<u>Experimental precautions and controls</u>. Prior to the beginning of each condition, <u>S</u> was told to assume a comfortable position and to avoid making excessive movements during the course of an experimental

run. Throughout the experiment the amplified output of a "white noise" generator was fed through a speaker into the electrically shielded room in an attempt to minimize the probability of S being distracted by extraneous noises, whether they were generated inside or outside the laboratory. The apparatus used in recording the various physiological variables was calibrated in the conventional manner by generating known signals of the appropriate frequency and amplitude range and noting the magnitude of the processed signals.

Results

Each S's data were subjected to individual analysis to assess consistent treatment effects for each S, which might otherwise have been masked by the grouping process. The dependent variables (ECP, HR, and RT) were analyzed to ascertain whether there were any significant effects due to variations in "arousal" and "attention". The ECPs to S_E were also tested for any significant within-6-sec-interval effects. Tests for first, second, and third-order interactions among these variables were also made. The statistical analyses performed on each of the dependent variables for each S are summarized in Tables 1-16 (see Appendix). The results are described below for each S separately.

Subject L.S.

Variance analyses on the ECP. Statistical analyses revealed that for the ECP to both S_2 and S_E there was a significant "arousal" effect ($p<.01$); but only for the ECP to S_2 was there a significant "attentional" effect ($p<.05$). In addition, there was a significant "Arousal" X "Attention" effect ($p<.01$), as well as a significant within-6-sec-interval effect ($p<.05$). The summated ECPs obtained under the "arousal" and "attention" conditions are shown in Figure 1. The statistical results are graphically presented in Figures 2 through 10.

Figure 2 shows the mean amplitude of the ECP to S_2 under the different "arousal" and "attention" conditions. It can be seen that the presence of shock (contingent or noncontingent) had the effect of significantly enhancing the amplitude of the ECP over the no shock situation. The significant effect due to shifts in "attention" on the ECP to S_2 is apparent in the differences between ECP amplitude in the distraction (attenuation of ECP) and the no distraction conditions.

In Figure 3 are plotted the means for the ECP to S_E as a function of "arousal" and "attention". It can be seen that "arousal" exerted a significant influence on the amplitude of the ECP to S_E. However, the direction of this influence is somewhat unexpected; the greatest attenuation of the ECP occurs in the noncontingent shock situation rather than the no shock situation. It is possible that the intermittent shock had a distracting influence on S which is being reflected in the ECP amplitude. There were no significant effects due to experimental manipulations of the "attentional" state; this is reflected in the present figure. When S was counting S_E, the amplitude of the ECP was only slightly enhanced over that obtained in the condition in which he was to ignore them. The significant interaction effect between "arousal" and "attention" ($p<.01$) suggests that the degree to which S was attending to these stimuli was influenced by the arousal condition in which he was performing.

Figure 4 reflects the relationship of the ECP to S_2 and S_E as a function of "arousal" and "attention". Plotted in this figure are the

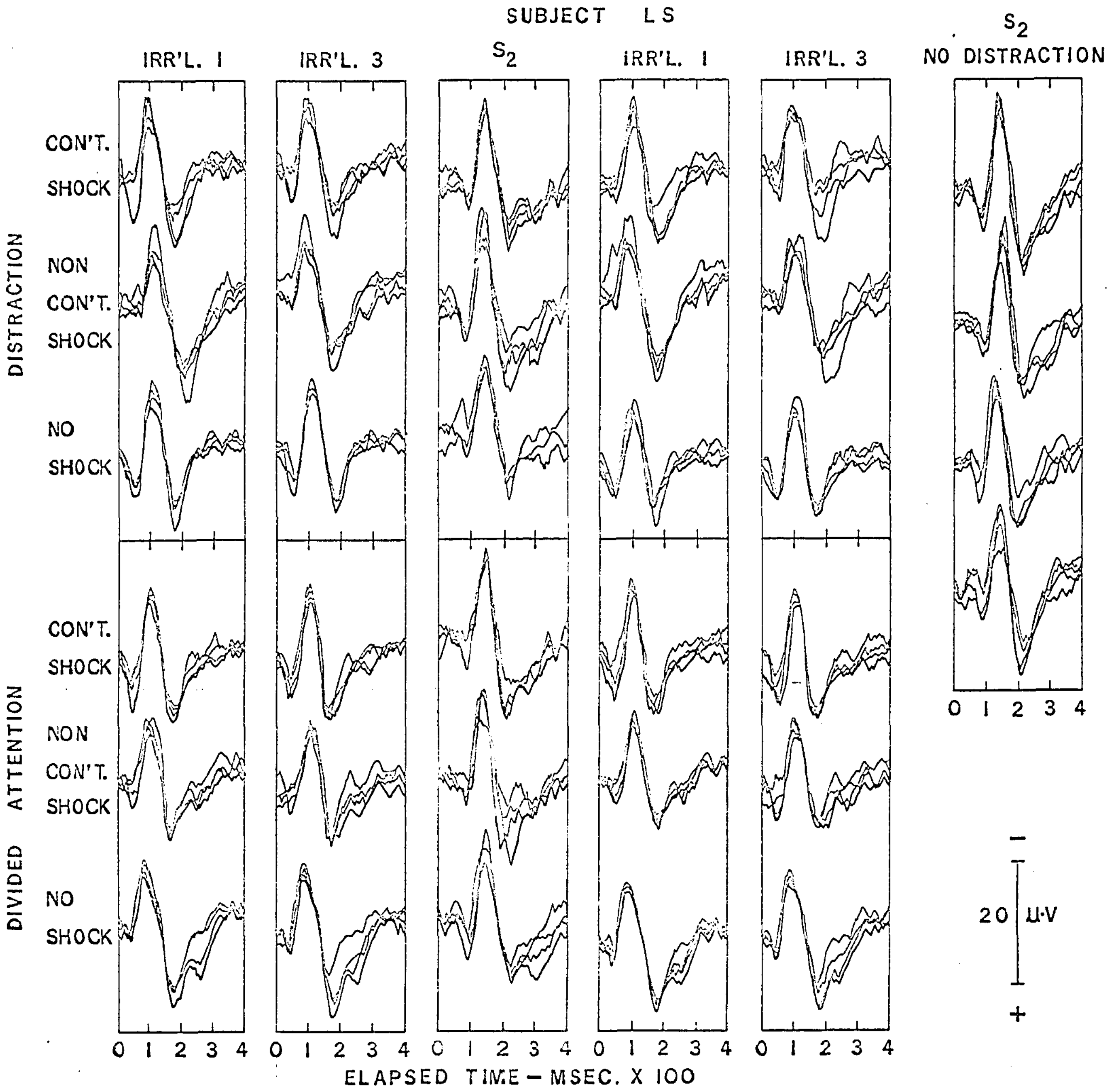


FIG. 1. Effects of "arousal" and "attention" on averaged ECPs to S_2 and S_E (10 µV=50 MM). (IRR'L. same as S_E)

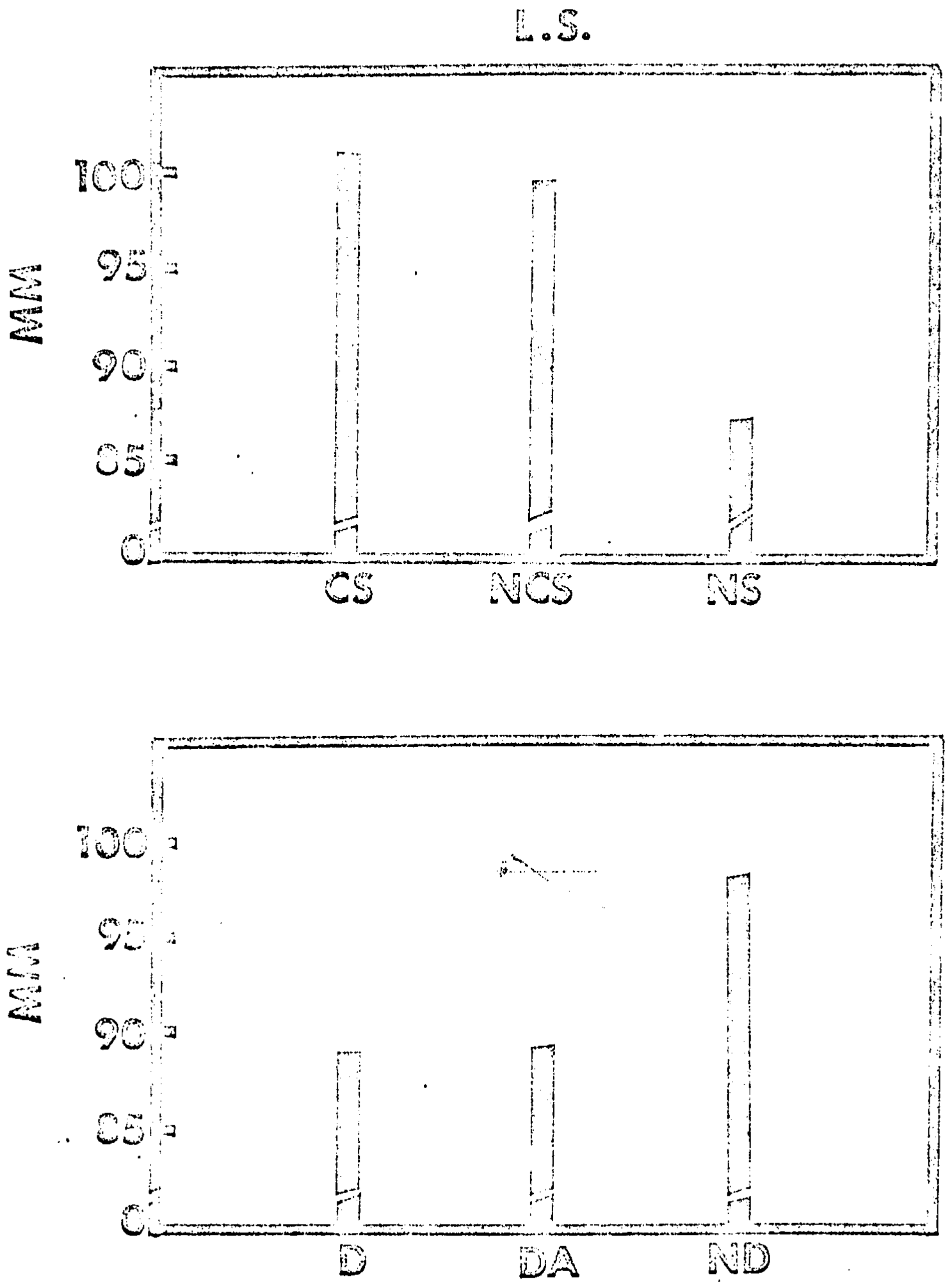


FIG. 2. Effects of "arousal" and "attention" on the amplitude of the ECP to S_2 (10 μV=50 MM).

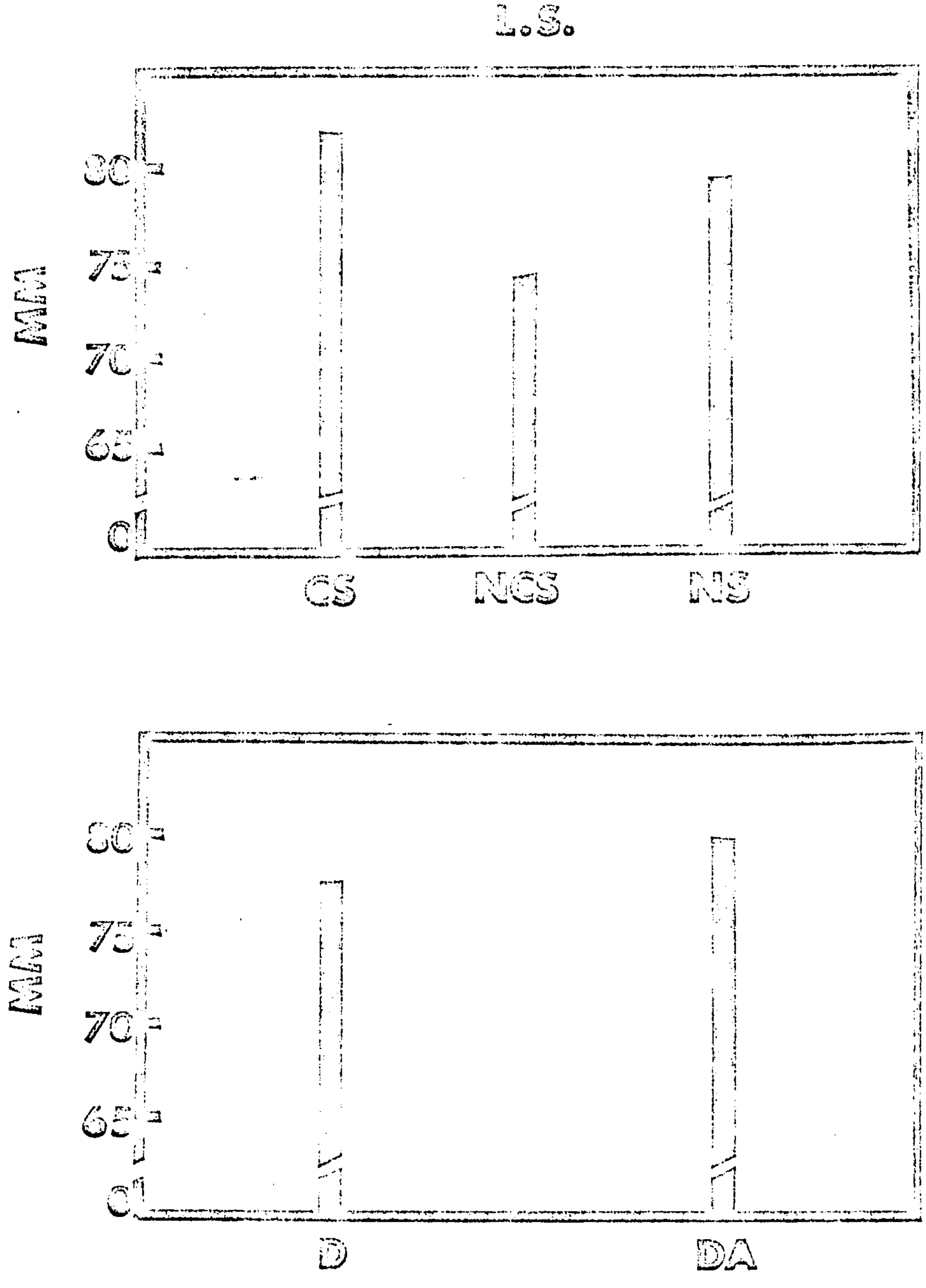


FIG. 3. Effects of "arousal" and "attention" on the amplitude of the ECP to S_E (10 μV=50 MM).

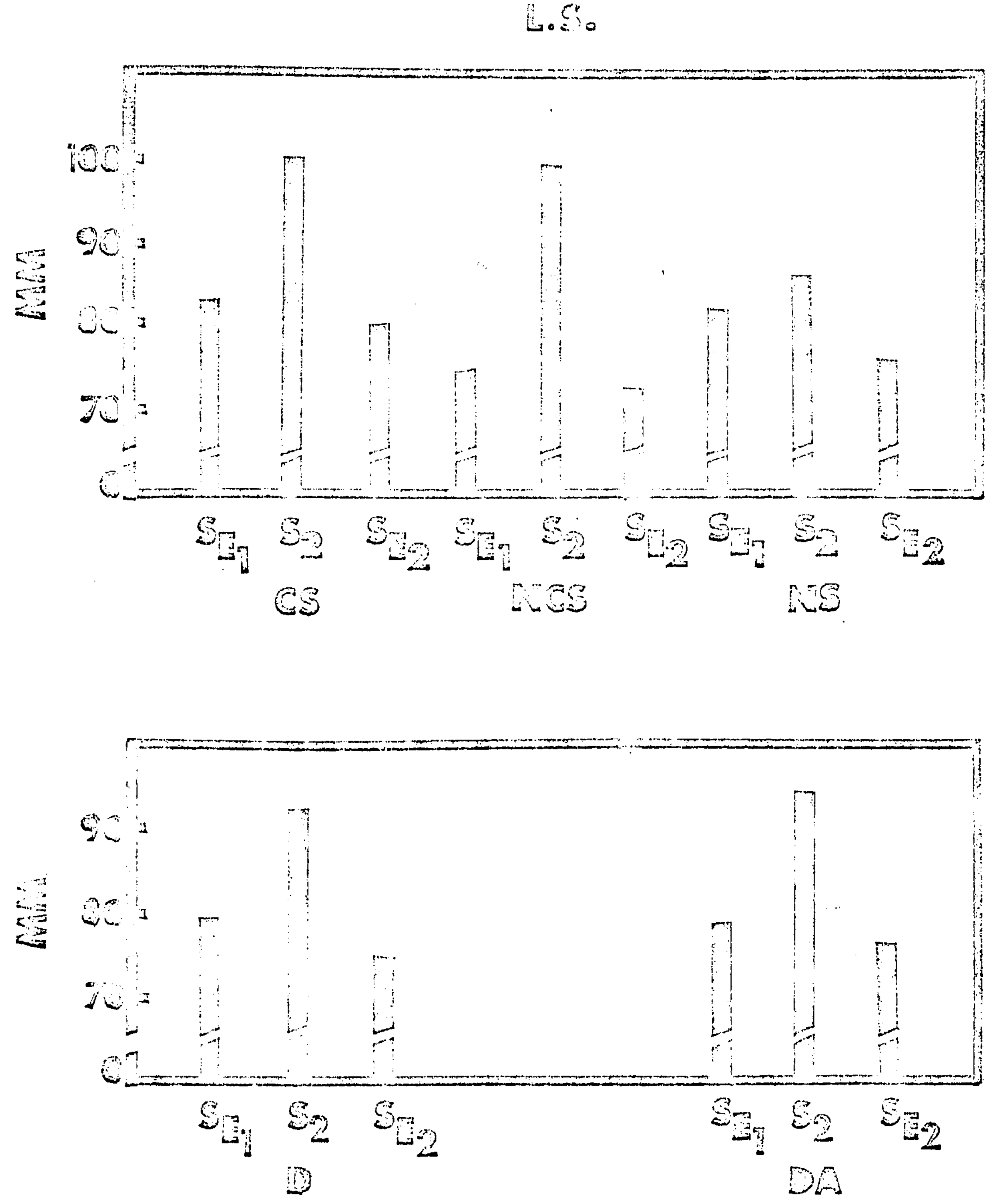


FIG. 4. Effects of "arousal" and "attention" on the amplitude of the ECP to S_2 and S_E (10 μV=50 MM).

means for the amplitude of the ECP to S_E in the S_1-S_2 and S_2-S_1 intervals and the mean of the ECP to S_2. Essentially, this figure summarizes graphically the results of the previous two figures.

Figure 5 illustrates the mean change in the amplitude of the ECP to S_E as a function of whether it occurred in the S_1-S_2 or S_2-S_1 interval and as a function of whether it occurred in the first or third sec of the interval. For this S there was a significant difference in the amplitude of the ECP due to the interval in which it occurred. It is clear from this figure that the amplitude of the ECP was larger in the S_1-S_2 interval than in the S_2-S_1 interval.

Figures 6 and 7 reflect the interactions of the above effects with "arousal" and "attention". Statistical analysis revealed a significant interaction effect of "Attention" X ECPs occurring in the first or third sec ($p<.05$). It can be seen in Figure 7 that the amplitude of the ECP to S_E occurring in the first sec is larger than that obtained in the third sec under the distraction condition. However, in the divided attention condition the ECPs to stimuli occurring in the third sec were larger than those to the first sec. The "Arousal" X First or Third interaction effect approached significance.

Variance analysis on HR. The heart rate response was one of deceleration in the S_1-S_2 interval and acceleration in the S_2-S_1 interval (see Figure 8). Changes in HR as a function of "arousal" were quite significant ($p<.01$), but the other major variable, "attention", exhibited no such effect. The means representing the average HR change within the 6-sec interval are plotted in Figure 9 for the three "arousal" and "attention" conditions. It is evident from this figure

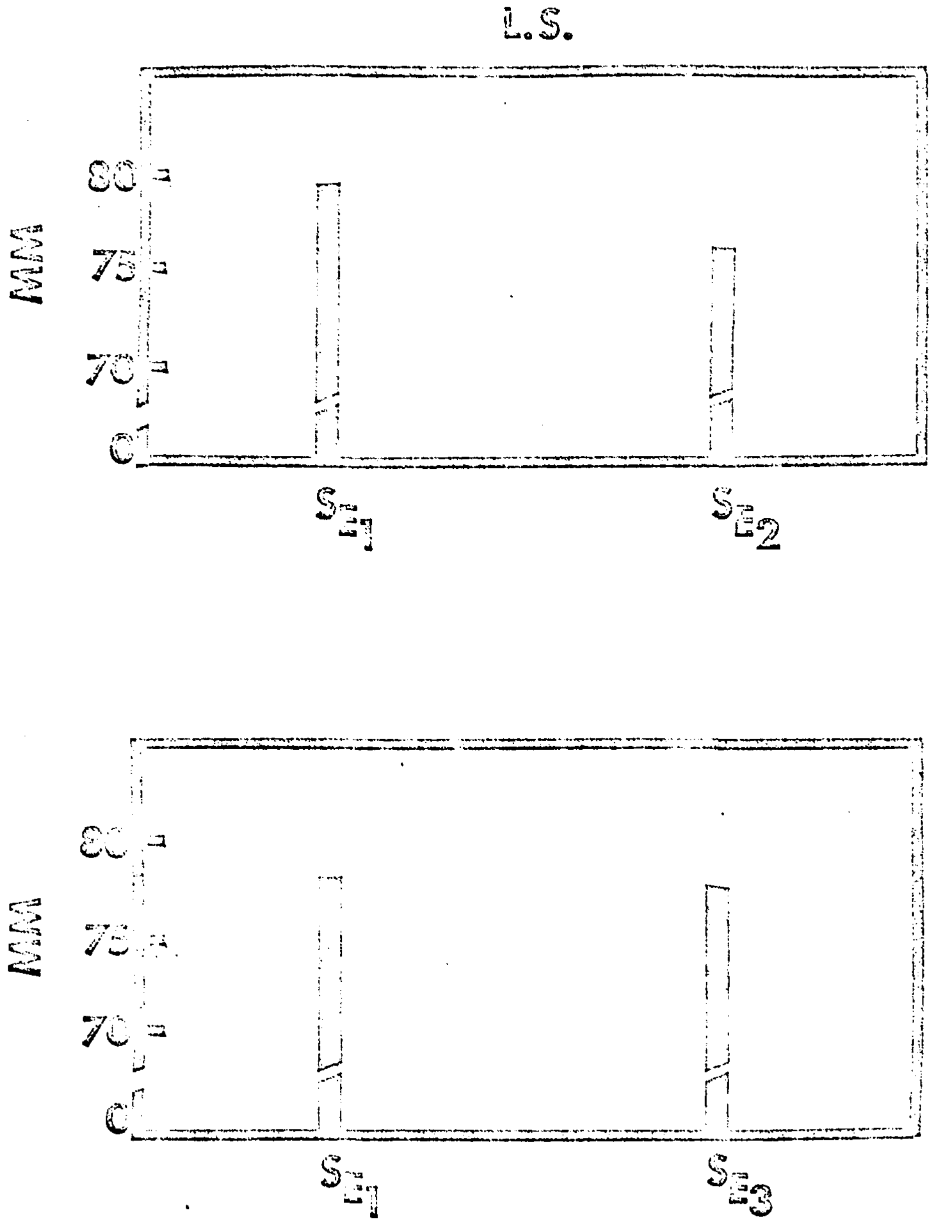


FIG. 5. Changes in the amplitude of the ECPs to S_E as a function of whether they occurred in the S_1-S_2 or S_2-S_1 interval and as a function of whether they occurred in the first or third sec of the interval (10 μV=50 MM).

