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EEG CORRELATES OF EMOTIONAL TASKS RELATED TO ATTENTIONAL DEMANDS

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This research brings together two separate areas: (1) that of EEG processes associated with positive and negatively valenced emotional material; and (2) that of traditional psychophysiological research related to the "intake" and "rejection" of environmental stimuli. Forty males on each of two days were presented with tasks reflecting both attentional demands and affectual processing. Heart rate and bilateral EEG measures from frontal, parietal and temporal sites were recorded. Using a FFT (fast Fourier transform) electrocortical activity in the 2–7 Hz, 8–15 Hz, and 16–24 Hz was determined and analyzed. The results suggest emotional valence (i.e. positive and negative) and attentional demands (i.e. intake vs rejection) are differentially represented in terms of EEG functioning. An interaction of attentional demand with hemisphere was found for EEG alpha activity in the temporal and parietal areas. For emotional valence there was a significant main effect for EEG beta activity in both the temporal and parietal areas. Differential hemispheric activity was found using a factor analytic technique (PARAFAC) with positively valenced tasks being associated with right temporal beta. Heart rate changes for the attentional dimension were consistent with previous research.

INTRODUCTION

Support has accumulated from various sources to suggest that lateralized central nervous system activity and emotionality are functionally related (Tucker, 1981). Unilateral lesion research indicates the importance of an intact right hemisphere for the accurate interpretation of affective stimuli (Wechsler, 1973; Heilman et al., 1975). Wechsler (1973) reported that the right hemisphere served a critical role in the ability to recall emotionally charged material presented in a verbal fashion. Likewise, Heilman et al. (1975) demonstrated that patients with right hemisphere dysfunctions experienced relative impairment in the comprehension of affective speech patterns and greater difficulty in determining the emotional mood of speakers.

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Although the right hemisphere is clearly implicated in emotional processing, other research suggests bilateral hemispheric involvement (cf. Sackeim et al., 1982). Unilateral sodium amytal injections (Perria et al., 1961; Terzian, 1964) and unilateral brain lesions (Hecaen, 1962; Gainotti, 1969; Gainotti, 1972) suggest that left hemisphere trauma may precipitate a catastrophic depressive reaction in contrast to trauma to the right hemisphere which evokes a more euphoric reaction. Robinson et al. (1984) have reported differential anterior/posterior as well as hemispheric involvement with mood disorders. In an examination of stroke patient groups, Robinson et al. found that patients with left frontal lesions reported significantly more severe depression whereas less depression was noted in patients with lesions in the posterior left hemisphere. A different pattern was seen in the right hemisphere with depression being more pronounced in patients with lesions in the right posterior areas while patients with anterior lesions were more cheerful.

Research with neurologically intact subjects has also suggested differential hemispheric activity in terms of emotionality. Safer and Leventhal (1977) employed a dichotic listening paradigm and reported greater right hemispheric involvement with subjective/emotional information. Sackheim et al. (1978) had subjects judge facial expression and interpreted their results to suggest right hemisphere involvement in the recognition of emotions. Recording lateral eye movement, Schwartz et al. (1975) suggested greater right hemisphere involvement was associated with the recall of facts about emotional experiences or the differentiations of emotional words.

Electrocortical research has also suggested differential hemispheric activation related to emotionality with both psychiatric (Flor-Henry, 1979) and normal populations (Harman and Ray, 1977; Davidson et al., 1979; Ehrlichman and Weiner, 1980; Tucker et al., 1981) using a variety of emotionally valenced tasks. The particular emotional valence associated with each hemisphere has varied. For example, Harman and Ray (1977) reported differential hemispheric changes over time with the recall of positive and negative past events. Left hemisphere power (3–30 Hz) increased during the positive affect condition and decreased during the negative affect condition. Using similiar tasks, Ehrlichman and Weiner (1980) showed greater right hemispheric activation during positive emotional tasks. Both of these studies reported EEG activity recorded from temporal locations. While watching a television show, Davidson et al. (1979) required subjects to subjectively rate using a pressure-sensitive device how well they liked/disliked various parts of the program. Bilateral frontal and parietal EEG activity in the alpha range was compared during liked and disliked segments. The results indicated relatively greater right frontal alpha activity during liked segments and relatively greater left frontal alpha activity during disliked segments. No significant differences were reported for parietal activity. Tucker et al. (1981) used a mood induction procedure and then presented subjects with cognitive tasks. These results were interpreted similiar to Davidson et al.'s (1979) since negative mood was associated with greater left frontal EEG alpha.

