Electroencephalography and clinical Neurophysiology, 82 (1992) 302–309

EEG 89660

Event-related desynchronization: the effects of energetic and computational demands

Frans Boiten [a], Joseph Sergeant [b] and Reint Geuze [c]

[a] *Experimental Psychology and* [b] *Clinical Psychology, University of Amsterdam, Amsterdam (The Netherlands), and* [c] *Experimental Clinical Psychology, University of Groningen, Groningen (The Netherlands)*

(Accepted for publication: 25 October 1991)

Summary The effects of a subject's activation state on cognitive processing were studied, while subjects performed verbal and non-verbal tasks under a speed and accuracy instruction. It was found that stressing speed influenced the level of prestimulus alpha power and consequently the amount of relative event-related desynchronization (ERD). Increasing task complexity led to an increase in the amount and duration of relative ERD. Both prestimulus level of alpha power and relative ERD were asymmetrically distributed over the left and right hemispheres. No verbal/non-verbal task-dependent asymmetries in phasic ERD were found.

The data suggest that the level of prestimulus alpha power is mainly influenced by the subject's activation state, whereas relative ERD mainly reflects phasic changes in cognitive processing.

Key words: Event-related desynchronization; Arousal; Activation

Numerous studies have demonstrated that during mental activity there is suppression of alpha rhythm (Glass et al. 1984; Dawson et al. 1985). The majority of research on suppression of alpha power has been applied to the study of hemispheric differences (see for review Glass 1984). Asymmetrical (tonic) suppression of alpha rhythm during tasks which are supposed to engage one-half of the brain, compared with a baseline condition, is usually taken to be an indicator of cortical specialization. Several investigators have demonstrated that suppression of alpha power is greater over the left hemisphere, when subjects perform verbal and numerical tasks which depend upon the cognitive specialization of the left hemisphere. The reverse is true for visuo-spatial tasks which are thought to engage the right hemisphere (Rebert and Mahoney 1978; Rebert et al. 1984). Other research involved in the study of attention has suggested that 'arousal' can be monitored by phasic desynchronization whereas 'activation' can be monitored by tonic desynchronization (Pribram 1981).

The purpose of the present paper was to study the effect of mental activity induced by two different classes of task variables upon phasic desynchronization of alpha rhythm. This desynchronization can be measured by event-related desynchronization (ERD). Quantification of the ERD was first reported by Pfurtscheller (1977) and Pfurtscheller and Aranibar (1977). ERD is measured by the time-locked average power associated with desynchronization of the alpha rhythm (Sergeant et al. 1987). This method differs with respect to most research on suppression of alpha power, since it allows monitoring of phasic suppression of alpha power during task performance. It thereby excludes the problems connected with the evaluation of task-induced suppression of alpha power by means of a baseline condition, such as applied traditionally. One of these problems being the large separation in time of measurement of the baseline condition and the stimulus-induced changes.

In this study mental activity will be evoked by two classes of task variables which have been reported to engage differentially the subjects arousal and activation system. Following the definition of Pribram and McGuiness (1975) arousal should occur whenever an input is surprising, complex or novel. Task difficulty and the surprise effects or uncertainty about the stimulus to be received have been reported to induce arousal (Berlyne 1969). Van Winsum et al. (1984) demonstrated that the ERD, like arousal, is a phasic response to input, augmented with increasing complexity of the stimuli. Unlike arousal, activation is a tonic process, more internally controlled and probably depends more on motivation than orienting on external input (Pribram 1981). An example is keeping up performance during

Correspondence to: Drs. F.A. Boiten, University of Amsterdam, Psychological Laboratory, Roetersstraat 15, 1018 WB Amsterdam (The Netherlands).

loss of sleep (activation variable). Task variables, such as time-on-task and event rate have also been reported to manipulate the subject's tonic activation state (Rohrbaugh et al. 1979; Sanders 1983).