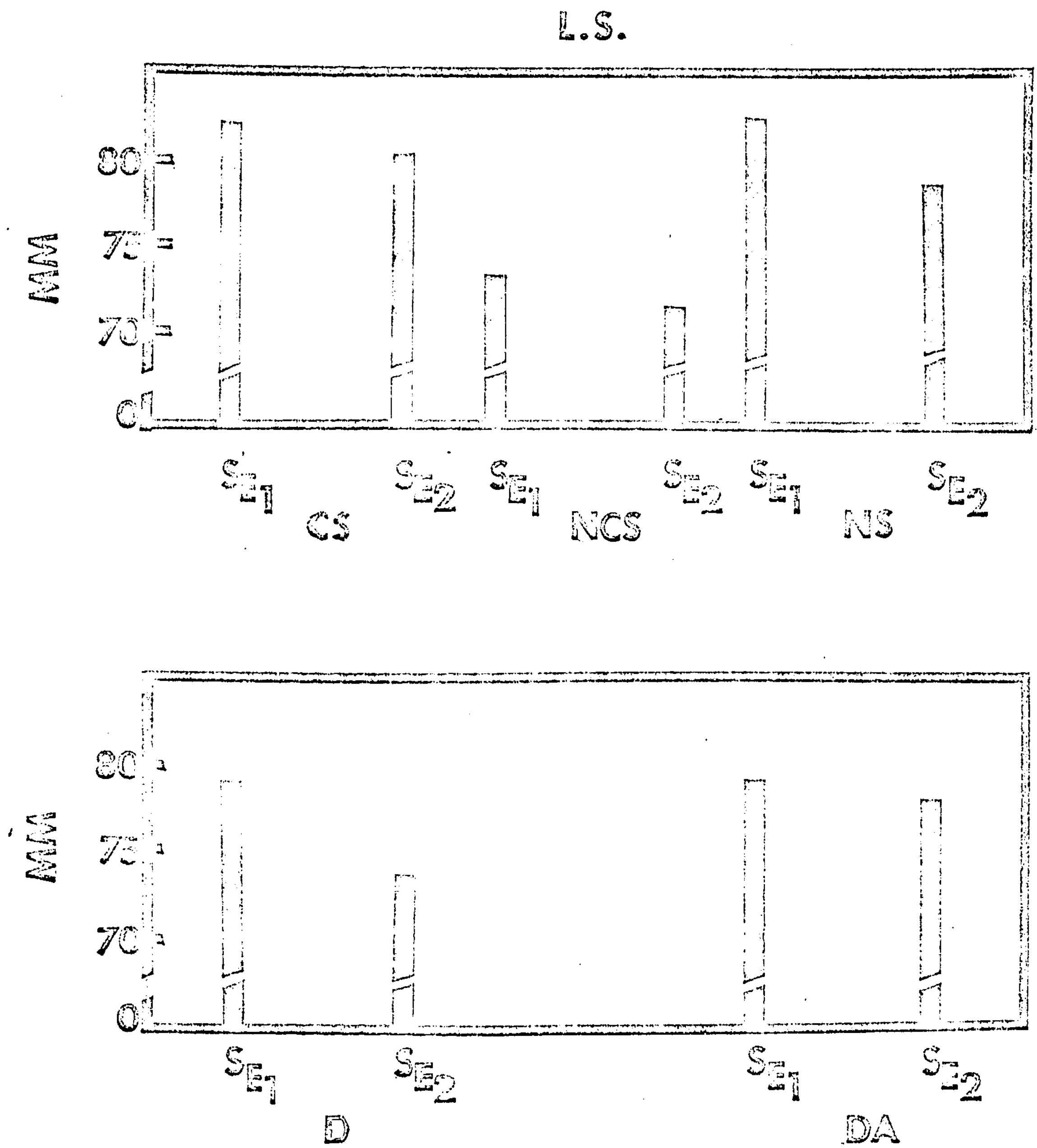


FIG. 6. Changes in the amplitude of the ECP to S_E in the S_1-S_2 and S_2-S_1 intervals as a function of "arousal" and "attention" (10 µV = 50 MM).

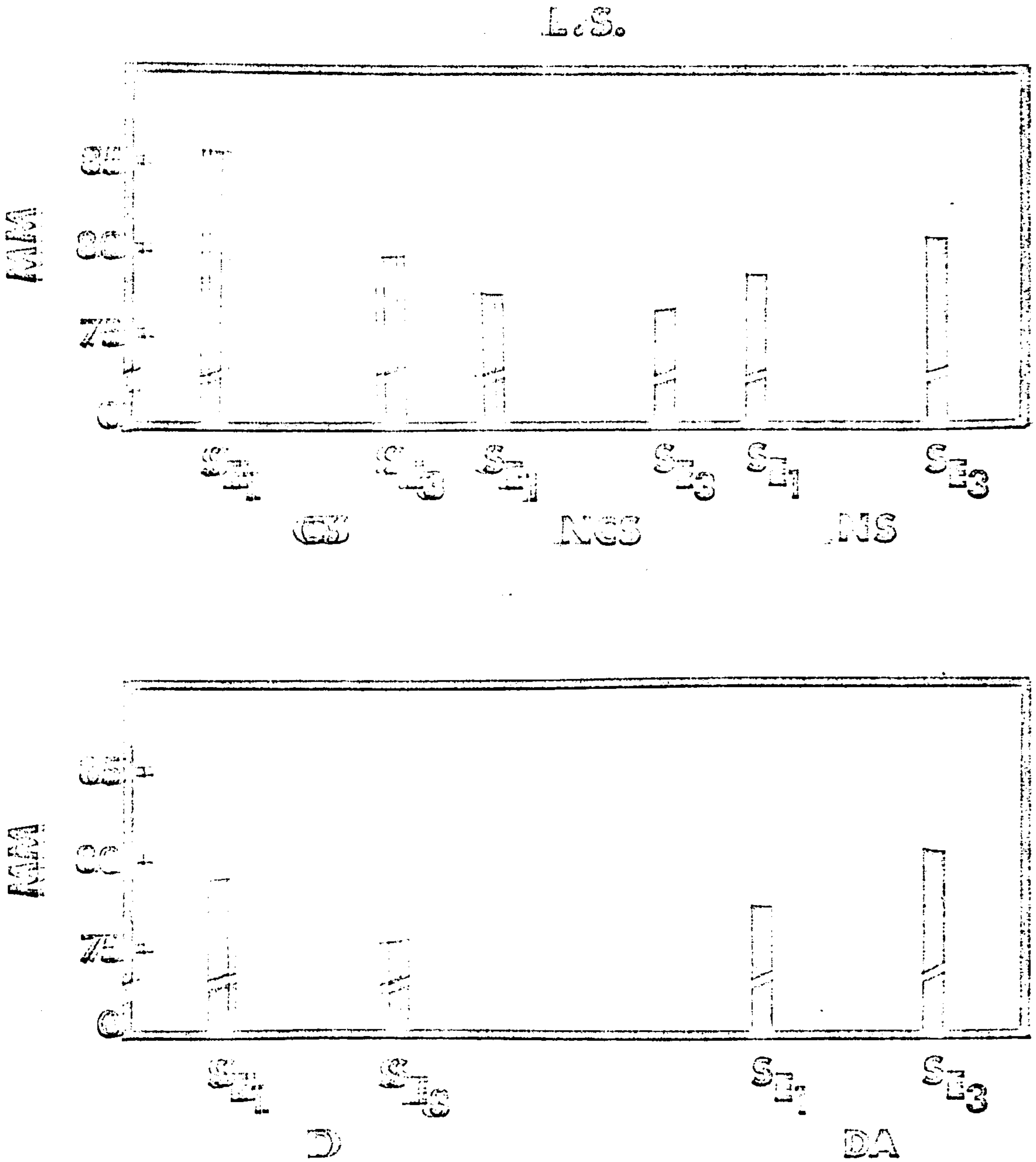


FIG. 7. Changes in the amplitude of the ECP to S_E occurring in the first and third sec as a function of "arousal" and "attention" (10 µV = 50 MM).

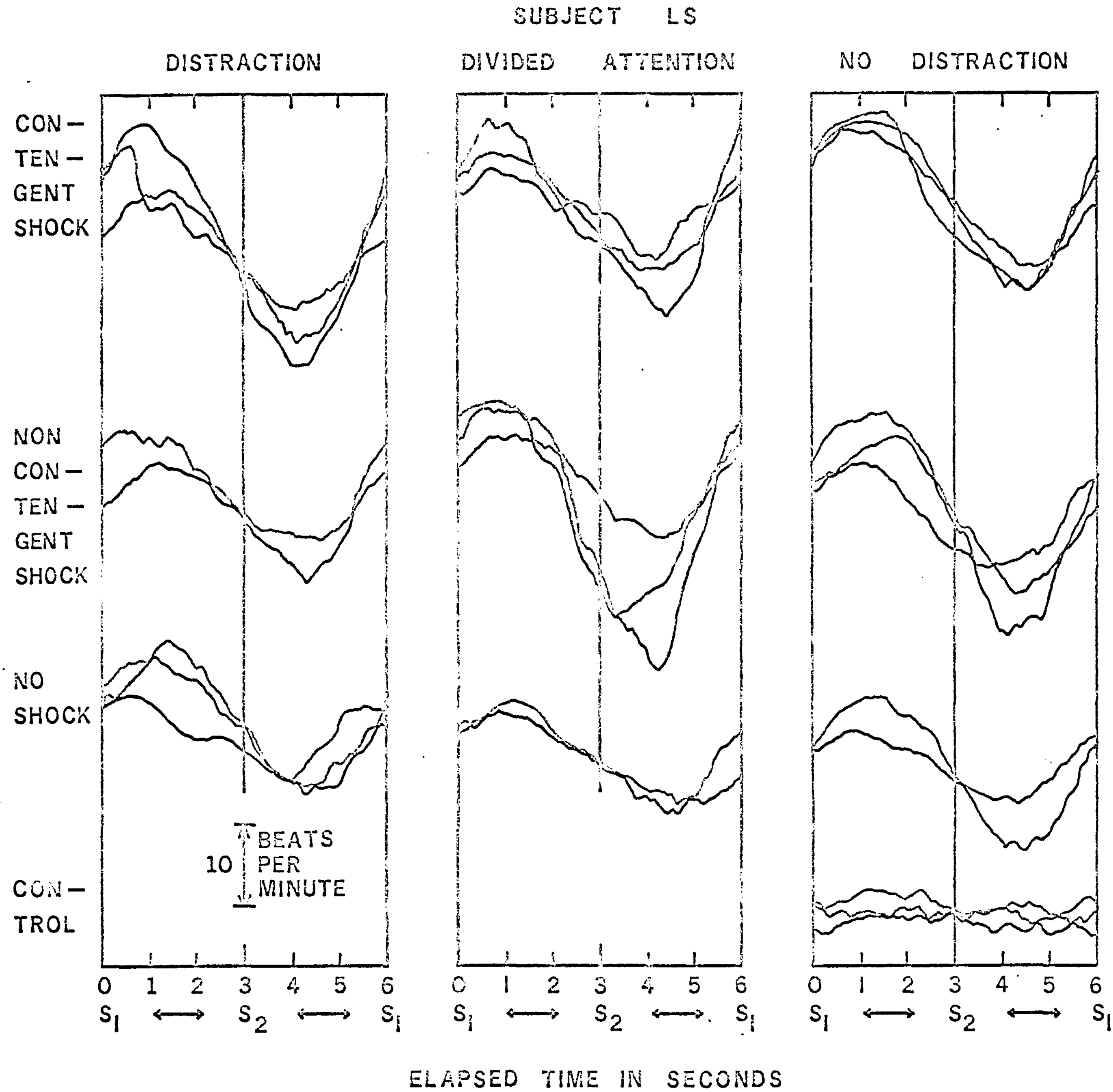


FIG. 8. Effects of "arousal" and "attention" on HR averaged across each 6-sec interval (10 BPM=60 MM).

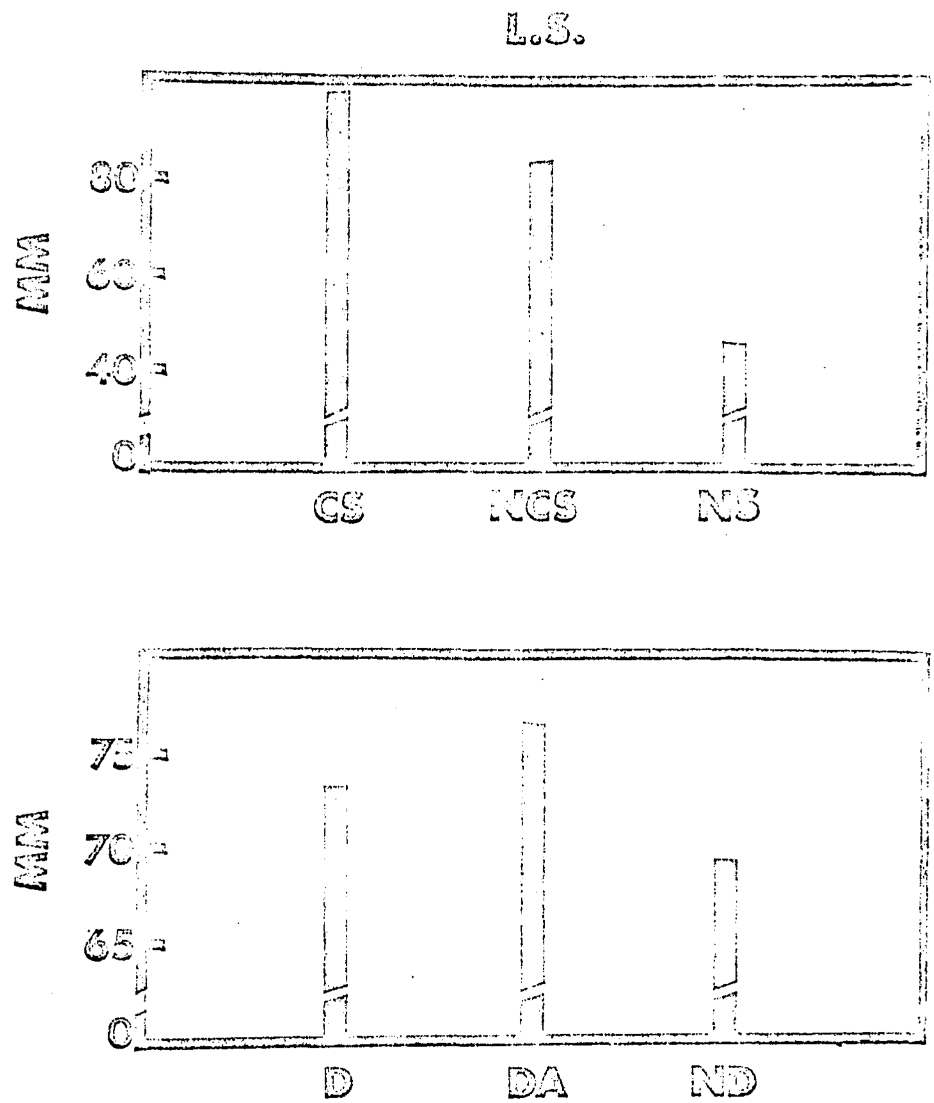


FIG. 9. Mean changes in HR averaged across each 6-sec interval as a function of "arousal" and shifts in "attention" (10 BPM=60 MM).

that the magnitude of the change in HR was dependent upon the presence of shock. The greatest change in HR occurred under contingent shock and the least under no shock. There was a tendency, though not significant, for HR change to be greater when distraction was present in the situation.

Variance analysis on RT. Both "arousal" and "attention" had a significant effect ($p<.01$) on reaction time performance; this is reflected in Figure 10. It is evident that for this S RTs were shortest under contingent shock and longest under no shock. It also appears that noncontingent shock had almost as enhancing an effect on performance as contingent shock. Clearly, the "attentional" effect on RT performance is exhibited in the distraction and no distraction conditions. When S_E were not present, RTs were significantly shorter ($p<.01$) than when these stimuli were present and S was required to ignore or count them. It should also be noted that this S's performance was essentially the same whether he was ignoring or attending to S_E. These behavioral data are concomitant with S's physiological data which showed no difference between the ECPs to S_2 under the distraction and divided attention conditions.

Subject S.H.

Variance analyses on the ECP. Variance analyses showed that for the ECP to both S_2 and S_E there was a significant "arousal" effect ($p<.01$), a significant "attentional" effect ($p<.01$), and a significant interaction effect of "Arousal" X "Attention" ($p<.05$). In addition, there was a significant within-6-sec-interval effect ($p<.05$) reflecting changes in the ECPs to S_E as a function of where they occurred in the

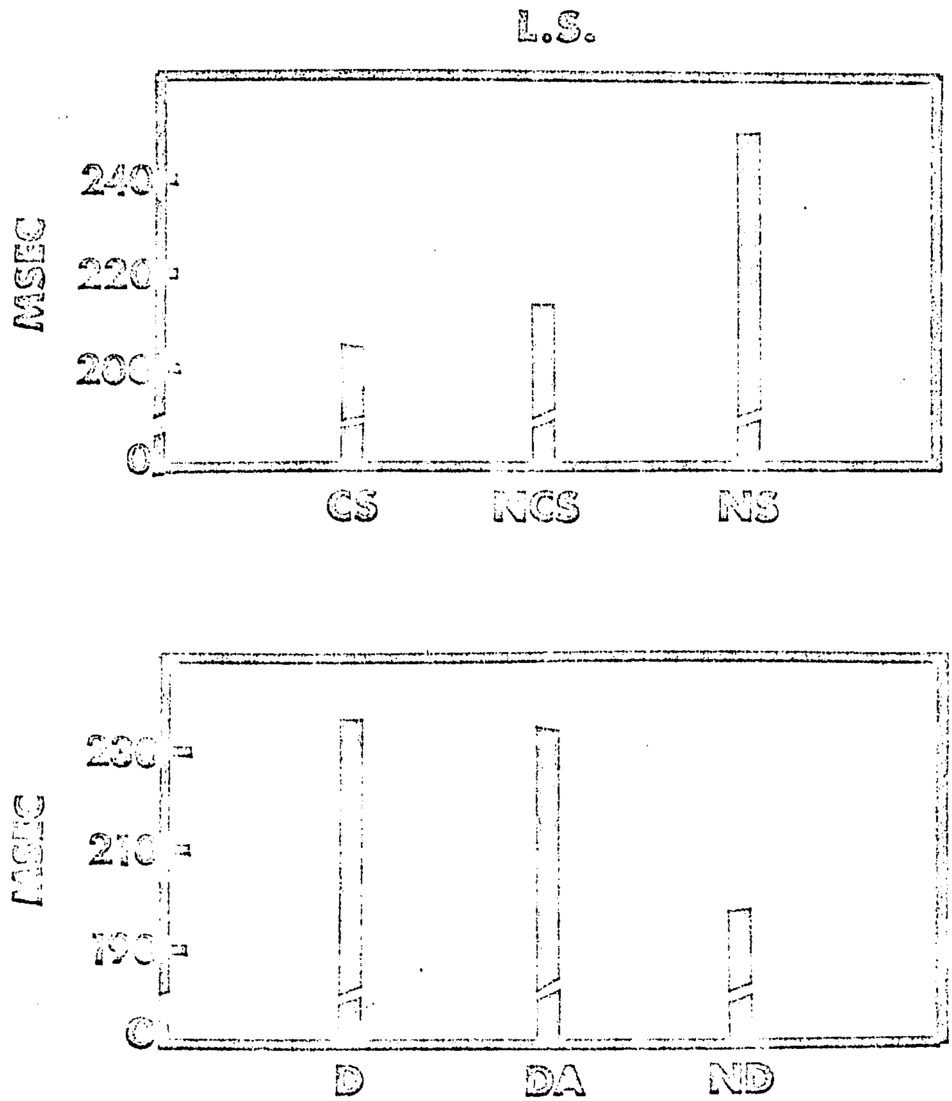


FIG. 10. Changes in RT as a function of "arousal" and shifts in "attention".

interval. These statistical findings are graphically presented in Figures 11 through 18.