Since the EEG studies examining emotion, mood and preference have used a variety of tasks and procedures involving different frequency bands and areas of the cortex, it remains unclear as to whether or not the discrepant EEG results may be attributed to variation in the EEG measures being recorded (e.g. different frequency bands), the manner in which different areas of the cortex (e.g. frontal, parietal and temporal) are involved in the processing of emotional material, or the task requirements themselves (e.g. the particular emotional task in which subjects are engaged). The present study is an initial attempt to clarify these issues.

Not only do we need to consider the methodological issues in EEG research but also the underlying theoretical implications. Since EEG research has historically been based on an arousal model it is surprising that more attention has not been paid to the implications of this underlying theory for EEG research. Historically arousal and emotionality have been viewed as related if not similiar processes. The traditional approach to emotionality and arousal has assumed a unitary continuum of arousal (e.g. Duffy, 1962). In EEG research the common assumption has been that alpha activity reflects arousal and has an inverse relationship with mental processes (Adrian and Matthews, 1934). Alpha has also been assumed to co-vary inversely with beta. However, there are reasons to suggest this simple view of EEG activity offers a limited perspective. There also exists empirical evidence to suggest that alpha activity and beta activity are not always inversely related (Daniel, 1965).

General theoretical presentations have been made suggesting the replacement of the unitary arousal model with a more differentiated one distinguishing motor, perceptual and cognitive involvement (Kahneman, 1973). Posner (1975) suggested an information processing approach based on an attentional model which differentiates alertness, selection of information, and degree of conscious effort. Pribram (1981) related emotion to neuropsychological processes referred to arousal, activation and effort, each of which may be reflected in EEG activity. Although these models differ in particular aspects, Tucker and Williamson (1984) have recently suggested an underlying similarity of processes represented in these models related to hemispheric functioning. This is particularly relevant to the present research as it suggests a rationale for differentiation of emotional/feeling processes from attentional factors involved in specific tasks.

Following Darrow (1929) and Lacey (1967) a distinction can be made between two types of attentional tasks. The first type Lacey referred to as "intake" tasks involving passive observation of environmental stimuli. The second type Lacey called "rejection" tasks such as mental arithmetic in which a person must "reject" external input which might interfere with the task. Different cardiovascular responses are associated with intake (heart rate deceleration) and rejection tasks (heart rate acceleration) (Lacey et al., 1963). On the physiological level the Laceys (Lacey and Lacey, 1978) have suggested a link between autonomic arousal as represented by cardiovascular functioning and cortical arousal as represented by electrocortical measures involving baroreceptor activity in the carotid sinus. Walker and Sandman (1979) have investigated changes in average evoked potentials (AEP) and heart rate and report that heart rate changes are differentially reflected in the two hemispheres with lower heart rate being associated with greater amplitude right hemispheric AEPs and higher heart rate associated with larger amplitude left hemsiperic AEPs. Since previous research has demonstrated that the attentional demands of specific tasks are related to cardiovascular responding, and since cardiovascular responding may differentially affect electrocortical activity, it is imperative that attentional factors be considered in understanding EEG correlates of emotional processing.

The previous discussion raises two general questions related to the EEG correlates of emotional and attentional factors which will be addressed in this present study. First, are positive and negative emotionally valenced tasks distinguished by bilateral EEG activity at specific sites and at different frequencies? And second, do attentional factors influence EEG activity independent of the emotional valence of the task?

METHOD

Subjects

Subjects for this study were 40 right-handed males of college age. Handedness was assessed by an 18 item questionnaire adapted from the items reported by Rackowski et al. (1974). No subject reported a history of familial sinistrality.

Procedure

Subjects completed the experimental procedure on each of two separate days. The second day differed from the fist only in order of task presentation. Subjects were randomly assigned to one of four separate orders of task presentation. Each day subjects received 8 separate tasks reflecting both attentional demands and affectual processing. The attentional factor reflected either internal attentional focus (e.g. remember an event from your past) or external attentional focus (e.g. look at a picture). Each of these attentional demand tasks also reflected either positive or negative affectual valence. The internal attentional focus ("reject tasks") included tasks similar to those used by Harman and Ray (1977) and Ehrlichman and Weiner (1980). These four tasks required that the subject recall pleasant and unpleasant events from their past as well as imagine future pleasant and unpleasant events. The external focus ("intake tasks") involved the presentation of slides generally considered to involve positive (Hare et al., 1971; Ekman and Friesen, 1975) or negative affect (Safer, 1981). These slides included landscapes, happy faces, sad faces, and accident scenes. During all tasks subjects were instructed to keep their eyes open and to focus on the screen in front of them. The duration of each task presentation was 30 s.

Apparatus

Subjects were tested in an experimental room (approx. 3.5×2.1 m) seated in a comfortable lounge chair with the projection screen placed 1.5 m in front of the subject. Slides were projected through a one-way window located behind the chair. A low wattage lamp was on the room at all times. EEG electrodes (Ag/AgCl) were attached to the subject using an elastic cap with fixed connectors at the standard sites. Heart rate electrodes were attached on each side of the body above the rib cage a few inches above the waist line. Mean inter-beat intervals were calculated for each task. The EEG was recorded bilaterally from the frontal (F3 and F4), temporal (T3 and T4), and parietal (P3 and P4) areas referenced to linked ears with less than 5000 Ω impedance. The EEG and heart rate signals were amplified by a Beckman R611 polygraph and the EEG analyzed online by a Fourier transform (FFT) program running on a PDP 11/34 computer sampling approximately 100 times/s/channel. Three frequency bands were calculated (2–7 Hz, 8–15 Hz and 16–24 Hz) and used in the analyses. Paper records were inspected for artifact control at the time of the experiment and later independently inspected by two other individuals. A three-mode factor analytic technique (PARAFAC) was also used to check for extreme individual EEG data.

RESULTS

The results are based on analyses of variance with days (2), attentional focus (internal-external), valence (positive-negative) and hemisphere as within subject variables. Separate analyses were performed for each frequency band by site (frontal-parietal-temporal). There were no main effects for days and this factor will not be discussed further.

Statistically significant interactions were present between the attentional focus and hemisphere factors in the temporal ($F_{1,39} = 10.068$; $P < 0.003$) and parietal ($F_{1,39} = 10.891$; $P < 0.002$) areas for the middle frequency band (8–15 Hz). The results for both parietal and temporal data were similiar with more activity (higher FFT power) noted during internal than external tasks and the right hemisphere showing greater between task differences than the left hemisphere. These data are plotted in Figs. 1 and 2. There were no additional significant interactions involving hemisphere except for a low frequency (2–7 Hz) three-way interaction involving attention, emotional valance, and hemisphere in the frontal areas ($F_{1,39} = 4.994$; $P < 0.031$). All data are presented in Table I. The main effect for

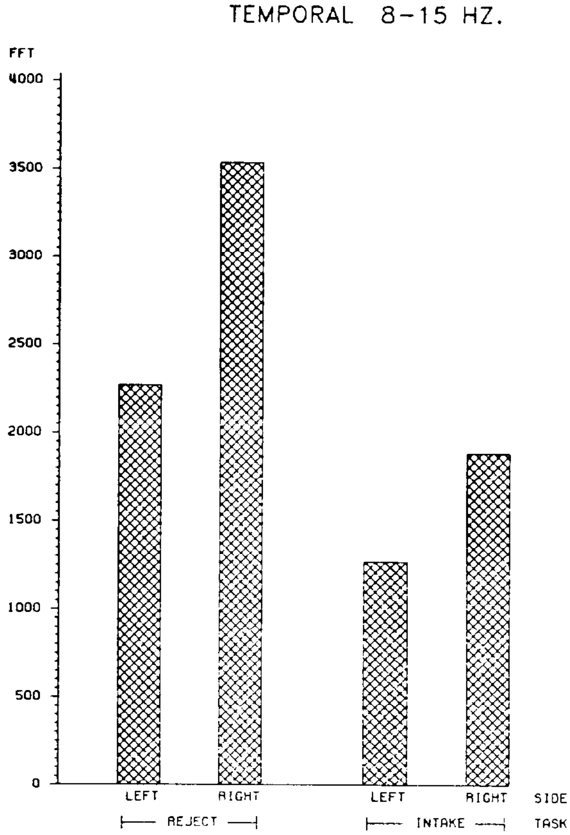

Fig. 1. FFT power in the alpha range (8–15 Hz) for left and right temporal areas during intake and rejection tasks.