Figure 11 shows the mean amplitude of the ECP to S_2 as a function of changes in "arousal" and "attention". It can be seen in this figure that contingent shock had the effect of significantly enhancing the amplitude of the ECP over the no shock situations. It is also apparent that introducing distraction into the experimental situation resulted in a significant attenuation in ECP amplitude to S_2. The interaction effect of these two variables ($p<.05$) indicates that the extent to which S was attending to the relevant stimulus was dependent upon the presence or absence of shock.

In Figure 12 are plotted the means for the ECP to S_E as a function of "arousal" and shifts in "attention". This figure shows that under contingent shock the ECP amplitude to S_E is significantly enhanced over the no shock situation. The "attention" effect is also clear. When S is counting these stimuli, the ECPs to these are significantly enhanced as compared to when he is ignoring them. A significant interaction between "arousal" and stimulus irrelevance was also found.

Figure 13 reflects the relationship of the ECP to both S_2 and S_E as a function of changes in "arousal" and "attention". Plotted in this figure are the amplitude of the ECP to S_E in the S_1-S_2 interval, S_2-S_1 interval, and the mean of the ECP to S_2. Essentially, this figure summarizes graphically the results of the previous two figures.

Figures 14 and 15 illustrate the mean changes in the amplitude of the ECPs to S_E as a function of whether they occurred in the S_1-S_2 or S_2-S_1 interval and as a function of whether they occurred in the

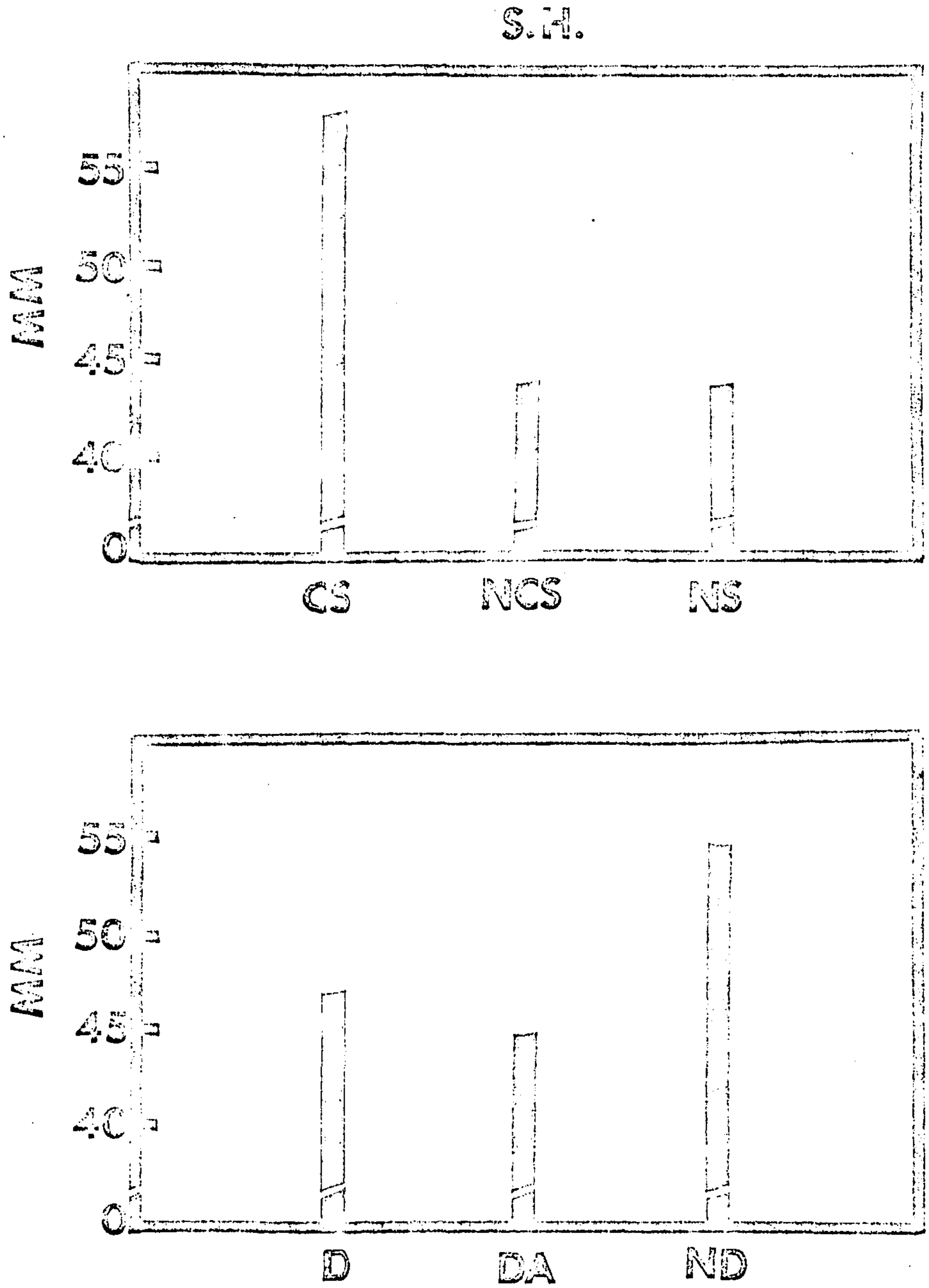


FIG. 11. Effects of "arousal" and "attention" on the amplitude of the ECP to S_2 (10 μV=50 MM).

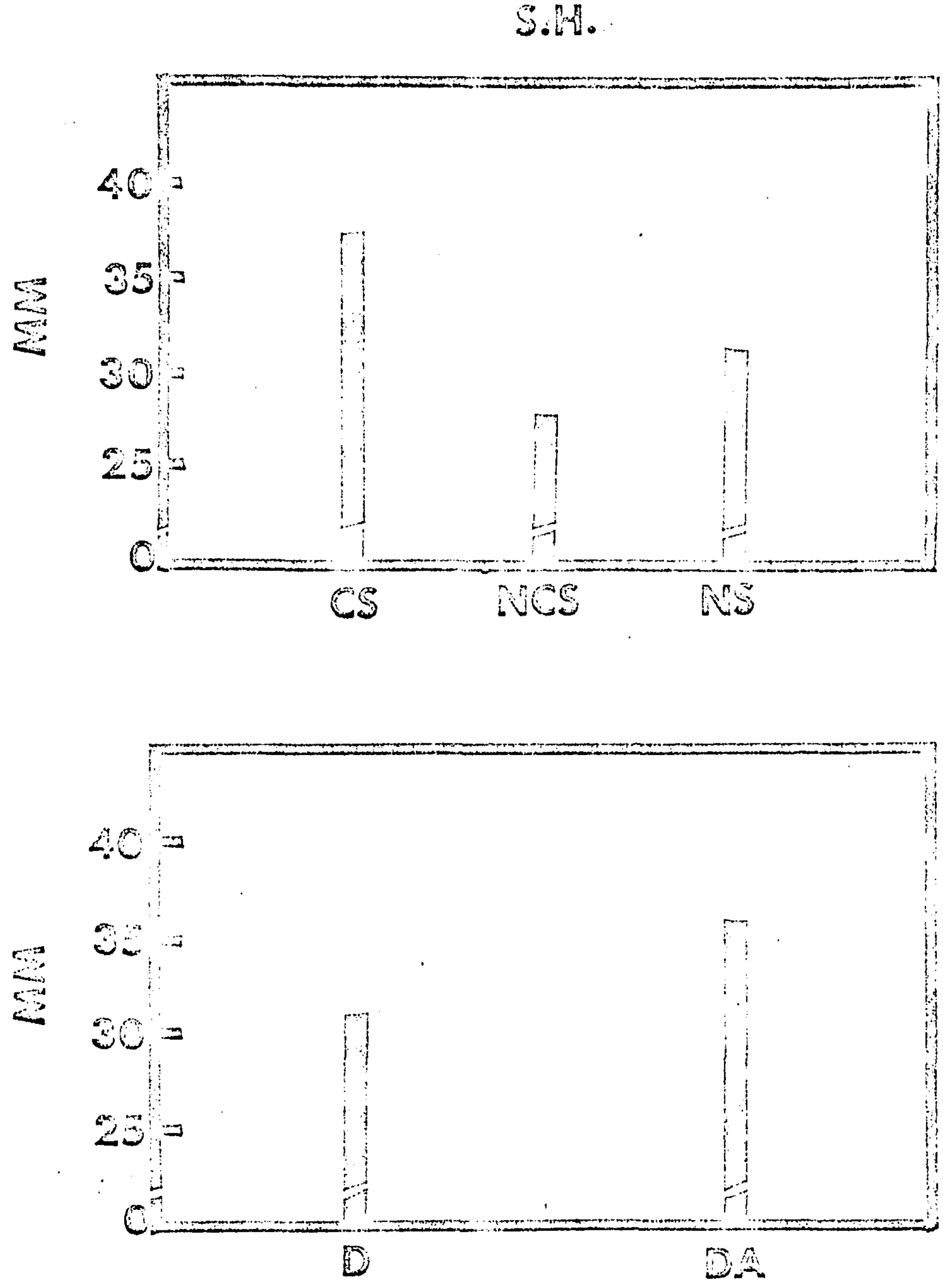


FIG. 12. Effects of "arousal" and "attention" on the amplitude of the ECP to S_E (10 μV=50 MM).

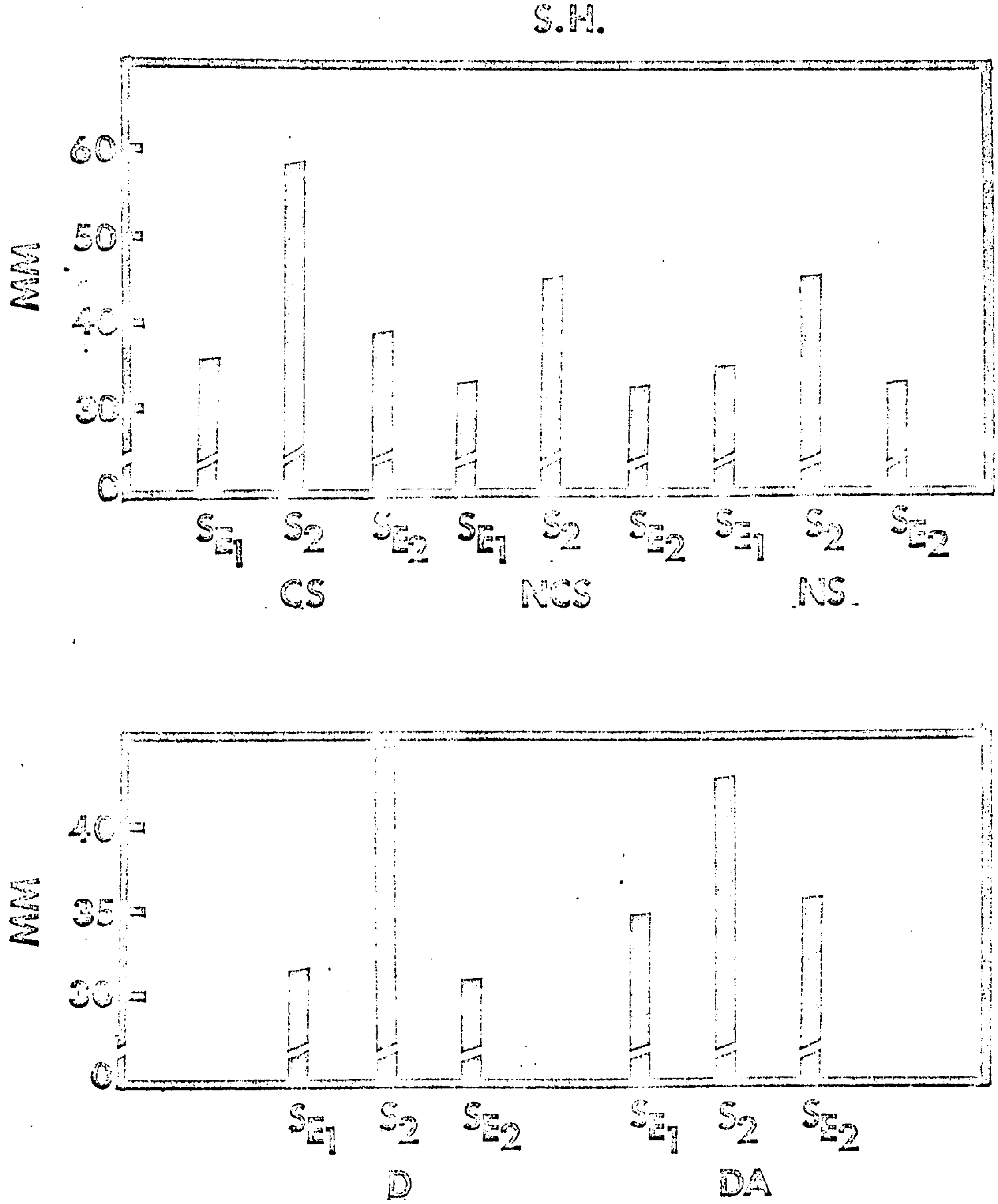


FIG. 13. Effects of "arousal" and "attention" on the amplitude of the ECP to S_2 and S_E (10 μV=50 MM).

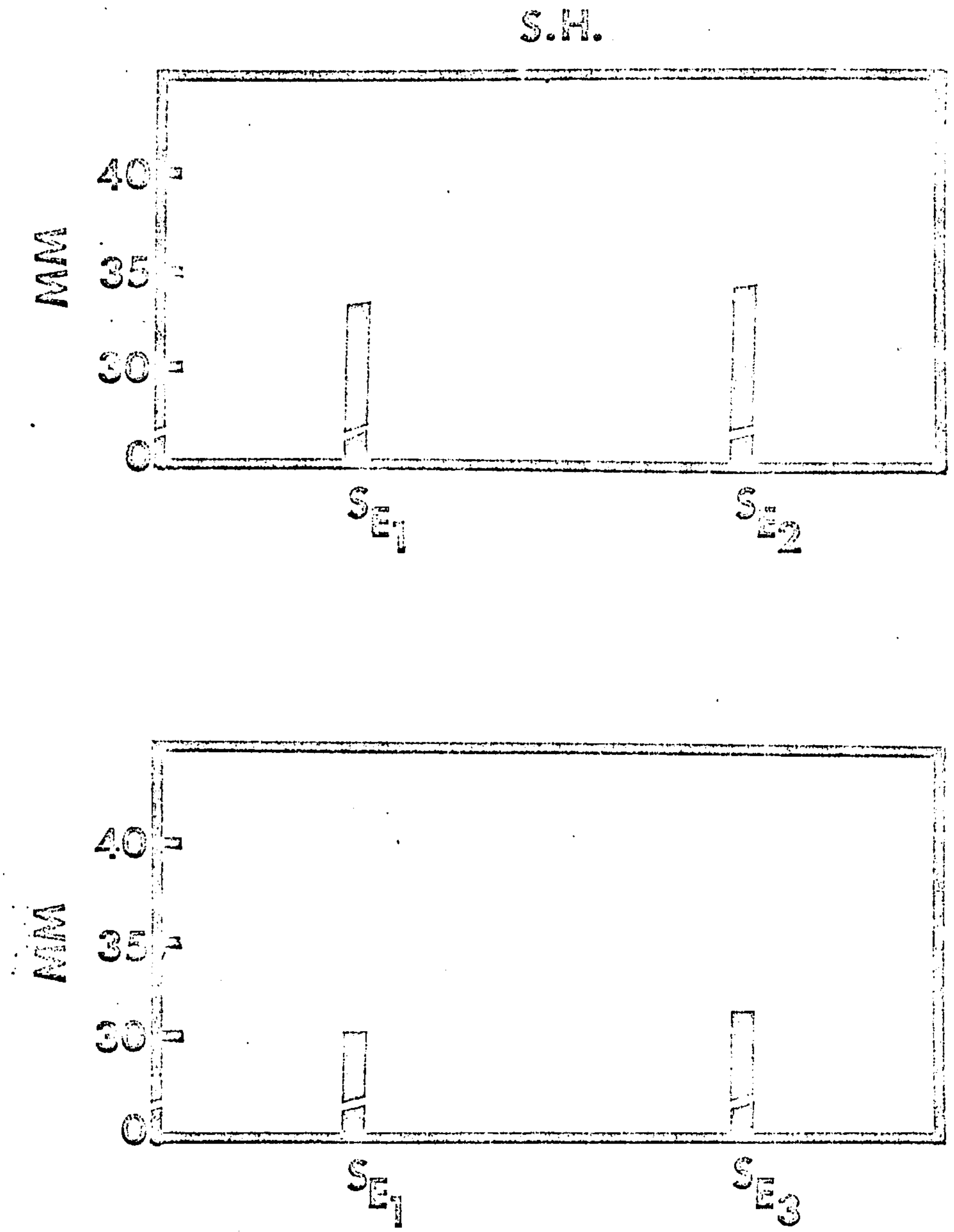


FIG. 14. Changes in the amplitude of the ECPs to S_E as a function of whether they occurred in the S_1-S_2 or S_2-S_1 interval and as a function of whether they occurred in the first or third sec of the interval (10 μV=50 MM).

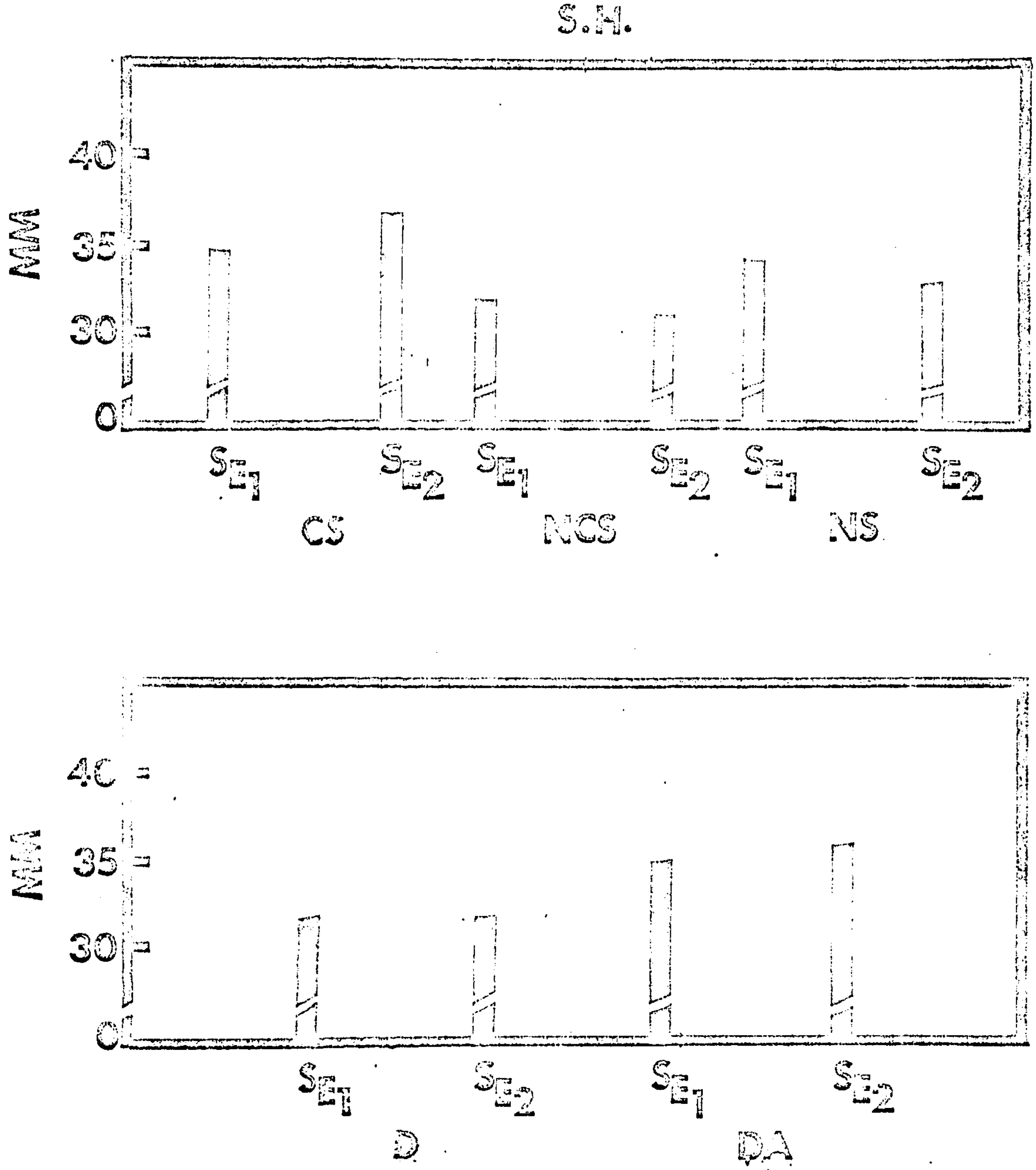


FIG. 15. Changes in the amplitude of the ECP to S_E in the S_1-S_2 and S_2-S_1 intervals as a function of "arousal" and "attention" (10 μV = 50 MM).

first or third sec of the interval. Statistical analysis indicated that for this S there was a significant interaction effect of S_1-S_2/S_2-S_1 X First or Third Sec ($p<.01$); this suggests that whether the amplitude of the ECP was changed significantly depended upon whether it occurred to flashes in the first or third sec and whether it was in the S_1-S_2 or S_2-S_1 interval.

Figure 16 reflects the interaction of the above effects with "arousal" and "attention". Analysis showed a significant interaction between "arousal" and ECPs to the first or third sec ($p<.05$) as well as an interaction effect between "attention" and ECPs to flashes in the first or third sec ($p<.05$). It can be seen in this figure that the ECPs to flashes occurring in the first sec are smaller than those in the third sec under both contingent and noncontingent shock; just the reverse was true for the no shock situation. The "attentional" effect is also discernible. In the distraction condition, the ECPs to stimuli occurring in the first sec are larger than those to the third; the reverse is true for the divided attention condition.

Variance analysis on HR. Statistical analysis revealed that experimental manipulations of "arousal" and "attention" had a significant effect on HR changes within the 6-sec interval ($p<.01$). There was also a significant interaction between these variables ($p<.05$). The mean changes in HR as a function of "arousal" and "attention" are shown in Figure 17. The effects of "arousal" are clear. The HR change was greatest under contingent shock, intermediate under noncontingent shock, and smallest under no shock. The "attentional" effects are also present. Changes in HR were more pronounced under the distraction than the no distraction conditions.

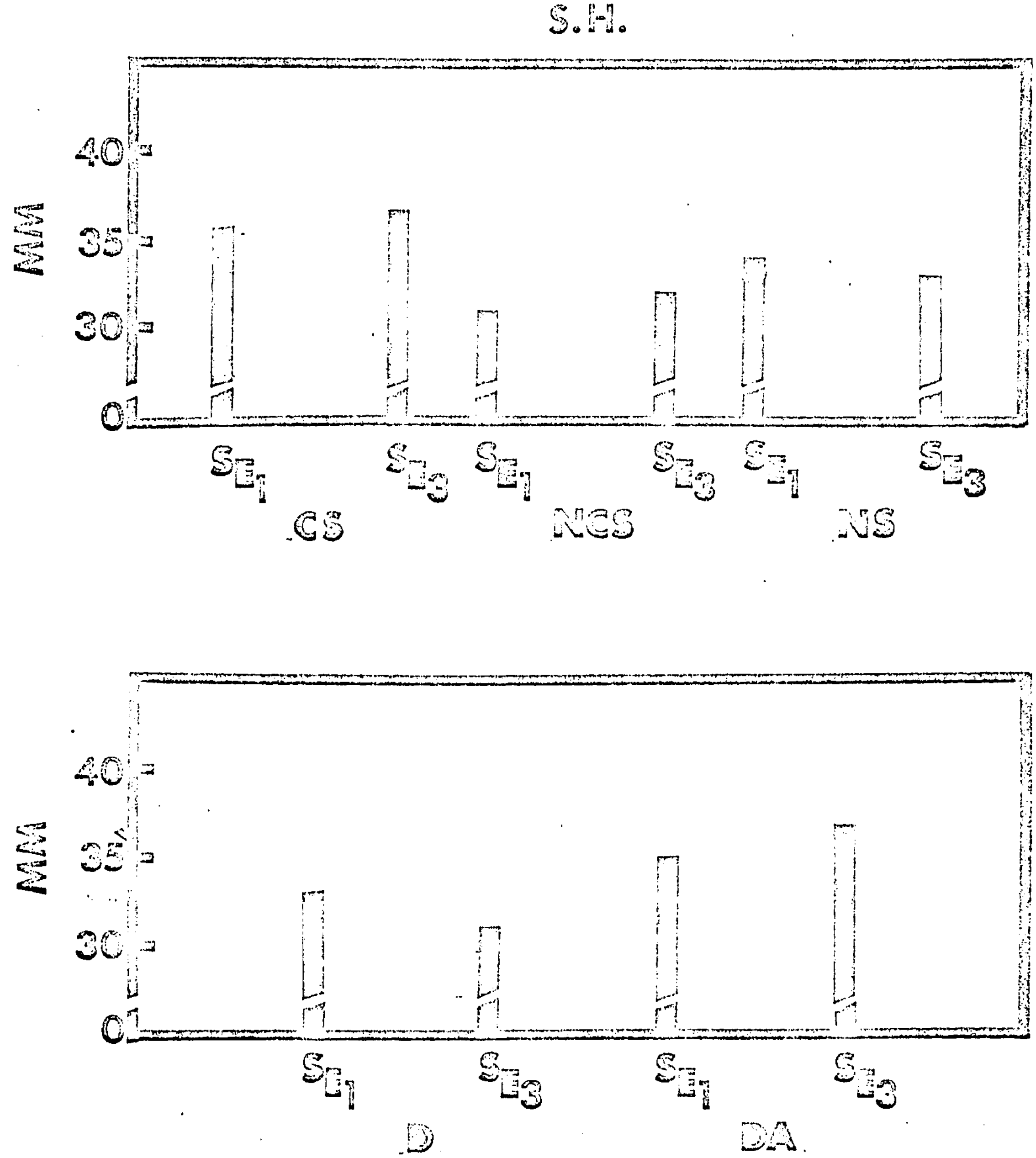


FIG. 16. Changes in the amplitude of the ECP occurring in the first and third sec as a function of "arousal" and "attention" (10 UV 50 MM).

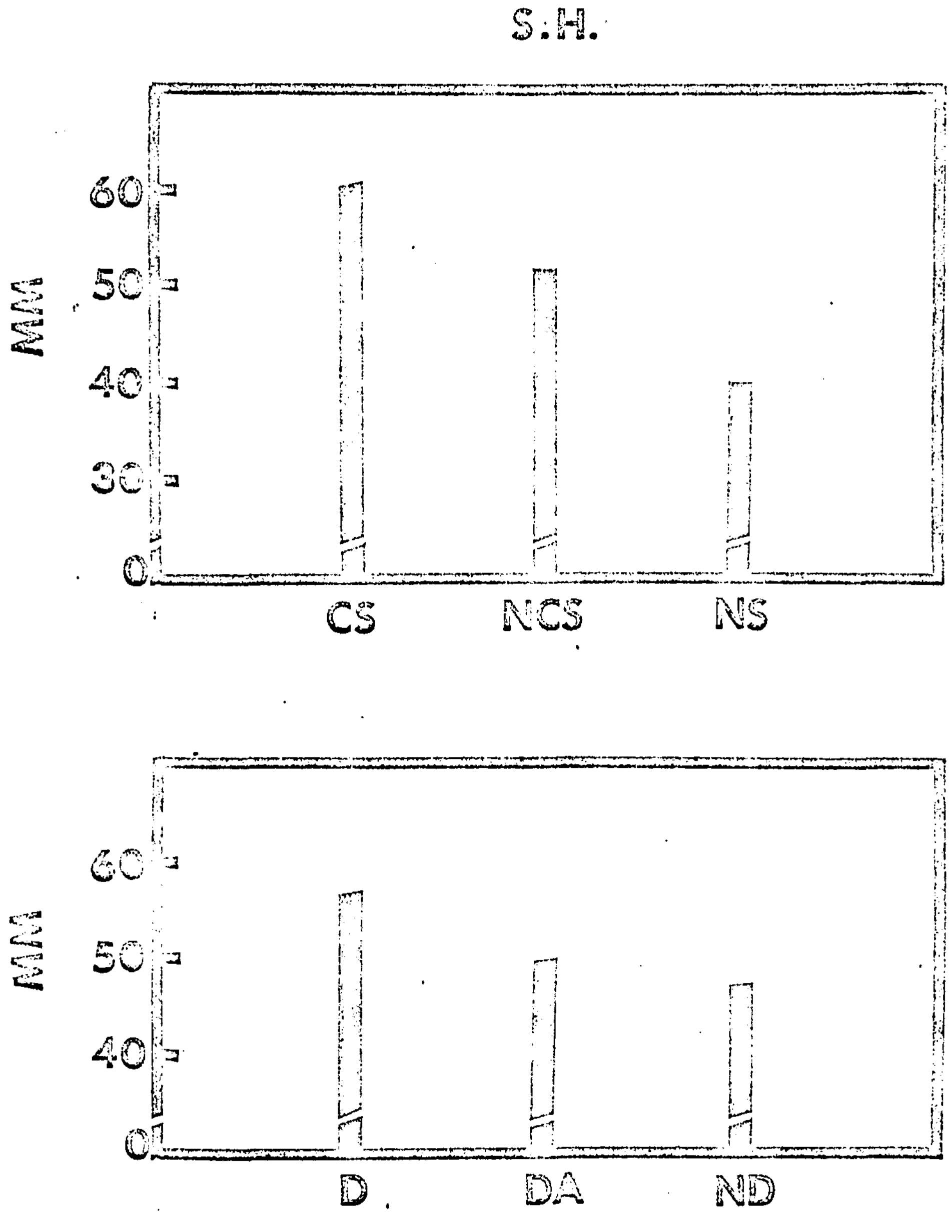


FIG. 17. Mean changes in HR averaged across each 6-sec interval as a function of "arousal" and shifts in "attention" (10 BPM:60 MM).

Variance analysis on RT. The significant effects of "arousal" and "attention" on RT ($p<.01$) are illustrated in Figure 16. The RTs under contingent shock were approximately 40 msec shorter than those obtained under noncontingent shock. The effects of shifts in "attention" are also shown in this figure. The RTs were longest when S was required to count S_E as well as respond to S_2 and shortest when no distraction was present.

Subject B.S.

Variance analyses on the ECP. Variance analyses showed that both changes in "arousal" and "attention" had a significant influence on the amplitude of the ECP to S_2 ($p<.05$) and on the amplitude of the ECP to S_E. The interaction between these major variables was not significant. In addition, no significant within-6-sec-interval effect on the ECPs to S_E was found. These findings are graphically presented in Figures 19 through 26.

Figure 19 shows the mean amplitude of the ECP to S_2 under the three levels of "arousal" and "attention". It is apparent that shock threat enhanced the amplitude of the ECP to S_2. It is also clear that introducing distraction into the experimental situation greatly reduced the amplitude of the ECP to S_2 ($p<.01$).

Figure 20 illustrates the effects of "arousal" and "attention" on the ECP to S_E. It is readily apparent that the presence of shock had an enhancing effect ($p<.05$) on ECP amplitude. The amplitude of the ECP was also influenced by shifts in "attention" toward (enhancement) and away from (attenuation) S_E.

Figure 21 reflects the relationship of the ECP to S_2 and S_E as a function of "arousal" level and "attention". Plotted in this figure

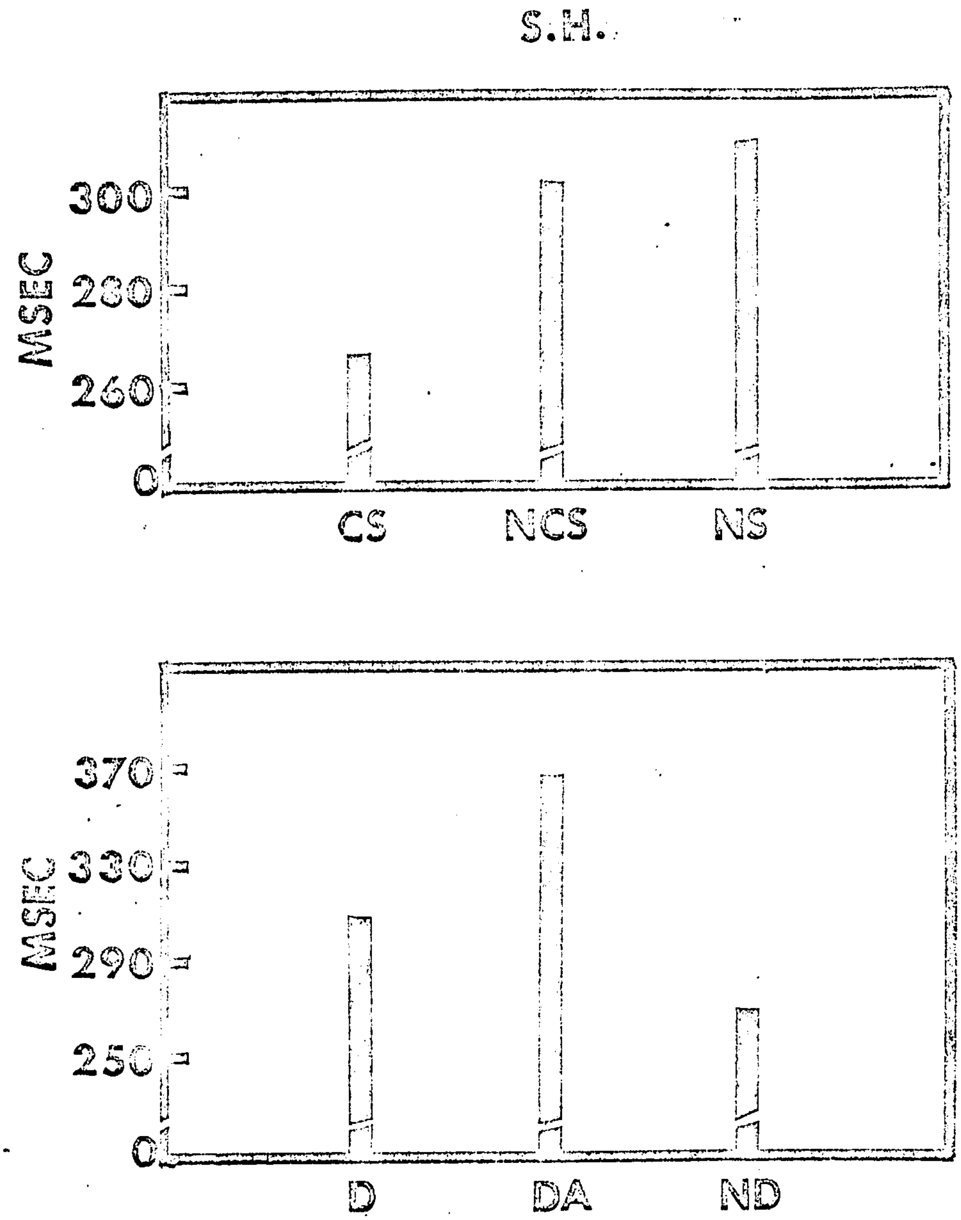


FIG. 18. Changes in RT as a function of "arousal" and shifts in "attention".

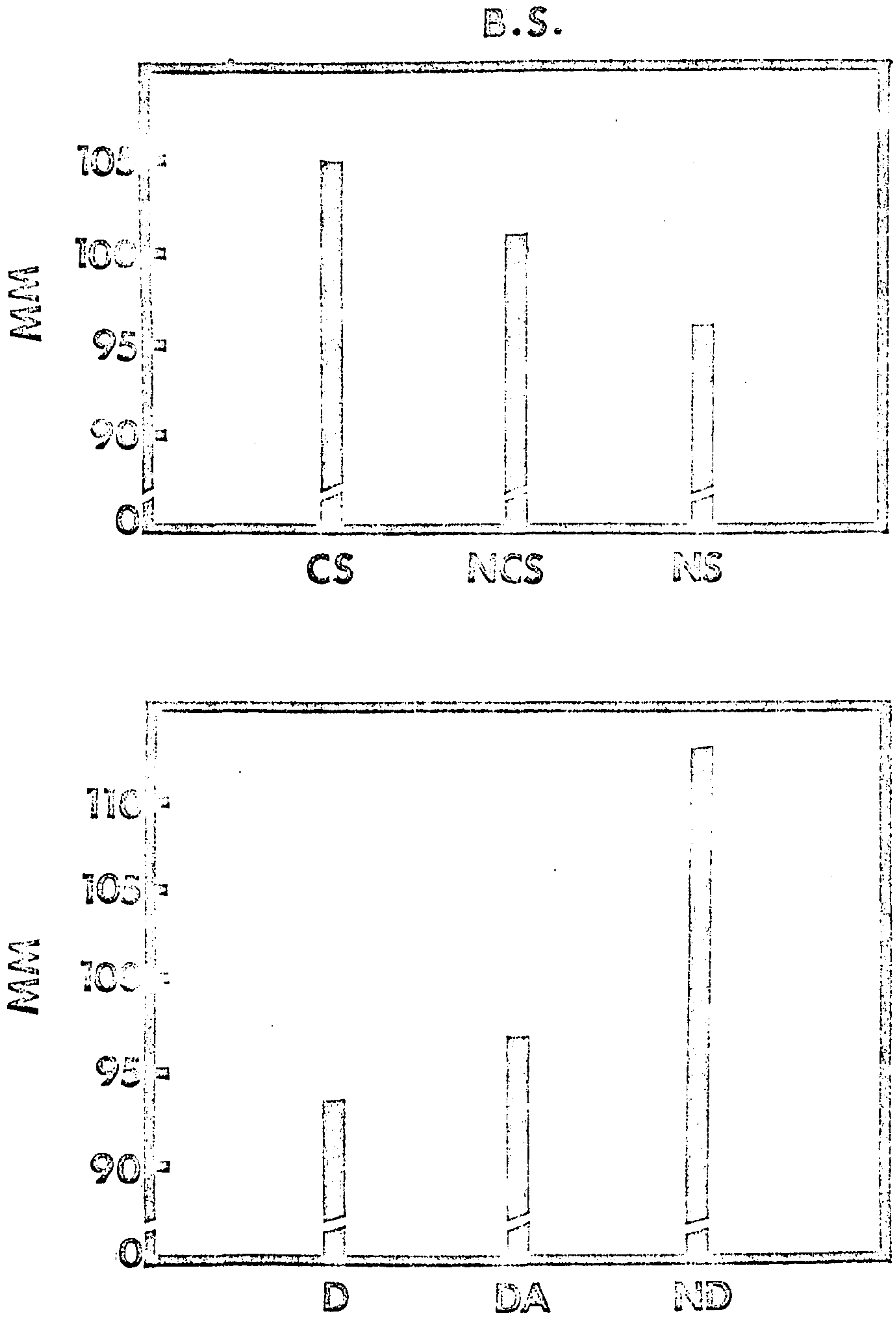


FIG. 19. Effects of "arousal" and "attention" on the amplitude of the ECP to S_2 (10 μV=50 MM).

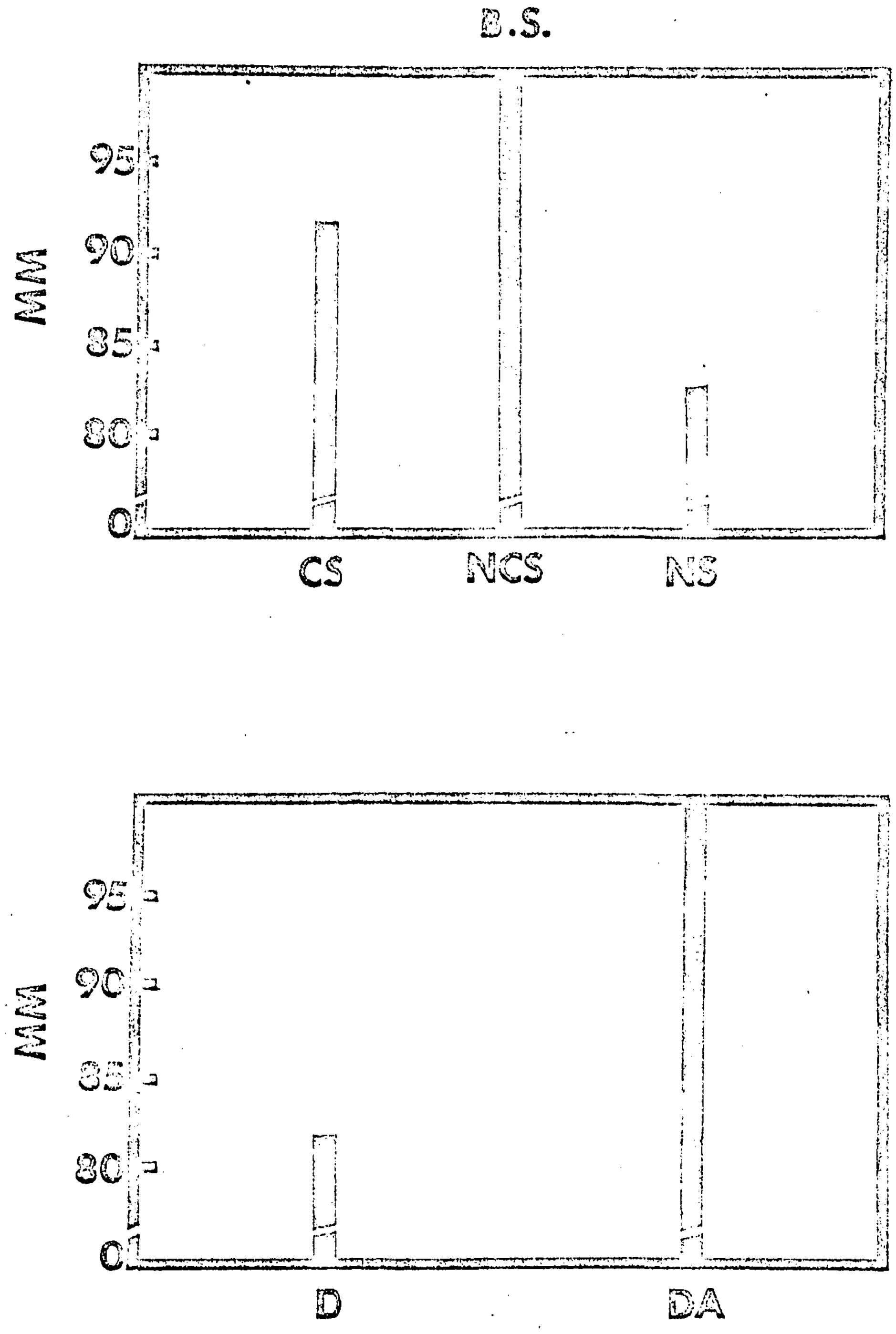


FIG. 20. Effects of "arousal" and "attention" on the amplitude of the ECP to S_E (10 μV=50 MM).