the attentional factor was significant for all three sites in the middle frequencies (8–15 Hz; frontal: $F_{1,39} = 35.799$; $P < 0.0001$; parietal: $F_{1,39} = 47.378$; $P < 0.0001$; temporal: $F_{1,39} = 46.443$; $P < 0.0001$) and in the upper freqencies (16–24 Hz.; frontal: $F_{1,39} = 13.813$; $P < 0.001$; parietal: $F_{1,39} = 54.976$; $P < 0.0001$: temporal: $F_{1,39} = 20.721$; $P < 0.0001$). The attention main effect was also found for the low frequencies (2–7 Hz) in the parietal areas ($F_{1,39} = 5.407$; $P < 0.025$). In each of these cases there was more activity (higher FFT power) during the internal than the external tasks. There was also a significant main effect for emotional valence (positive-negative) in the temporal ($F_{1,39} = 7.91$; $P < 0.008$) and parietal ($F_{1,39} = 6.328$; $P < 0.016$) areas in the upper frequency band (16–24 Hz). In these cases there was more activity (higher FFT power) during positive than negative tasks. These effects were independent of

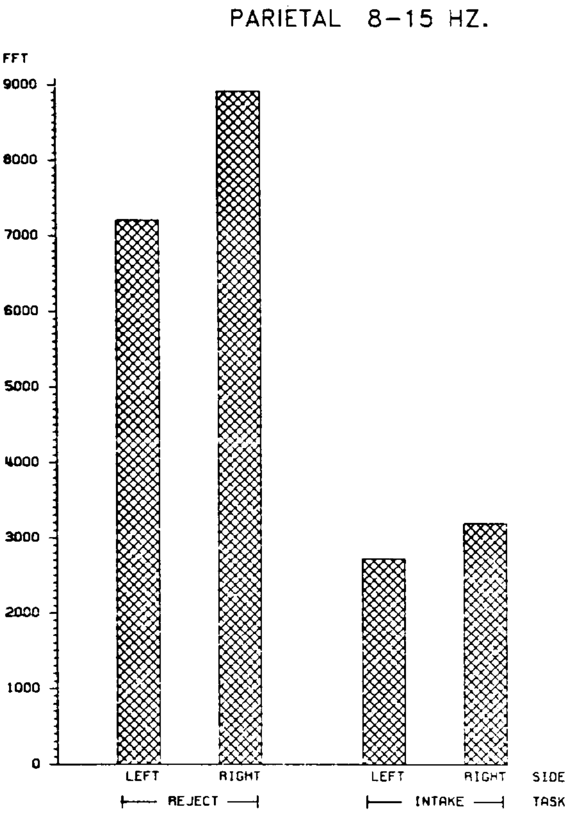

Fig. 2. FFT power in the alpha range (8–15 Hz) for left and right parietal areas during intake and rejection tasks.

hemisphere. Significant main effects for hemisphere were found in the beta frequencies for the parietal ($F_{1,39} = 4.534$; $P < 0.04$) and temporal ($F_{1,39} = 13.216$; $P < 0.001$) areas; in the alpha frequencies for the parietal ($F_{1,39} = 6.158$; $P < 0.018$) and temporal ($F_{1,39} = 17.751$; $P < 0.001$) areas and in the low (2–7 Hz) frequencies for the temporal ($F_{1,39} = 19.477$; $P < 0.0001$) and frontal ($F_{1,39} = 4.286$; $P < 0.045$) areas. In all cases there was greater power in the right hemisphere.