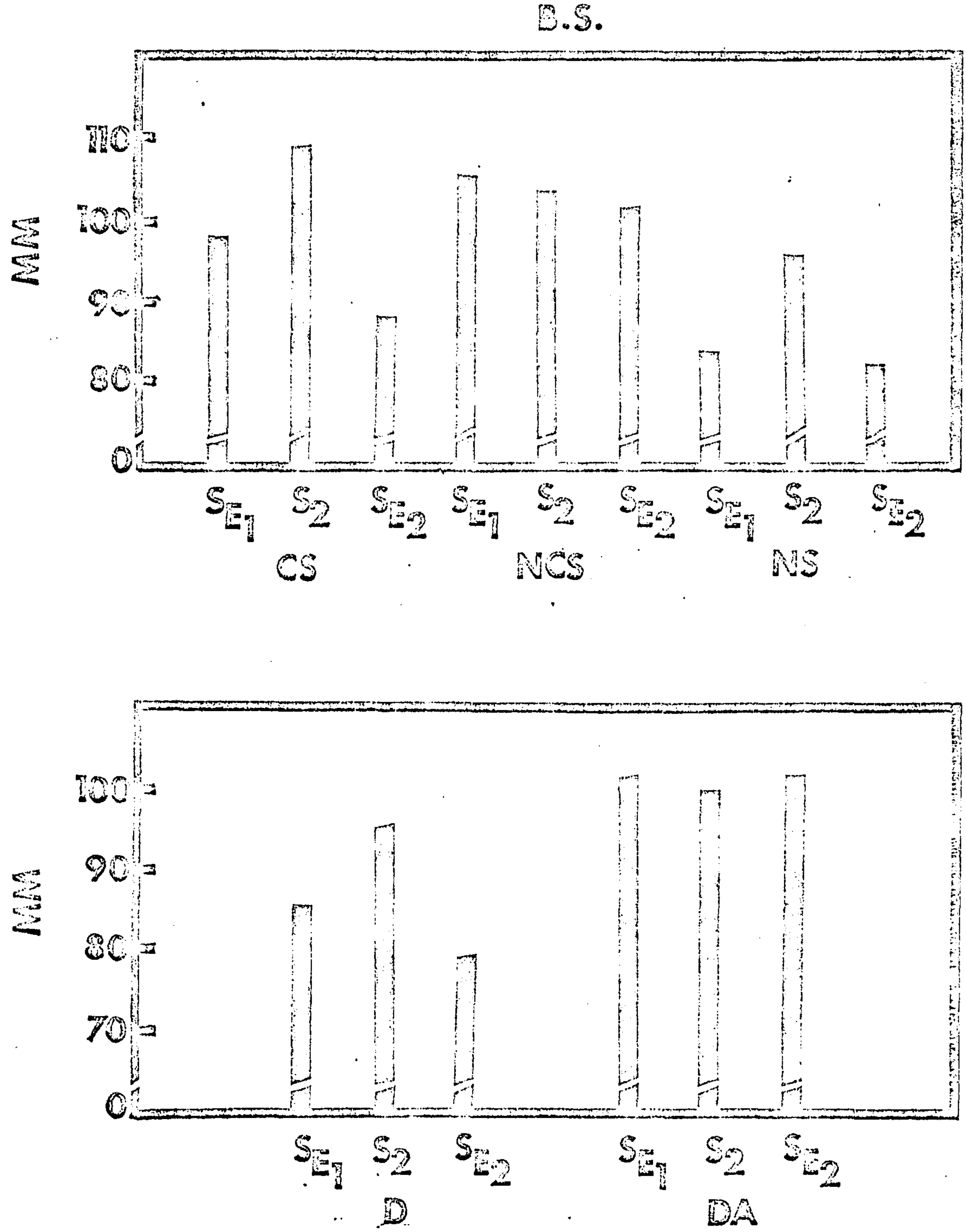


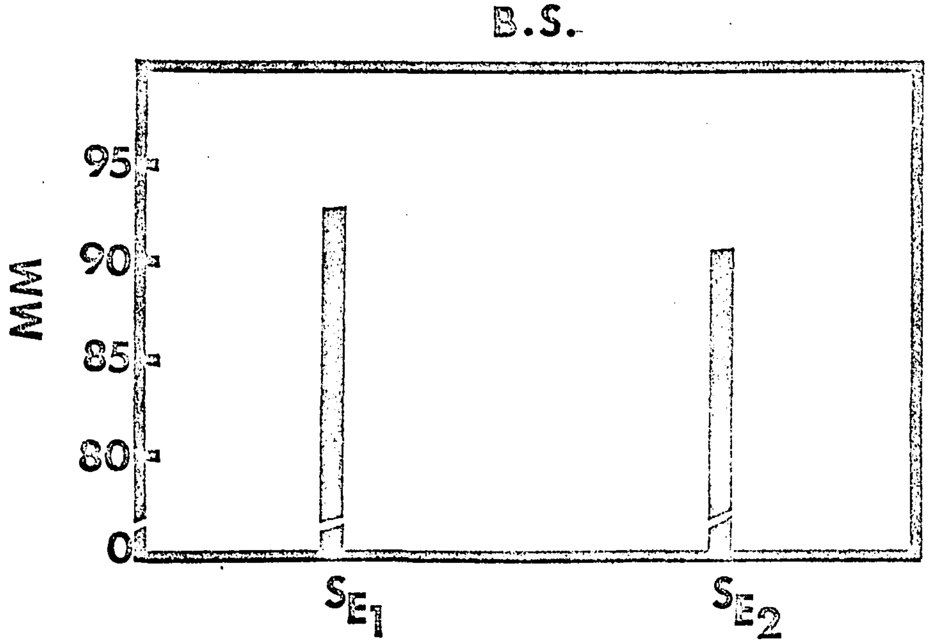
FIG. 21. Effects of "arousal" and "attention" on the amplitude of the ECP to S_2 and S_E (10 μV=50 MM).

are the means for the amplitude of the ECPs to S_E in the S_1-S_2 interval, S_2-S_1 interval, and the mean of the ECP to S_2. Essentially, this figure summarizes graphically the results of the previous two figures.

Figure 22 illustrates the mean changes in the amplitude of the ECPs to S_E as a function of whether they occurred in the S_1-S_2 or S_2-S_1 interval and as a function of whether they occurred in the first or third sec of the interval. For this S there were no significant differences in the amplitude of the ECPs as a function of the interval in which they occurred; nor was there a significant effect due to whether the ECPs occurred in the first or third sec. This is reflected in the present figure. There were no significant "Arousal" or "Attention" X Within effects as can be seen from the means plotted in Figures 23 and 24.

Variance analysis on HR. The significant effects due to changes in "arousal" ($p<.01$) and "attention" ($p<.05$) are shown in Figure 25. This figure contains the mean changes in HR during a 6-sec interval. The effect of "arousal" is dramatically shown. Changes in HR were greatest under contingent shock, intermediate under noncontingent shock, and least under no shock. The "attentional" effect is also evident. Changes in HR were greatest under the divided attention condition, intermediate under distraction, and least under no distraction. The significant interaction between "arousal" and "attention" suggests that the degree to which S was attending to S_2 was influenced by the "arousal" condition in which he was performing.

Variance analysis on RT. Performance was significantly influenced both by "arousal" ($p<.01$) and shifts in "attention" ($p<.01$). These



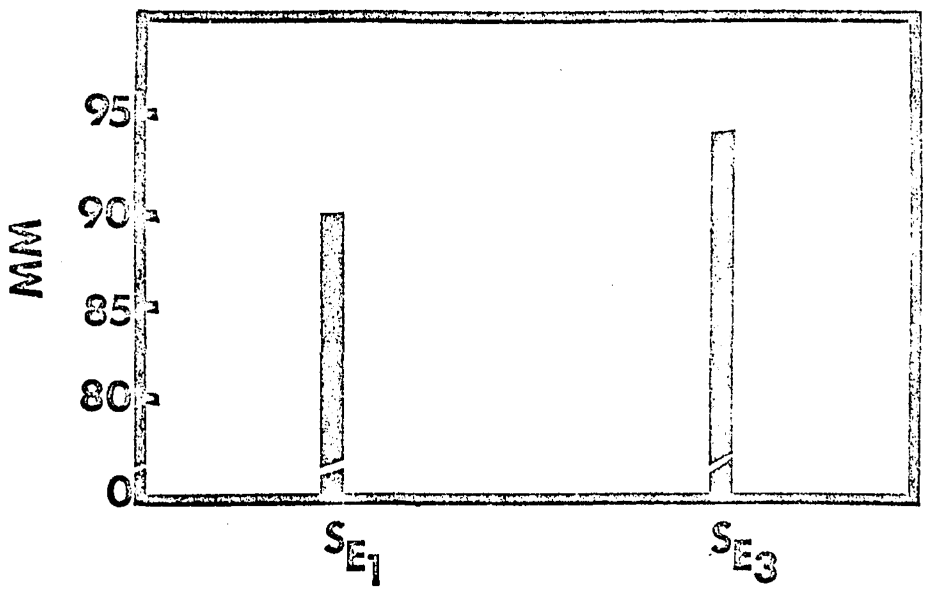


FIG. 22. Changes in the amplitude of the ECPs to S_E as a function of whether they occurred in the S_1-S_2 or S_2-S_1 interval and as a function of whether they occurred in the first or third sec of the interval (10 μV=50 MM).

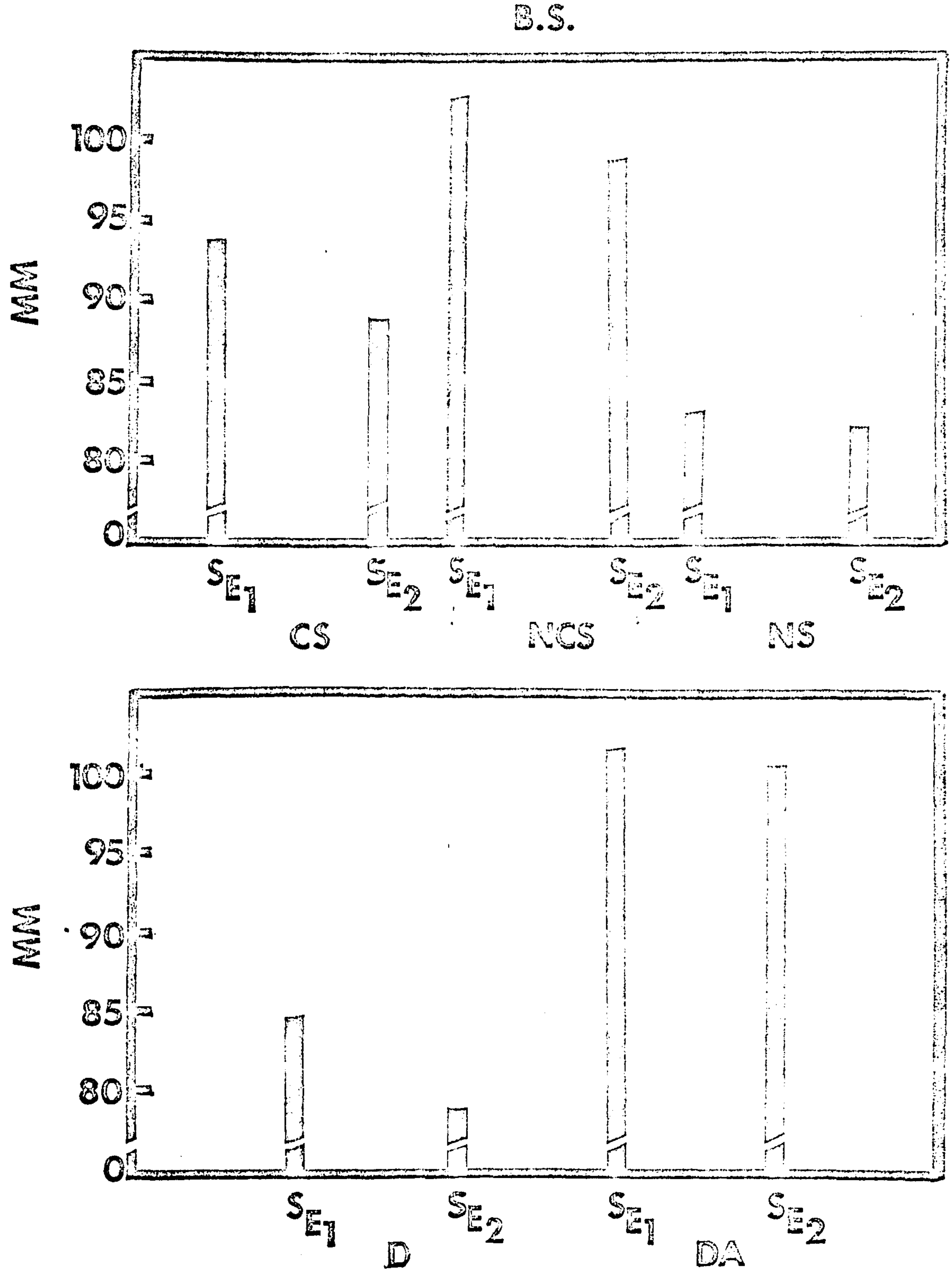


FIG. 23. Changes in the amplitude of the ECP to S_E in the S_1-S_2 and S_2-S_1 intervals as a function of "arousal" and "attention" (10 μV= 50 MM).

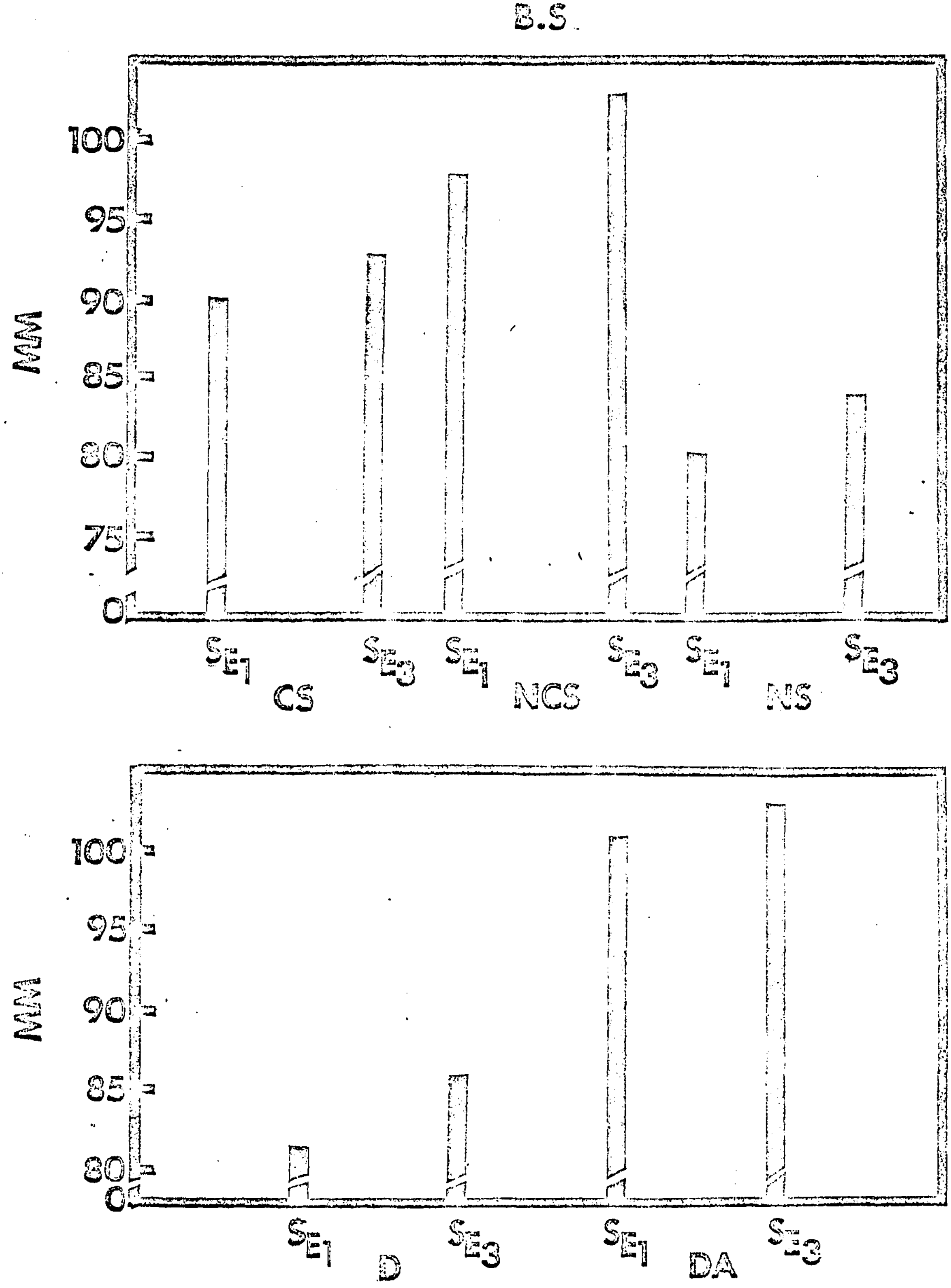


FIG. 24. Changes in the amplitude of the ECP to S_E occurring in the first and third sec as a function of "arousal" and "attention (10 μV= 50 MM).

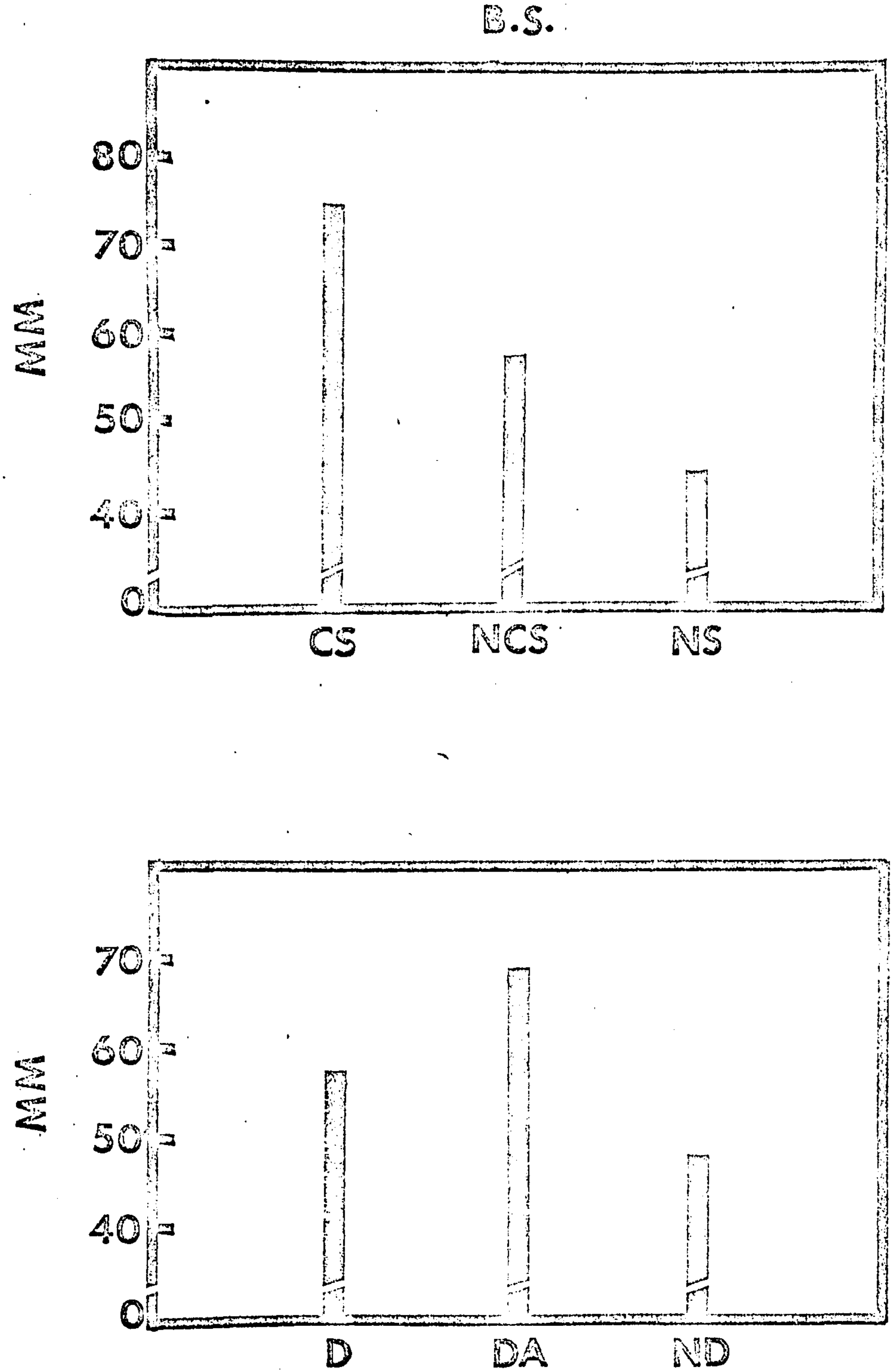


FIG. 25. Mean changes in HR averaged across each 6-sec interval as a function of "arousal" and shifts in "attention" (10 BPM 60 MM).

findings are clearly shown in Figure 26 in which the mean changes in RT as a function of "arousal" and "attention" are plotted. Shock threat significantly decreased RT performance by approximately 65 msec over the no shock condition. The "attentional" effect is also pronounced. Shifting "attention" away from S_2 and toward S_E lengthened reaction time performance by approximately 65 msec. The interaction effect of these two variables approached significance.

<u>Subject</u> <u>S</u>.<u>S</u>.

<u>Variance analyses on the ECP</u>. Changes in the amplitude of the ECPs to both S_2 and S_E were found to be significantly influenced by variations in "arousal" level ($p<.01$) and shifts in "attention" ($p<.01$). There was also a significant interaction effect between these major variables ($p<.05$) for the ECPs to both S_2 and S_E. No significant 6-sec interval effect on the amplitude of the ECP to S_E was found. These findings are graphically illustrated in Figures 27 through 34.

Figure 27 shows the mean amplitude of the ECP to S_2 as a function of changes in "arousal" and "attention". It is immediately apparent that the amplitude of the ECP shows greater enhancement under the shock threat situation. The changes in the amplitude of the ECP due to shifts in "attention" are also dramatically demonstrated in Figure 27. In the distraction condition where <u>S</u> is told to ignore S_E, the ECP to S_2 is essentially of the same magnitude as that obtained in the no distraction condition. However, when <u>S</u> was required to count S_E while also responding to S_2, the amplitude of the ECP to S_2 was significantly reduced.

Figure 28 contains the means for the ECPs elicited by S_E under the three levels of "arousal" and two levels of "attention". This

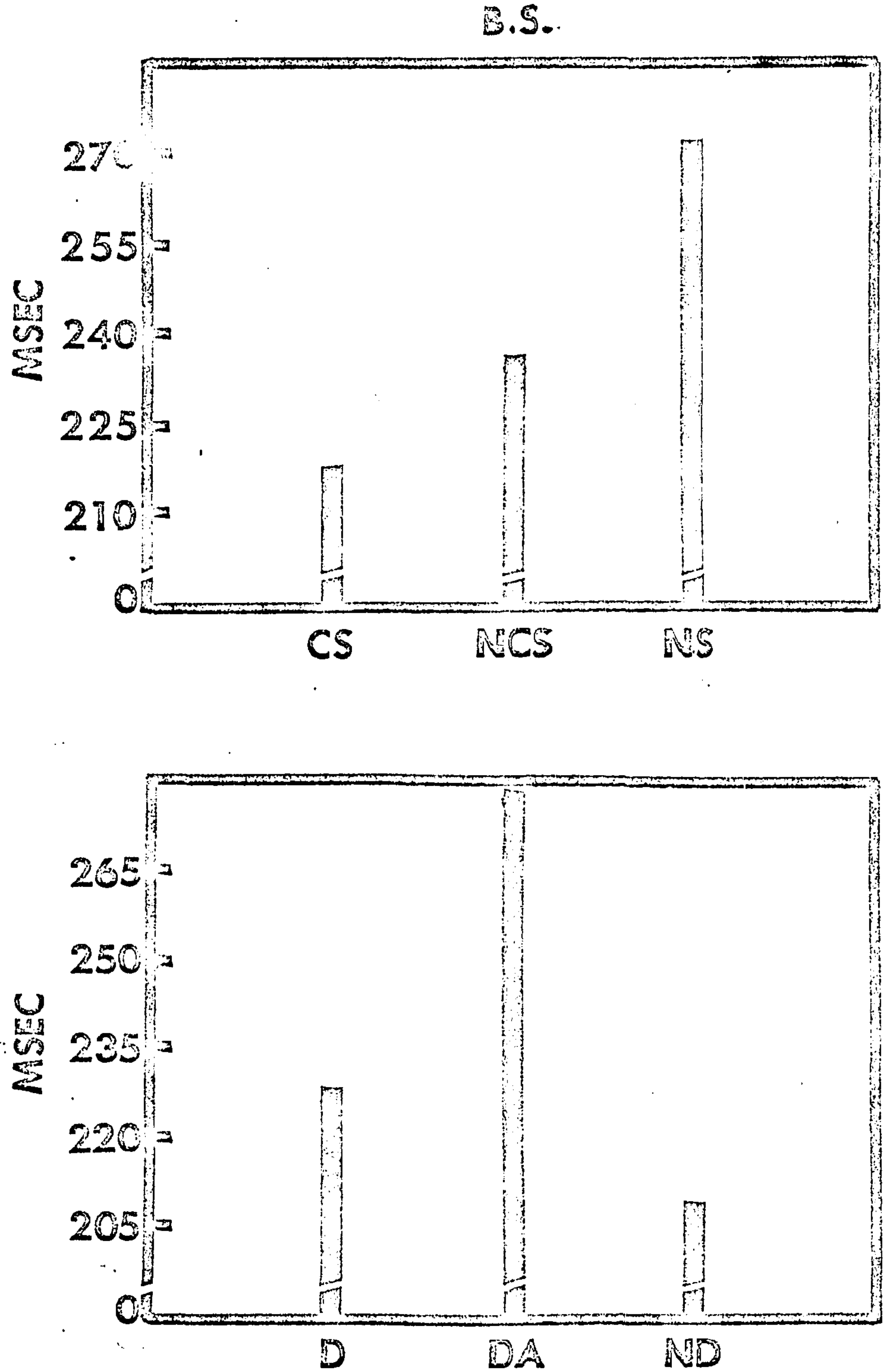


FIG. 26. Changes in RT as a function of "arousal" and shifts in "attention".

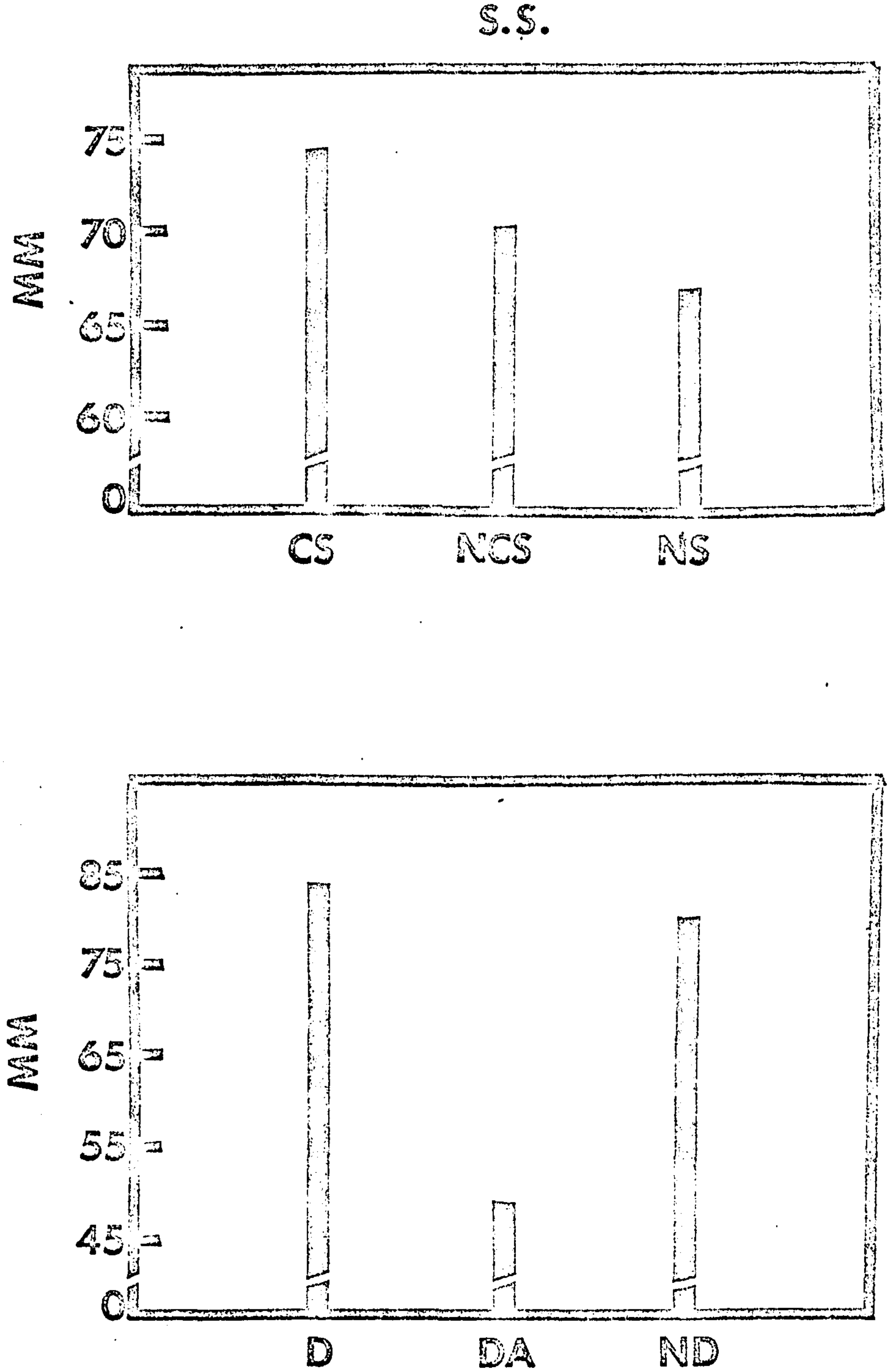
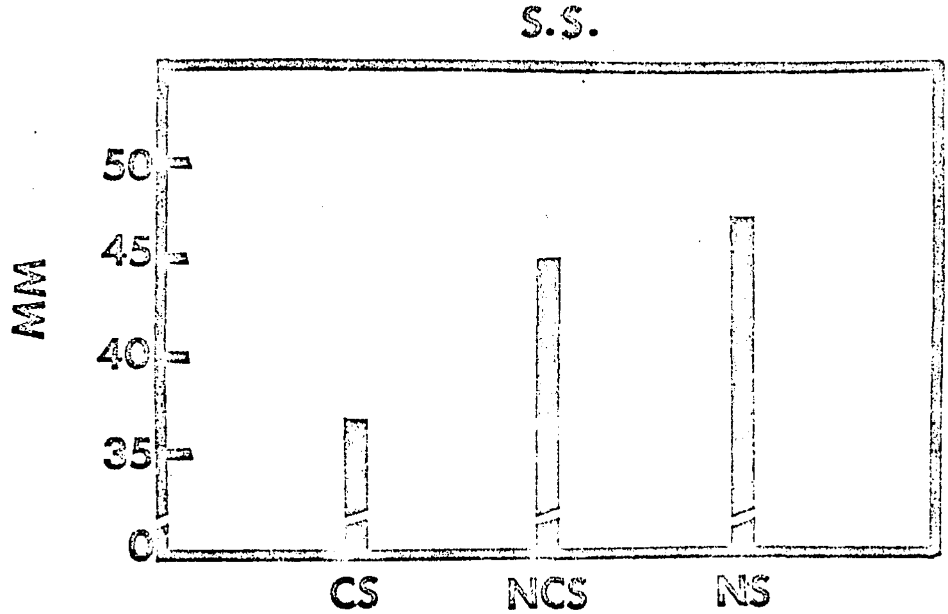


FIG. 27. Effects of "arousal" and "attention" on the amplitude of the ECP to S_2 (10 μV=50 MM).



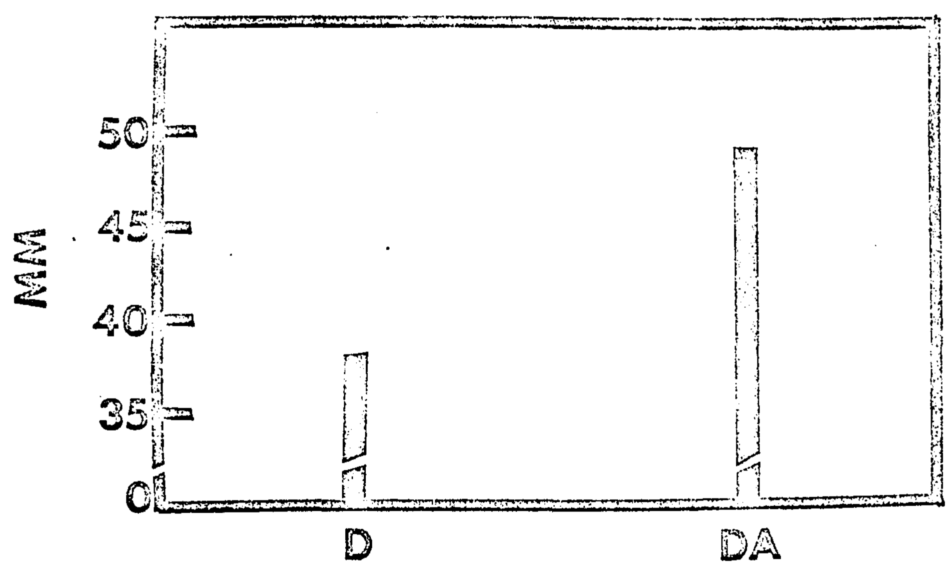


FIG. 28. Effects of "arousal" and "attention" on the amplitude of the ECP to S_E (10 μV=50 MM).

figure reflects clearly what happens to the ECP amplitude to S_E as "attention" is shifted from S_2 to S_E; there is a significant enhancement of the amplitude of the ECP to S_E. The effect of "arousal" is also illustrated. The ECP to S_E is smallest in amplitude in the contingent shock condition and largest in the no shock condition. This effect is understandable in light of the significant interaction between "arousal" and "attention" ($p < .05$) which suggests that the extent to which S was attending to S_E was dependent upon the presence or absence of shock.

Figure 29 reflects the relationship of the ECPs to S_2 and S_E as a function of "arousal" and "attention". Plotted in this figure are the means for the amplitude of the ECPs to S_E in the S_1-S_2 and S_2-S_1 intervals and the mean of the ECP to S_2. Essentially, this figure summarizes graphically the results of the previous two figures.

Figure 30 illustrates the mean changes in the amplitude of the ECPs to S_E as a function of whether they occurred in the S_1-S_2 interval, S_2-S_1 interval, and as a function of whether they occurred in the first or third sec of the interval. Figures 31 and 32 reflect the interaction of these effects with "arousal" and "attention". As noted previously, however, there was no significant tendency for the ECP to be larger or smaller in the S_1-S_2 or S_2-S_1 interval or for ECPs occurring in the third sec to be significantly different from those in the first sec.

Variance analysis on HR. Changes in HR were found to be significantly dependent upon "arousal" level ($p < .01$). This finding is clearly shown in Figure 33 in which the mean changes in HR across a 6-sec interval as a function of "arousal" and "attention" are plotted. The HR change is greatest under those conditions in which shock is present.

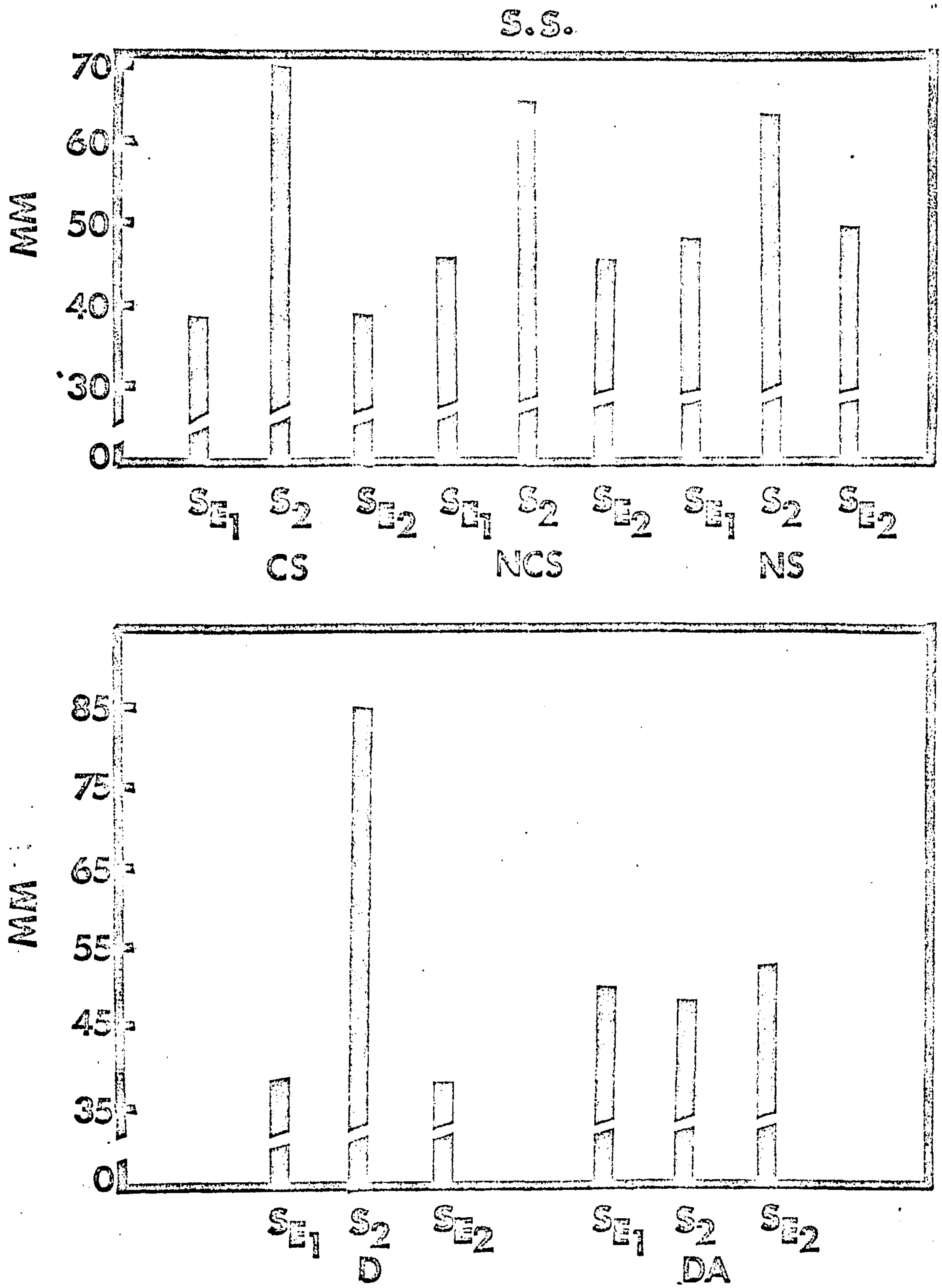


FIG. 29. Effects of "arousal" and "attention" on the amplitude of the ECP to S_2 and S_E (10 μV=50 MM).

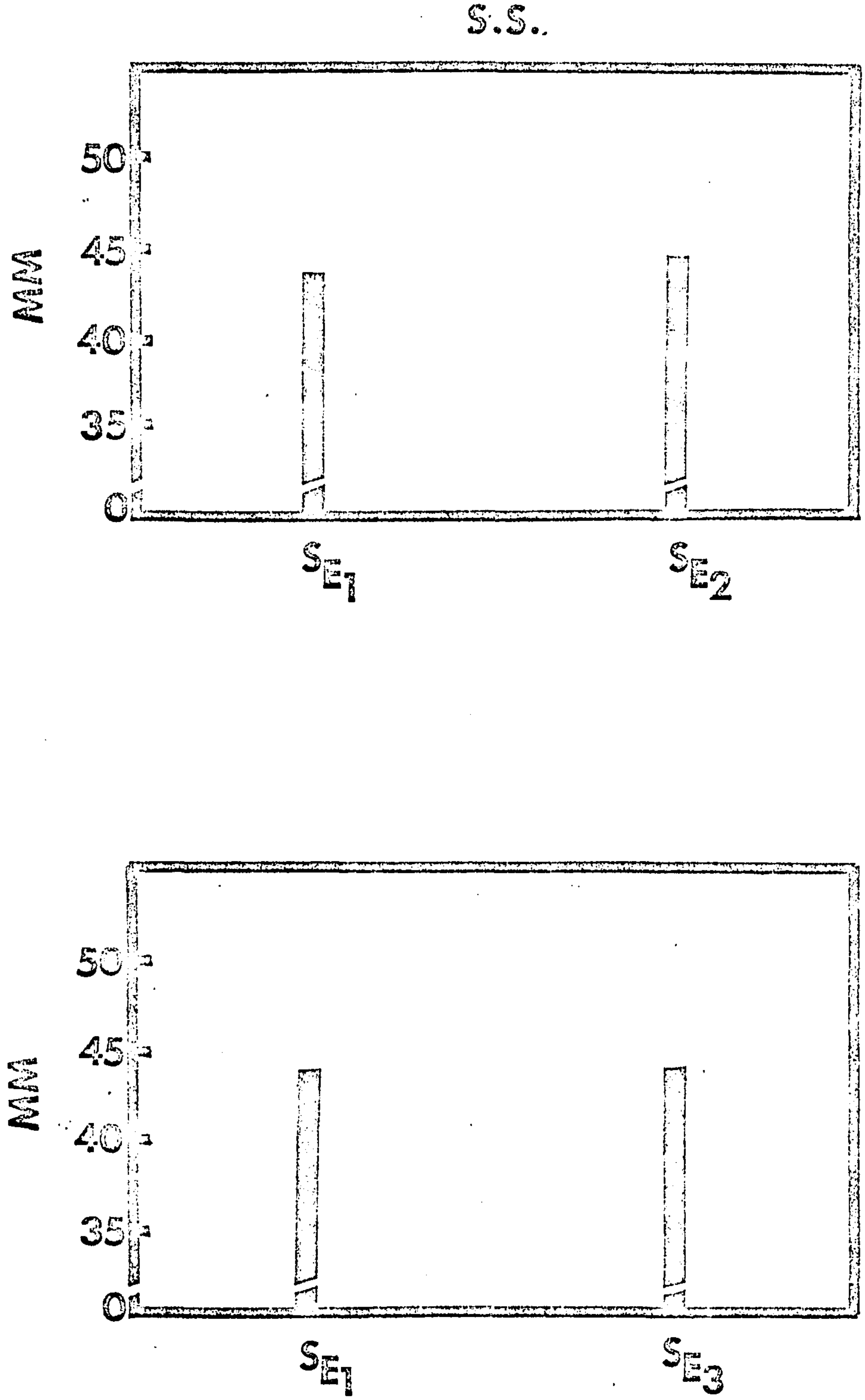


FIG. 30. Changes in the amplitude of the ECPs to S_E as a function of whether they occurred in the S_1-S_2 or S_2-S_1 interval and as a function of whether they occurred in the first or third sec of the interval (10 μV=50 MM).