In order to examine the relationship between the tasks and EEG activity in the various bands, a three-mode factor analytic technique (PARAFAC) was used (see Harshman and Berenbaum, 1981, for a description of this technique). Briefly PARAFAC describes the different relative involvement of EEG in relation to three separate modes: (1) left and right frontal, temporal and parietal sites; (2) the eight tasks on each of two days; and (3) the 40 subjects. The subject mode allowed us to determine if any given subject contributed differently from the others and thus represented an outlier. Data from this third mode will not be formally presented in this report. The data presented in this report relate to alpha and beta activity. Because of the magnitude differences between alpha and beta activity, a separate analysis was performed for each. In terms of alpha activity, a simple structure emerged with the greatest variance being accounted for by a factor involving

TABLE I

FFT power for frontal, temporal and parietal areas

	Tasks			
	Reject positive	*Reject negative*	*Intake positive*	*Intake negative*
Theta and Delta (2–7 Hz)				
Frontal				
F3	4964	5334	4555	4949
F4	5847	5653	4893	5472
Temporal				
T3	1890	1798	1665	1801
T4	2716	2675	2339	2554
Parietal				
P3	3205	3263	2755	2921
P4	3426	3444	2880	3065
Alpha (8–15 Hz)				
Frontal				
F3	3222	3127	1738	1755
F4	3175	3043	1644	1696
Temporal				
T3	2354	2189	1316	1224
T4	3594	3481	1890	1882
Parietal				
P3	7399	7025	2748	2696
P4	9144	8701	3213	3181
Beta (16–24 Hz)				
Frontal				
F3	548	524	453	447
F4	589	554	468	479
Temporal				
T3	487	384	339	283
T4	809	543	582	462
Parietal				
P3	523	478	354	336
P4	576	532	383	370

NOTE: FFT power values divided by 100,000.

TABLE 2

PARAFAC analyses

Measure	Factors involving tasks under study	
	Alpha	Beta
Site		
F3	0.60	0.03
F4	0.59	0.16
T3	0.40	0.60
T4	0.68	2.36
P3	1.47	0.09
P4	1.59	0.20
Task		
Day 1		
REJECT		
Positive (past event)	0.97	1.76
Positive (future)	0.99	2.02
Negative (past)	1.11	0.60
Negative (future)	1.04	0.46
INTAKE		
Positive (landscape)	0.35	0.92
Positive (face)	0.45	1.24
Negative (face)	0.43	0.20
Negative (accident)	0.34	0.70
Day 2		
REJECT		
Positive (past)	1.61	1.38
Positive (future)	1.67	1.06
Negative (past)	1.45	0.58
Negative (future)	1.60	0.17
INTAKE		
Positive (landscape)	0.44	0.71
Positive (face)	0.59	1.14
Negative (face)	0.60	0.01
Negative (accident)	0.45	0.38

Note: these are the first factors extracted from two separate PARAFACs, one with alpha and one with beta.

rejection tasks and the left and right parietal areas. In terms of beta activity a factor emerged involving positive emotional tasks which was associated with right temporal activity. These data are presented in Table II.

As a manipulation check, heart rate data were compared across the conditions in the study. The differences between the intake and rejection tasks were significantly different ($F_{1,39} = 39.14$; $P < 0.0001$) with higher heart rates being found on the rejection tasks.

DISCUSSION

The results of this study suggest that emotional valence (i.e. positive and negative) and attentional demands (i.e. intake and rejection) are differentially represented in terms of EEG functioning. In general alpha activity (8–15 Hz) showed differential hemispheric involvement in relation to the intake/rejection dimension. This pattern was present in the temporal and parietal areas for the Fourier data but not in the frontal areas. The PARAFAC analysis also pointed out strong involvement of parietal alpha activity with the attentional dimension. On the other hand, the beta frequencies (16–24 Hz) were sensitive to the emotional valence of the task as well as the attentional dimension. As would have been predicted by previous cardiovascular research, there was a significant difference in heart rate between intake and rejection tasks with the intake tasks showing a lower heart rate.

Since the intake/rejection difference appeared in both heart rate and alpha activity in the present study, this raises the question of a possible relationship between cardiovascular activity and hemispheric alpha. Recent research (Walker and Walker, 1983) suggests one possibility. Walker and Walker reported a relationship between EEG activity and carotid pressure. The results of their study showed that readings from the carotid artery were time locked to the rhythmic oscillations of the EEG, especially in the alpha band. This suggested that cardiac activity plays a role in synchronizing alpha. It might also be speculated that it is through this mechanism that cardiovascular activity has an inhibitory effect on cortical processing. The particular candidate for such a mechanism would be the baroreceptor system since research with animals has shown baroreceptor stimulation produces cortical and behavioral inhibition (Bonvallet et al., 1954; Bonvallet and Allen, 1963; Dworkin et al., 1979). With humans Lacey and others have speculated a link between cardiovascular changes in response to intake and rejection tasks and this system. Thus, it is possible that increased alpha during rejection tasks in this present study was associated with such a mechanism whose purpose was to reduce unneeded external stimulation and allow for more efficient internal processing (e.g. recall of past events).

In terms of emotionality the PARAFAC analysis suggested a unique involvement of the right temporal areas in positive emotionally valenced tasks. From Table II it is possible to note that all positive tasks, both intake and reject, across both days are loaded with right temporal lobe beta. This is particularly interesting since this study held the processing demands of the positive and negatively valenced tasks constant. In other words, recalling a positive or negative event from one's past should require similiar cognitive processes and should not require overt or differential motor responses. Likewise attending to a face displaying positive or negative emotional expression should involve similiar task requirements. Thus EEG activity in the present study may be seen to reflect more than just motor task requirements as has been suggested previously (Gevins et al., 1979). We also found similiar results along the emotional dimension from both the intake and rejection tasks in the present study, which suggests both the perception of emotion in the intake tasks and the emotional valence memory tasks in the rejection condition are reflecting the same underlying emotional process.

The contribution of the right temporal area to those processes involving positive emotionality are intriguing seen in the light of research with temporal lobe epilepsy. Patients with right temporal lobe epilepsy have described themselves as more elated than patients with left temporal lobe epilepsy who described themselves as more angry, paranoid, and dependent (Bear and Fedio, 1977). Thus in both the Bear and Fedio study and the present one there is a suggestion that the subjective experience of negative emotion or mood involves the left temporal areas whereas the subjective experience of positive affect involves the right hemisphere. However, the situation may be more complicated for in the Bear and Fedio study the appearance of emotional behavior produced a different relationship. The same right temporal lobe patients who described themselves as more elated were described by raters as being more emotional and displaying periods of sadness. The left temporal lobe group on the other hand described themselves as more negative yet were described by others as more ideational and contemplative. Thus, there exists the possibility that subjective emotion as experienced by the person and expressive emotion as observed by another person may lead to differing and opposite conclusions concerning differential hemispheric involvement in emotionality. Since the appearance of emotional responding was not considered in the present research, an interesting possibility in a future study would be to allow for this condition.

Along this line, it is possible that the Tucker et al. (1981) induction of a mood and the Davidson et al. (1978) reporting of subjective ratings of liking also invoked a different emotional dimension from that tapped in the present study. A case for this possibility can be made empirically since both the Tucker and the Davidson research found EEG hemisperic differences in the frontal areas whereas the present as well as previous research (Harman and Ray, 1977) from this and other labs (e.g., Ehrlichman and Weiner, 1980) reported bilateral temporal EEG differences. The exception in the present study was the significant interaction found in the frontal areas for low frequency (2–7 Hz) EEG activity. The meaning of this interaction is unclear at this time. Future research is needed to address types of emotional activity at both separate frequencies and separate sites. Perhaps, there exist separate aspects of emotional processing differently reflected in the brain. The first aspect would be a subjective dimension in the emotional "flavor" of the task (e.g., remembering happy or sad events) which is reflected in the temporal area. The second aspect might be an evaluation factor (e.g. rate the pleasantness of a TV program) reflected in the frontal areas. There may also exist the possibility of a third factor which would reflect an expressive dimension of emotion which would serve to communicate with others and which must on some level involve the motor and language areas of the brain. To date, research addressing this third area of emotional expression has used electromyographic rather than electrocortical measurements. However, future research combining both EMG and EEG approaches should prove fruitful.

The results from the present study also are consistent with a previous parallel study from this lab using cognitive tasks (Ray and Cole, 1984). In this cognitive study, parietal alpha activity also reflected attentional demands (i.e. intake and rejection) whereas parietal beta activity reflected hemispheric tasks (i.e. analytic and synthetic tasks). Thus in research using both emotional and cognitive tasks, it is possible to conclude that alpha reflects attentional factors although it is not possible at this time to suggest which aspects of attention (i.e. perceptual, motor preparation, etc.) are represented by alpha activity. It is also possible to suggest that the emotional valence of a task is seen in more posterior beta activity. The exact mechanism involved again waits to be described. However, in light of the results of the present study it becomes important that we reconceptualize the traditionally held view of EEG alpha as reflecting arousal as well as attempt better conceptualizations of our constructs of arousal, attention, and emotionality.

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