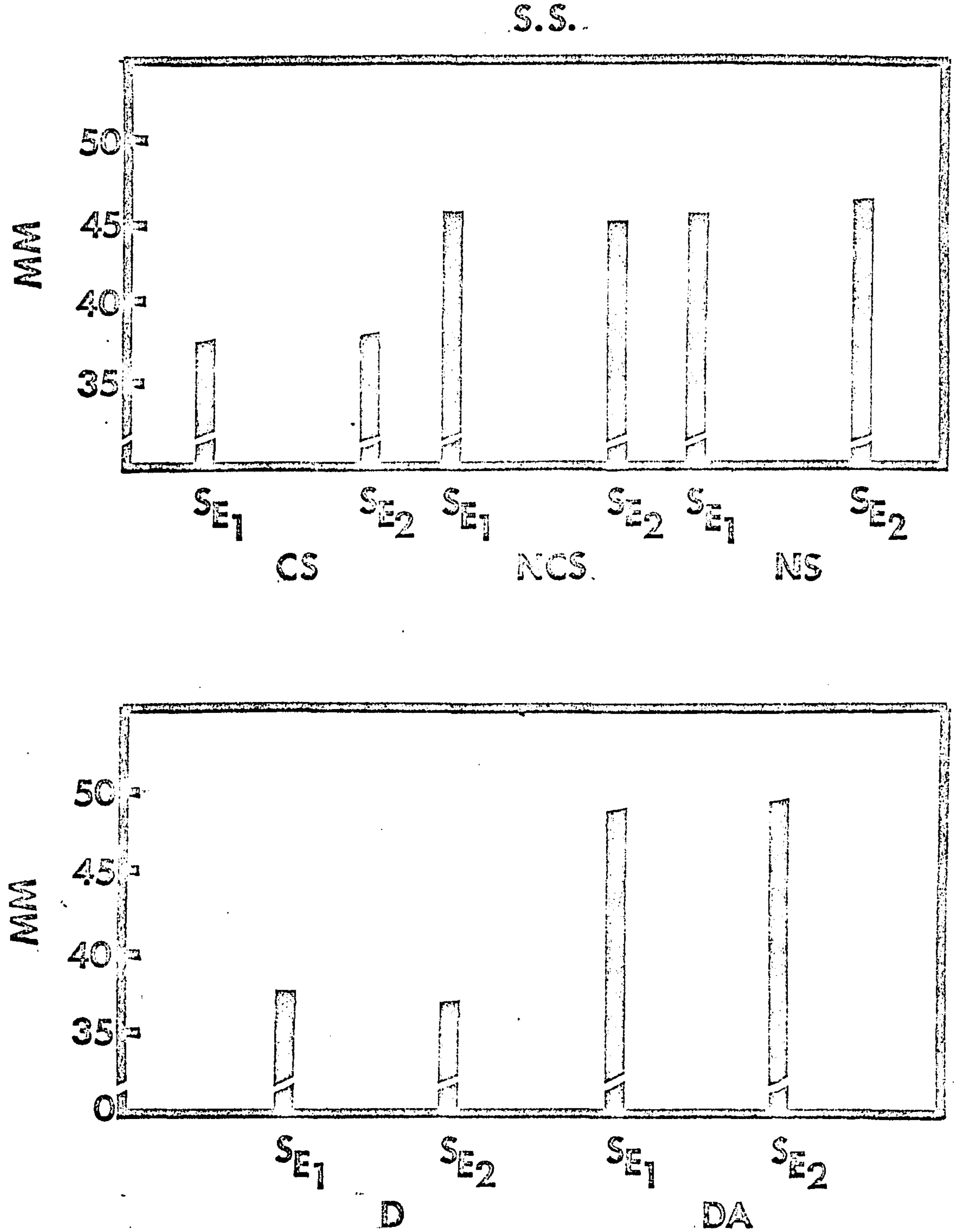


FIG. 31. Changes in the amplitude of the ECP to S_E in the S_1-S_2 and S_2-S_1 intervals as a function of "arousal" and "attention" (10 μV = 50 MM).

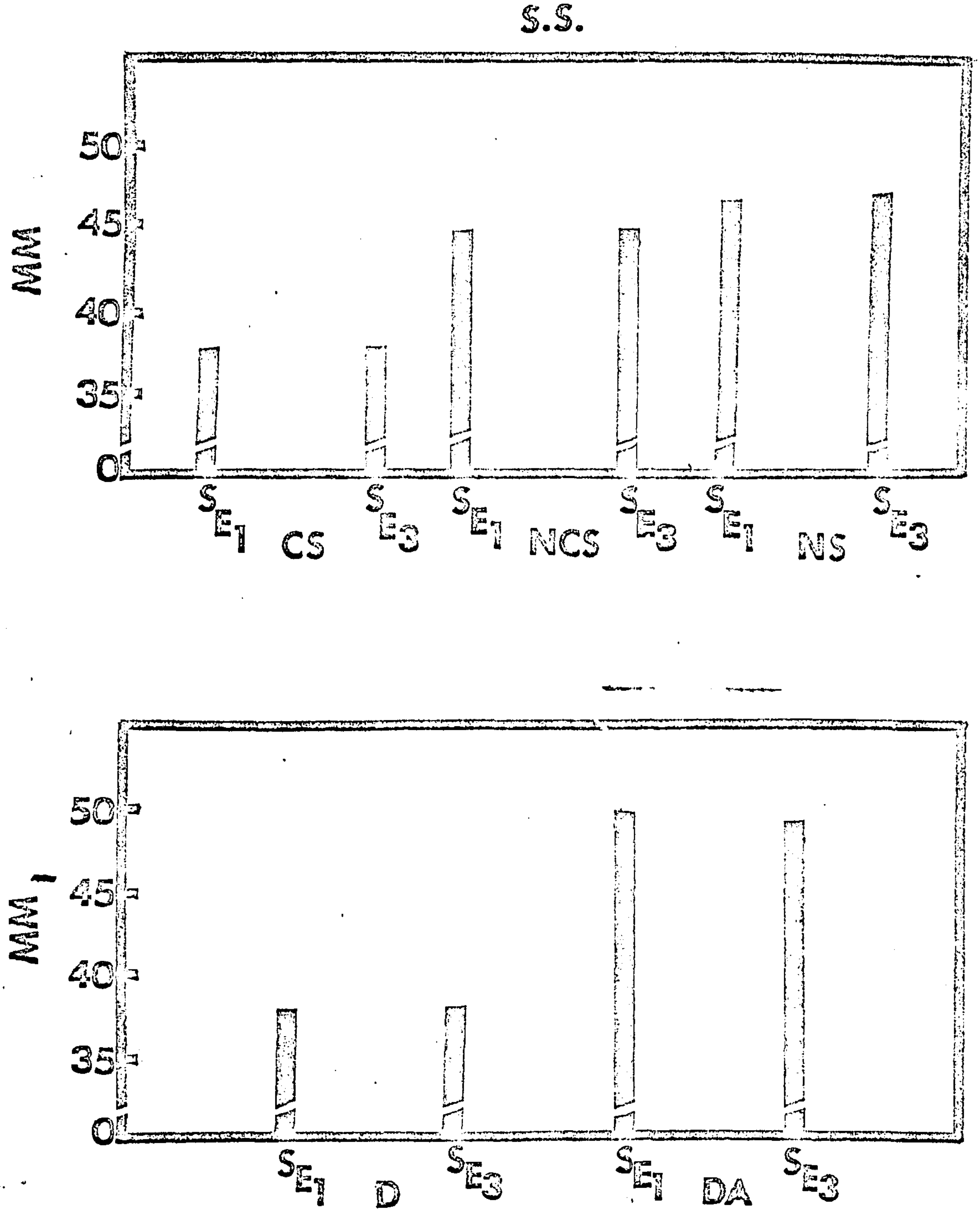


FIG. 32. Changes in the amplitude of the ECP to S_E occurring in the first and third sec as a function of "arousal" and "attention" (10 μV = 50 MM).

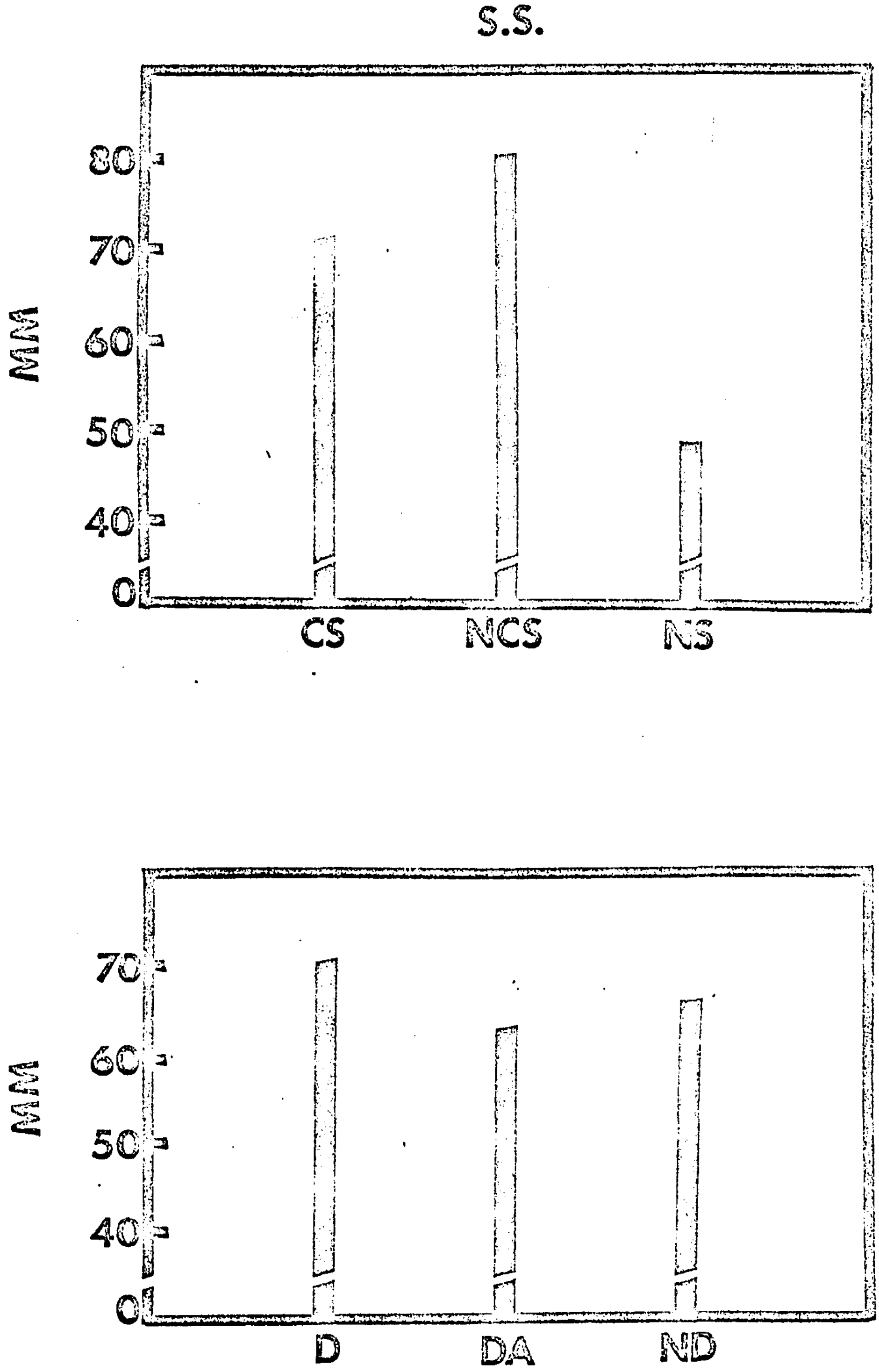


FIG. 33. Mean changes in HR averaged across each 6-sec interval as a function of "arousal" and shifts in "attention" (10 BPM=60 MM).

Changes in HR were not found to be significantly influenced by shifts in "attention". The interaction of "Arousal" X "Attention" was significant ($p < .05$) and suggests that how attentive S was to the stimulus was dependent upon the "arousal" condition in which she was performing.

Variance analysis on RT. The significant decrease in RT as a function of "arousal" ($p < .01$) is illustrated in Figure 34. Performance under contingent shock was more efficient, i.e., RTs were 40 msec shorter. The significant effect of "attention" on RT performance ($p < .01$) is also illustrated in this figure. In the divided attention condition RTs were approximately 80 to 90 msec longer than those obtained in the distraction and no distraction conditions. There was also a significant interaction effect between "arousal" and "attention" ($p < .05$).

Results of the Experimental Manipulations on CNV

The CNV data collected on the four Ss were not subjected to any type of statistical analysis. This decision was made after the visual inspection of the superimposed tracings of each S's data for each of the experimental conditions had been closely examined. The extreme variability within each S's data made it appear highly unlikely that there were any systematic effects on the CNV due to the major experimental variables. The reasons for this variability are unclear though several possibilities suggest themselves.

Most investigators have recorded CNVs with a relatively short (0.5-2.0 sec) and fixed time interval between warning and response signals. In the present study the time interval between S_1 and S_2 varied randomly from 2 to 3 sec. Hence, it is possible that this variability in the time relationship upset the expectancy paradigm.

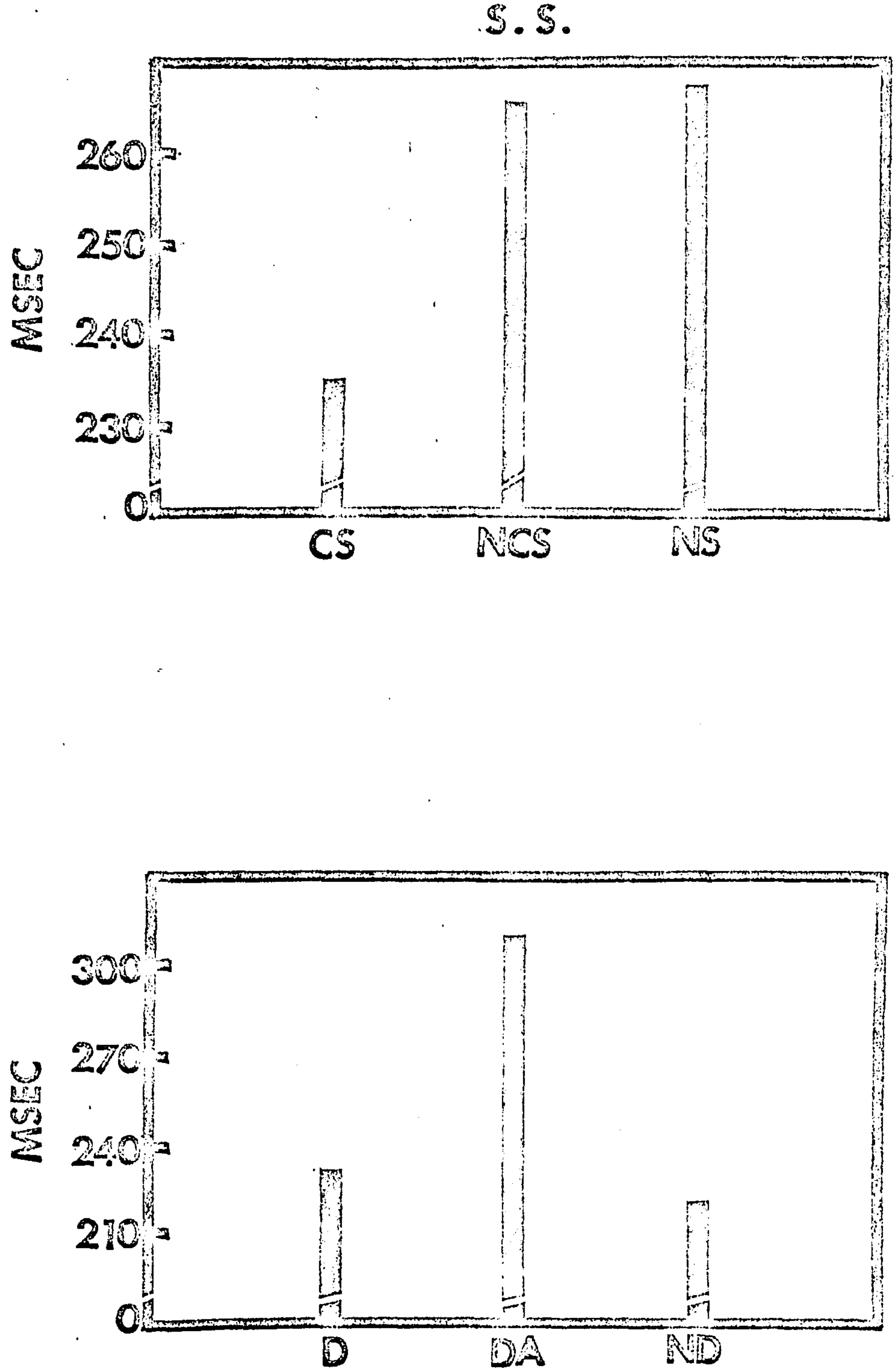


FIG. 34. Changes in RT as a function of "arousal" and shifts in "attention".

A second possible explanation of the lack of any CNV effects involves the consideration of ocular artifacts. In many instances, regardless of the experimental condition, the slow potential shifts recorded from the Ss were positive rather than negative. Even though the Ss were told to fixate a point in the center of the screen at all times, it is possible that eye movements introduced variability into the CNV.

General Summary of the Results

ECP data. The amplitude of the ECP to S_2 for all four Ss was found to be significantly affected by experimental manipulations of "arousal" level and "attention". For all Ss the presence of shock had the effect of significantly increasing the amplitude of the ECP to S_2 over the no shock condition. Manipulation of the "attention" variable also exhibited a significant effect on the amplitude of the ECP for all Ss. For three of the Ss the amplitude of the ECP to S_2 was significantly attenuated when additional stimuli were introduced into the situation, regardless of whether S had been instructed to ignore them or count them. A significant interaction between "arousal" and "attention" was found for two of the four Ss.

The amplitude of the ECP to S_E was also found to be significantly influenced by alterations in "arousal" level, although the direction of this influence was variable across Ss. For example, two Ss showed a greater enhancement of ECP amplitude in the presence of shock than in its absence, while just the opposite was true for the remaining two Ss. Experimental manipulation of the "attention" variable had a significant effect on the amplitude of the ECP to S_E for three of the Ss.

The ECP was smallest under the distraction condition when S_E were being ignored and largest in the divided attention condition in which the stimuli were counted. For these Ss there was also a significant "Arousal" X "Attention" interaction effect. Two of the four Ss showed ECPs to the S_E occurring in the S_1-S_2 interval to be significantly enhanced over those occurring in the S_2-S_1 interval. However, the ECPs to S_E in the first sec were found to be larger than those occurring in the third sec.

HR data. The changes in HR were found to be significantly dependent upon variations in "arousal" level for all Ss. Without exception the greatest HR change occurred in the presence of shock. For two of the four Ss manipulations of the "attentional" state exerted a significant influence on changes in HR. That is, HR change was greatest in the divided attention condition and least in the no distraction condition.

RT data. All Ss showed a significant change in their RT performance as a function of variations in "arousal" level and "attention". The RTs were shortest under shock threat and longest in the absence of shock. When Ss were responding to S_2 with no S_E present, RTs were shortest; conversely, when Ss were required to respond to S_2 as well as count S_E, RTs were considerably lengthened.

Discussion

Effects of Arousal on the ECP

Numerous studies have demonstrated the relationship of the ECP, as a gross measure of cortical activity, to level of arousal. In general, the amplitude of the ECP has been found to increase with an increase in arousal level (Eason, Aiken, & White, 1964; Garcia-Austt, 1963;

Haider, Spong, & Lindsley, 1964). The present findings are consistent with those cited above. The amplitude of the ECP to S_2 under shock threat was significantly greater than that obtained under no shock. Similar results were obtained by Eason and Dudley (1971). The effect of arousal per se (noncontingent shock) on the amplitude of the ECP was variable across Ss. Generally, its effect was sufficient to enhance the amplitude of the ECP and decrease RT over the no shock situation. However, for one subject the presence of intermittent shock was clearly no more efficient than its absence in enhancing ECP amplitude or in improving performance.

For all subjects performance was more efficient under shock threat than in its absence. This relationship between shorter RTs and larger ECP amplitudes as a function of the alertness of the S has been noted by many investigators (Donchin & Lindsley, 1966; Eason & Dudley, 1971; Eason, Harter, & White, 1969; Groves & Eason, 1969; Lansing, Schwartz, & Lindsley, 1959). The results of the present study in general support the conclusion arrived at by Groves and Eason (1969) that the attentional aspect of avoidable shock exerts a predominant influence in increasing the amplitude of the ECP.

The arousal variable also had a significant influence on the amplitude of the ECP to S_E, but the direction of this influence varied across Ss. The striking variability among individuals can be understood only by considering the interindividual variability in the ability to resist distraction and/or to "attend to" two things at once. The significant interaction effects between the arousal and attention variables suggest that the degree to which the amplitude of the ECP to S_E was affected by arousal level was dependent upon the extent to which S was attending to the stimulus. Changes in both general arousal and specific attention must be taken into consideration.

Effects of Shifts in Attention on ECP

It has been previously shown (Eason et al., 1969) that when S is told to respond rapidly to flashes appearing in one visual field while ignoring those appearing in the other, much larger ECPs are obtained for the relevant than for the irrelevant stimuli. The results of the present investigation are consistent with the above finding. The data clearly indicate that shifts in attention toward and away from S_2 markedly affected the amplitude of the ECP to S_2. Depending on the direction of the shift, an enhancement or attenuation of the ECP was found. For example, when no distraction was present in the experimental situation and Ss were focusing only on S_2, the magnitude of the ECP was greatly enhanced relative to that obtained when distraction was present.

The effects of distraction on the amplitude of the ECP to S_2 varied according to each S's ability to focus attention on S_2 and/or ignore the distracting stimulus. Subject S.S. was particularly adept at this task. When she was instructed to ignore S_E, the ECP to S_2 was essentially of the same magnitude as in the condition in which S_E were not present. In addition, behavioral performance was approximately equivalent under both conditions. However, in the divided attention condition in which she was required not only to respond to S_2 but also to count S_E, the amplitude of the ECP to S_2 was significantly reduced while the ECP to S_E was significantly enhanced.

This S's data strongly support the position that the amplitude of the ECP elicited by a stimulus when it is attended to is greater than the ECP to an unattended stimulus in the same modality. It is highly unlikely, as argued by Jane (1962), that the differences in the amplitude of the ECPs could be attributed to generalized changes in the alertness of the S since in the same condition an attenuated response is obtained to one of the stimuli, an enhanced response to the other. This interpretation is further supported by the absence of a significant within-6-sec-interval effect on the amplitude of the ECP to S_E.

The data for the remaining three Ss are not as clear-cut as those previously discussed, apparently due to the inability of these Ss to resist distraction. Their data, nevertheless, are generally supportive of the ECP-attention relationship previously discussed. These results are similar to those reported by Donchin and Cohen (1967), Eason et al. (1969), Garcia-Austt et al. (1963), Jane et al. (1962), and Spong et al. (1965).

Within-6-Sec-Interval Effects on the ECP

Näätänen (1967) has provided some support for the position that when relevant and irrelevant stimuli are alternated in a regular manner, the enhancement of the ECP to the relevant stimuli may occur as a result of differential preparatory states rather than differential stimulus significance. Näätänen (1967) cites his study in which irrelevant clicks were presented between an S_1-S_2 interval as well as outside of this interval. His findings indicated that the ECPs to the inside clicks were greater than those to outside clicks, and concluded that general alertness could enhance the ECP to stimuli not attended. An experimental paradigm similar to Näätänen's was used in the present investigation in order to study further the implications of Näätänen's findings. Extraneous flashes occurred within the S_1-S_2 interval as well as outside of it; these stimuli functioned in a manner analogous to Näätänen's inside and outside clicks. The findings in the present study support in part those reported by Näätänen (1967). Two subjects showed a significant tendency for the ECPs occurring in the S_1-S_2 interval to be enhanced over those occurring in the S_2-S_1 interval. Nevertheless, if Näätänen's hypothesized state of generalized arousal is the crucial factor in ECP enhancement, one might expect that as the S_E moved closer in time to S_2, the ECPs to these would be more enhanced relative to those occurring earlier in the interval. However, in the present study the ECPs occurring to stimuli in the first sec were larger than those occurring to the third sec. Thus, although there are some findings in the present investigation consistent with Näätänen's, the inconsistencies are sufficiently great to warrant the alternative interpretation that changes in the amplitude of the ECP reflect more than variations in nonspecific arousal.

Effects of Arousal and Attention on HR

Considerable research has yielded inconsistencies in the direction of HR changes with conflicting interpretations as to the role of these changes. Probably the two most opposing points of view are represented by activation theory and Lacey's hypothesis of directional fractionation of autonomic responses. Under some circumstances, HR shows a deceleration that is paradoxical because it is accompanied by an increase in skin conductance (SC). Lacey (1959, 1963, 1967) has hypothesized that his directional fractionation of autonomic responses is associated with or related to attention to environmental inputs. Based on his findings of bidirectional changes in HR, Lacey has argued that HR, as well as SC, should never be used an an indicant of general arousal level, since he has shown the two to vary independently of one another. On the other hand, a number of studies have provided support for an activation theory interpretation of the autonomic response data. For example, Campos and Johnson (1966, 1967) report several studies in which an attempt was made to replicate Lacey's (1959, 1963) findings of directional fractionation of autonomic responses under attention to the environment conditions. The trend of the results, however, indicated that HR and SC tended to change in the same direction, whether in response to attention to the environment or in rejection of it. A recent study by Eason and Dudley (1971) also suggests an activation theory interpretation of the data; HR was found to be significantly affected by activation level and changed in a like manner with changes in SC, MT, and the ECP, even in the presence of dissociative physiological activity.

In the present investigation systematic changes in HR were found for all Ss. In the S_1-S_2 interval HR began to decrease approximately one sec prior to the onset of S_2, continued to decrease for about one sec following the onset of S_2, and then accelerated for the remainder of the S_2-S_1 interval until it reached its initial rate at the onset of S_1. Moreoever, for each S the magnitude of the change in HR across the 6-sec interval was found to be significantly dependent upon level of arousal. That is, changes in HR were greatest when shock threat was present and smallest in the absence of any shock threat. When S was required to sit passively and watch the light flashes, changes in HR for all Ss reflected only random fluctuations.

There was some support in the present investigation for the argument that shifts in attention are associated with changes in HR. For two Ss the magnitude of the change in HR was greatest under those conditions in which distraction was present. For these Ss there was also a significant interaction effect between arousal level and attention; this suggests that the extent to which S was attending to the stimulus was dependent upon the presence or absence of shock.

One can readily account for the obtained HR data by reference to an approach based on activation theory. A motor set explanation would be consistent with the contentions of Duffy (1962) since preparation for a response or the actual making of the response itself requires the expenditure of energy. Such an explanation suggests, however, that the influence which processes such as arousal (emotion, motivation) have on HR is mediated to some extent via the effect these processes have on somatic-motor activity (Obrist & Webb, 1967).

Interrelationships Between the Dependent Variables

Manipulations of the arousal dimension were reflected across all the dependent variables and in the same direction for two Ss. That is, the amplitude of the ECP to both S_2 and S_E was largest in the shock situation, HR change was greatest, and RTs were shortest. In addition, there were also changes across the dependent variables due to shifts in attention for three of the Ss. For example, when Ss had to count

S_E as well as react to S_2, the amplitude of the ECP to S_2 was smallest, RTs were longest, and the amplitude of the ECP to S_E was greatly enhanced. However, for one S there was some indication that shifting attention from one stimulus to two also resulted in changes in arousal level. That is, increases in the amplitude of the ECP to S_E and S_2 were obtained under the divided attention condition; changes in HR were also greatest under this condition. These data suggest the presence of an arousal influence in addition to the manipulation of attentional processes.

There was some indication of the confounding of arousal and attentional processes when shifting from contingent to noncontingent shock in two of the Ss data. For example, under contingent shock the amplitude of the ECP to S_2 was larger than that obtained in the noncontingent or no shock situation; however, the amplitude of the ECP to S_E was as small under contingent as noncontingent shock, while considerable enhancement occurred in the no shock condition. These data suggest that selective attention was exerting a more pronounced influence (than arousal) on changes in the ECP since those to S_2 were enhanced while those to S_E were reduced under contingent shock. The changes in HR and RTs reflect at an autonomic and behavioral level the changes occurring in the amplitude of the ECP to S_2, i.e., HR changes were greatest under contingent shock and RTs were shortest.

In general the changes across the dependent variables reflect both the separate and combined influences of arousal and attention. When these two variables were confounded, however, the effect of selective attention appeared more pronounced.

<u>Interindividual variability</u>. A recurring trend particularly in the ECP data was the marked interindividual variability. It is important then to consider what individual difference factors relating to attention might also relate to the ECP. The striking variability among Ss raises an issue that some individuals may be better able to focus their attention to ECP stimuli or resist distraction better than others. In fact Walter (1954) has suggested that distraction is one of the most personal characteristics of the human brain. It also seems probable that there are true differences between individuals in the ease or extent of arousal in the same situation; this latter factor might also be influential in determining the degree of distractibility experienced by an individual. Thus, some of the discrepant findings in arousal and attention studies may be due to a failure to consider interindividual factors which in themselves may constitute an important source of variation.

Summary

There were several problems under investigation in the present study. The first was related to the effects of experimental manipulations of arousal level and states of attention on the amplitude of the ECP to S_2. A secondary aspect of this problem was the examination of the implications of Näätänen's findings regarding the enhancement of the ECP to unattended stimuli as a consequence of changes in nonspecific arousal. The second problem was focused on the nature of the relationship of autonomic response patterns (specifically changes in HR) to changes in arousal and shifts in attention. A third problem under investigation was the effect of changes in the major variables, arousal and attention, on the CNV.

Changes in arousal level were experimentally induced by requiring S to make a reaction time response to S_2 under conditions of contingent, noncontingent, and no shock. The attentional state was varied by requiring S to attend to S_2 only, to attend to S_2 while ignoring S_E, and to attend to S_2 while also counting S_E. The ECPs to both S_2 and S_E, CNV, HR, and RT were recorded simultaneously for each of four Ss under the nine experimental conditions generated by these major independent variables.

The results indicated that the experimentally induced changes in arousal level clearly affected the amplitude of the ECP to S_2 for all Ss ($p < .01$). The presence of shock had an enhancing effect on the amplitude of the ECP to S_2. Shifts in attention had a significant attenuating effect ($p < .01$) on the amplitude of the ECP to S_2. There was a significant within-6-sec-interval effect ($p < .05$) on the amplitude of the ECP to S_E for two of the four Ss.

The findings also showed that behavioral performance was significantly affected by the experimental manipulations in arousal and attention ($p < .01$) and in the same direction as the ECP data. The changes in HR for all Ss were found to be significantly dependent upon arousal level ($p < .01$) and for two Ss upon shifts in attention ($p < .05$). No statistical analyses were performed on the CNV data due to the extreme variability within each S's data. Visual inspection of the superimposed tracings of the CNVs suggested the absence of any systematic effects due to the experimental manipulations in arousal level and attention.

Conclusions. The trend of the results favors a selective attention interpretation of changes in the amplitude of the ECP to S_2.

Nevertheless, there were significant effects on the amplitude of the ECP to S_E as a function of whether they occurred in the interval prior to S_2 or immediately following. This lends some support to Näätänen's contention that the amplitude of the ECP to unattended stimuli may be enhanced by non-specific arousal. However, ECPs occurring to S_E in the third sec of the interval were found to be smaller than those occurring in the first sec. The reverse finding would be expected if a state of generalized arousal were the crucial factor in ECP enhancement. Also, the fact that one S showed no significant within-interval effect on the ECPs to S_E argues strongly for an interpretation of ECP changes which attributes enhancement to factors other than variation in non-specific arousal. The HR data support an interpretation based on activation theory.

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Appendix

TABLE 1

VARIANCE ANALYSIS SUMMARY FOR ECP TO S_2

SUBJECT L.S.

Source of Variation	df	MS	ET	F
I. Between Columns	8	3.1		
A. Activation Level	2	6.9	III	7.7**
B. Attention	2	3.3	III	3.7*
C. A X B	4	1.1	III	1.2
II. Replications	3	8.5	III	9.4**
III. Rows X Columns	24	0.9		
A. I_A X II	6	1.2		——
B. I_B X II	6	0.3		——
C. I_C X II	12	1.2		——
Total	35	2.1		

*$p < .05$.

**$p < .01$.

TABLE 2

VARIANCE ANALYSIS SUMMARY FOR ECP TO S_E

SUBJECT L.S.

Source of Variation	df	MS	ET	F
I. Between Columns	23	1.5		
A. Activation Level	2	7.3	III	21.9**
B. Attention	1	0.9	III	2.7
C. Within-6-Sec-Interval	3	0.9	III	2.9*
D. A X B	2	3.8	III	11.5**
E. A X C	6	0.5	III	1.6
F. B X C	3	1.1	III	3.3*
G. A X B X C	6	0.3	III	0.9
II. Replications	3	8.1	III	24.4**
III. Rows X Columns	69	0.3		
A. I_A X II	6	0.5		____
B. I_B X II	3	1.6		____
C. I_C X II	9	0.3		____
D. I_D X II	6	0.6		____
E. I_E X II	18	0.2		____
F. I_F X II	9	0.5		____
G. I_G X II	18	0.6		____
Total	95	0.9		

*$p < .05$.

**$p < .01$.

TABLE 3

VARIANCE ANALYSIS SUMMARY FOR HR

SUBJECT L.S.

Source of Variation	df	MS	ET	F
I. Between Columns	17	14.2		
A. Activation Level	2	60.6	III	8.3**
B. Attention	2	1.6	III	___
C. Within-6-Sec Interval	1	35.9	III	4.9*
D. A X B	4	14.8	III	2.0
E. A X C	2	4.8	III	___
F. B X C	2	0.9	III	___
G. A X B X C	4	2.5	III	___
II. Replications	1	79.8	III	10.9**
III. Rows X Columns	17	7.3		
A. I_A X II	2	11.8		___
B. I_B X II	2	8.5		___
C. I_C X II	1	0.8		___
D. I_D X II	4	2.2		___
E. I_E X II	2	2.1		___
F. I_F X II	2	6.6		___
G. I_G X II	4	13.9		___
Total	35			

*$p < .05$.

**$p < .05$.

TABLE 4

VARIANCE ANALYSIS SUMMARY FOR RT

SUBJECT L.S.

Source of Variation	df	MS	ET	F
I. Between Columns	8	2904.9		
A. Activation Level	2	5766.2	III	19.5**
B. Attention	2	5009.5	III	16.7**
C. A X B	4	422.0	III	1.4
II. Replications	3	249.6	III	0.8
III. Rows X Columns	24	295.2		
A. I_A X II	6	254.2		———
B. I_B X II	6	473.9		———
C. I_C X II	12	227.2		———
Total	35	887.8		

*$p < .05$.

**$p < .01$.

TABLE 5

VARIANCE ANALYSIS SUMMARY FOR ECP TO S_2

SUBJECT S.H.

Source of Variation	df	MS	ET	F
I. Between Columns	8	3.2		
A. Activation Level	2	7.8	III	33.8**
B. Attention	2	3.2	III	14.1**
C. A X B	4	0.9	III	3.8*
II. Replications	3	0.4	III	1.6
III. Rows X Columns	24	0.2		
A. I_A X II	6	0.5		——
B. I_B X II	6	0.2		——
C. I_C X II	12	0.1		
Total	35	0.9		

*$p<.05$.

**$p<.01$.

TABLE 6

VARIANCE ANALYSIS SUMMARY FOR ECP TO S_E

SUBJECT S.H.

Source of Variation	df	MS	ET	F
I. Between Columns	23	0.8		
A. Activation Level	2	1.8	III	11.9**
B. Attention	1	4.1	III	27.3**
C. Within-6-Sec Interval	3	0.6	III	4.0*
D. A X B	2	2.6	III	17.6**
E. A X C	6	0.3	III	2.1
F. B X C	3	0.5	III	3.1
G. A X B X C	6	0.3	III	1.9
II. Replications	3	1.2	III	7.9**
III. Rows X Columns	69	0.2		
A. I_A X II	6	0.6		———
B. I_B X II	3	0.5		———
C. I_C X II	9	0.7		———
D. I_D X II	6	0.5		———
E. I_E X II	18	0.4		———
F. I_F X II	9	0.3		———
G. I_G X II	18	0.4		———
Total	95	0.3		

*$p < .05$.

**$p < .01$.

TABLE 7

VARIANCE ANALYSIS SUMMARY FOR HR

SUBJECT S.H.

Source of Variation	df	MS	ET	F
I. Between Columns	17	4.9		
A. Activation Level	2	17.4	III	40.6**
B. Attention	2	4.2	III	9.8**
C. Within-6-Sec Interval	1	27.3	III	63.4**
D. A X B	4	1.2	III	2.8*
E. A X C	2	0.4	III	1.1
F. B X C	2	2.1	III	5.0*
G. A X B X C	4	0.5	III	1.2
II. Replications	2	10.4	III	24.3**
III. Rows X Columns	34	0.4		
A. I_A X II	4	0.6		———
B. I_B X II	4	0.4		———
C. I_C X II	2	0.1		———
D. I_D X II	4	0.4		———
E. I_E X II	4	0.5		———
F. I_F X II	8	0.3		———
G. I_G X II	8	0.6		———
Total	53			

*p<.05.

**p<.01.

TABLE 8

VARIANCE ANALYSIS SUMMARY FOR RT

SUBJECT S.H.

Source of Variation	df	MS	ET	F
I. Between Columns	8	9270.3		
A. Activation Level	2	6427.3	III	12.6**
B. Attention	2	30023.8	III	58.9**
C. A X B	4	314.9	III	0.6
II. Replications	3	1008.1	III	1.9
III. Rows X Columns	24	509.8		
A. I_A X II	6	571.7		——
B. I_B X II	6	579.0		——
C. I_C X II	12	444.2		
Total	35	2554.9		

*$p<.05$.

**$p<.01$.

TABLE 9

VARIANCE ANALYSIS SUMMARY FOR ECP TO S_2

SUBJECT B.S.

Source of Variation	df	MS	ET	F
I. Between Columns	8	3.9		
A. Activation Level	2	14.4	III	4.4*
B. Attention	2	12.9	III	4.1*
C. A X B	4	0.2	III	——
II. Replications	3	9.1	III	2.9
III. Rows X Columns	24	3.2		
A. I_A X II	6	5.4		——
B. I_B X II	6	1.6		——
C. I_C X II	12	2.8		——
Total	35	3.8		

*$p<.05$.

**$p<.01$.

TABLE 10

VARIANCE ANALYSIS SUMMARY FOR ECP TO S_E

SUBJECT B.S.

Source of Variation	df	MS	ET	F
I. Between Columns	23	6.8		
A. Activation Level	2	9.9	III	3.7*
B. Attention	1	84.3	III	31.9**
C. Within-6-Sec Interval	3	3.2	III	1.2
D. A X B	2	2.7	III	1.0
E. A X C	6	0.2	III	____
F. B X C	3	0.7	III	____
G. A X B X C	6	0.6	III	____
II. Replications	3	14.8	III	5.6*
III. Rows X Columns	69	2.6		
A. I_A X II	6	12.1		____
B. I_B X II	3	6.4		____
C. I_C X II	9	0.9		____
D. I_D X II	6	0.9		____
E. I_E X II	18	1.1		____
F. I_F X II	9	0.6		____
G. I_G X II	18	0.4		____
Total	95			

*$p<.05$.

**$p<.01$.

TABLE 11

VARIANCE ANALYSIS SUMMARY FOR HR

SUBJECT B.S.

Source of Variation	df	MS	ET	F
I. Between Columns	17	14.2		
A. Activation Level	2	60.6	III	8.3**
B. Attention	2	1.6	III	____
C. Within-6-Sec Interval	1	35.9	III	4.9*
D. A X B	4	14.8	III	2.0
E. A X C	2	4.8	III	____
F. B X C	2	0.9	III	____
G. A X B X C	4	2.5	III	____
II. Replications	1	79.7	III	
III. Rows X Columns	17	7.3		
A. I_A X II	2	11.8		____
B. I_B X II	2	8.5		____
C. I_C X II	1	0.7		____
D. I_D X II	4	2.2		____
E. I_E X II	2	2.0		____
F. I_F X II	2	6.6		____
G. I_G X II	4	13.9		
Total	35			

*$p<.05$.

**$p<.01$.

TABLE 12

VARIANCE ANALYSIS SUMMARY FOR RT

SUBJECT B.S.

Source of Variation	df	MS	ET	F
I. Between Columns	8	4037.7		
A. Activation Level	2	3546.4	III	17.9**
B. Attention	2	11721.9	III	59.1**
C. A X B	4	441.2	III	2.2
II. Replications	3	1768.6	III	8.9**
III. Rows X Columns	24	198.2		
A. I_A X II	6	212.7		——
B. I_B X II	6	134.8		——
C. I_C X II	12	222.7		——
Total	35	1210.4		

*p<.05.

**p<.01.

TABLE 13

VARIANCE ANALYSIS SUMMARY FOR ECP TO S_2

SUBJECT S.S.

Source of Variation	df	MS	ET	F
I. Between Columns	8	3.0		
A. Activation Level	2	1.7	III	8.5**
B. Attention	2	8.4	III	42.0**
C. A X B	4	0.9	III	4.7*
II. Replications	3	3.9	III	19.8**
III. Rows X Columns	24	0.2		
A. I_A X II	6	0.1		———
B. I_B X II	6	0.2		———
C. I_C X II	12	0.3		
Total	35	3.4		

*p<.05.

**p<.01.

TABLE 14

VARIANCE ANALYSIS SUMMARY FOR ECP TO S_E

SUBJECT S.S.

Source of Variation	df	MS	ET	F
I. Between Columns	23	1.3		
A. Activation Level	2	1.7	III	25.0**
B. Attention	1	2.4	III	34.3**
C. Within-6-Sec Interval	3	0.0	III	____
D. A X B	2	0.5	III	7.9**
E. A X C	6	0.1	III	1.7
F. B X C	3	0.1	III	1.0
G. A X B X C	6	0.3	III	1.5
II. Replications	3	5.1	III	-
III. Rows X Columns	69	0.1		
A. I_A X II	6	0.0		____
B. I_B X II	3	0.0		____
C. I_C X II	9	0.1		____
D. I_D X II	6	0.1		____
E. I_E X II	18	0.0		____
F. I_F X II	9	0.1		____
G. I_G X II	18	0.1		____
Total	95	0.9		

*$p<.05$.

**$p<.01$.

TABLE 15

VARIANCE ANALYSIS SUMMARY FOR HR

SUBJECT S.S.

Source of Variation	df	MS	ET	F
I. Between Columns	17	8.6		
A. Activation Level	2	36.2	III	12.8**
B. Attention	2	2.6	III	———
C. Within-6-Sec Interval	1	19.8	III	7.0*
D. A X B	4	8.9	III	3.2*
E. A X C	2	1.8	III	———
F. B X C	2	0.3	III	———
G. A X B X C	4	2.3	III	———
II. Replications	1	27.6	III	9.2*
III. Rows X Columns	17	2.8		
A. I_A X II	2	0.6		———
B. I_B X II	2	4.3		———
C. I_C X II	1	3.7		———
D. I_D X II	4	2.6		———
E. I_E X II	2	3.2		———
F. I_F X II	2	1.2		———
G. I_G X II	4	1.2		———
Total	35	1.2		

*$p < .05$.

**$p < .01$.

TABLE 16

VARIANCE ANALYSIS SUMMARY FOR RT

SUBJECT S.S.

Source of Variation	df	MS	ET	F
I. Between Columns	8	7937.6		
A. Activation Level	2	3824.2	III	14.2**
B. Attention	2	26661.2	III	10.0**
C. A X B	4	663.4	III	4.8*
II. Replications	3	1922.8	III	2.4
III. Rows X Columns	24	796.4		
A. I_A X II	6	269.3	III	———
B. I_B X II	6	2657.3		———
C. I_C X II	12	129.6		
Total	35	2525.2		

*$p<.05$.

**$p<.01$.