With respect to ERD, Van Winsum et al. (1984) reported that the amount of relative ERD was determined both by an 'activation' variable, event rate, and an 'arousal' variable, cognitive load, but independently. It was found that an increase in cognitive load resulted in an enhanced ERD. However, the ERD was also significantly larger during a low than during a high event rate. If one accepts that processing of stimuli during a high event rate is more 'activating' or stressful than during a low event rate, this would imply that the ERD reflects not only stimulus specific processes but energetic processes (activation) as well. This hypothesis was also recently proposed by Klimesch et al. (1988). In their experiment they examined the effects of expectancy and attention on search and retrieval processes in long-term memory. ERD mapping, a method to portray the regional ERD in the form of maps, was used to examine this question. One of their findings was that increased attention, manipulated by means of expectancy or the ability to prepare for the forthcoming task, increased cortical activation. That is, ERD was much more widespread over the cortex during high than during low attentional demands. Of interest for the present study was that, when subjects had to put more effort into preparing for the task (increased attention), the power in the prestimulus interval was suppressed for larger brain areas. Thus, expectancy not only affected the cortical processes following but also those preceding stimulus presentation. The effects of energetic and/or cognitive processes on prestimulus alpha power might explain why in Sergeant et al.'s (1987) study cognitive processing during a high event rate leads to a smaller ERD than during a low event rate. As a consequence of a heightened activation state, there should be an increase in cortical activation and hence alpha power suppression, which might not only be reflected by the ERD amplitude but also by a decrease in prestimulus alpha power. It is likely that lowered levels of prestimulus alpha power will influence and probably reduce the amount of ERD, since the power in the prestimulus interval was used as a reference to calculate the ERD. Thus, the range within which the ERD amplitude could take place was reduced (Wilder 1957). Separate analyses will be performed in this study for cognitive and energetic effects with respect to prestimulus alpha power.

In order to test the effects of mental activity or more specifically the effects of variations in activation and cognitive processing upon ERD, 4 task variables were employed: instructions (speed vs. accuracy), code (verbal vs. non-verbal tasks) task difficulty (easy vs. difficult) and response probability (50/50% vs. 20/80% probability). These task variables have been shown to influence energetic pools or different stages in the information processing chain. Instruction, i.e., subjects are required to respond as accurately or as fast as possible, is thought to manipulate the subjects activation state (Gaillard 1978; Sanders 1983). It is hypothesized that stressing speed will enhance activation state and decrease the amount of relative ERD. Variations in task difficulty and response probability are expected to manipulate computational processing and hence ERD. It has been demonstrated that the ERD is augmented with increasing task complexity (Van Winsum et al. 1984) The effects of response probability on ERD have not as yet been studied. The surprise effects or uncertainty about the stimulus to be received have, however, been reported to increase the complexity of an experimental task (e.g., Brookhuis et al. 1983). A low response probability is therefore expected to increase the complexity of the experimental task and hence the amount of ERD. To test the effects of cortical specialization on ERD, verbal and non-verbal tasks were employed in this study.

Method

Subjects

The subjects in this experiment (n = 8) were 5 men and 3 women aged 22–29 years. All subjects were right handed as indicated by their writing and skill behaviour and were paid for their participation. They had normal or corrected to normal vision. Subjects were moderate smokers, who consumed on the average 5 cups of coffee per day and were not known to abuse alcohol or drugs.

Task and experimental design

The experimental task consisted of a speed and an accuracy condition (see instructions). In both conditions subjects had to perform the same verbal and non-verbal tasks. In the non-verbal condition, horizontal or vertical pairs of parallel lines were displayed for 1000 msec on a video display. If the lines were judged to be the same length (1 cm), subjects were required to give a response by lifting the index finger of the dominant hand (same response). When lines of different length were presented, they were required to lift the index finger of the non-dominant hand (different response). The differences between line pairs, either horizontal or vertical, were equally distributed to the left or to the right side of the line pairs. All tasks were administered under two conditions of target probability: a 50/50% response probability (50% same length, 50% different length) and a 20/80% response-probability structure (20% same length, 80% different length). These two conditions were further subdivided

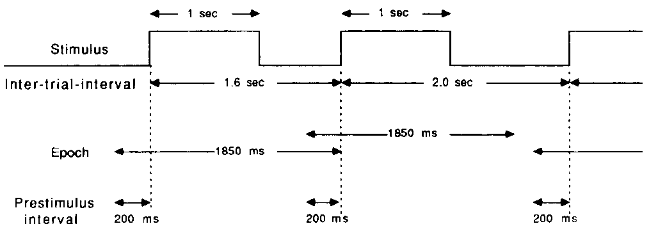


Fig. 1. Timing of stimuli (top) and the selection of epochs for ERD analysis. See text.

in two levels of task difficulty, an easy task (50% difference between lines) and a difficult task (20% difference between lines), see Table I.

In all verbal tasks two different letters were presented. In the easy task 2 letters were either vowels, which required a dominant hand 'same' response, or were consonants, which required a non-dominant hand 'different' response. For the sake of uniform terminology between the verbal and non-verbal tasks we use the terms 'same' and 'different' also for the verbal task responses. Vowels and consonants were equally distributed over the task. The difficult task consisted of 2-letter words or nonsense words. When a word was presented, subjects had to respond: 'same' (dominant hand response), when a nonsense word was presented subjects had to respond: 'different' (non-dominant hand response). Words and nonsense words consisted of a vowel and a consonant. Half of the words and nonsense words began with a vowel the other half with a consonant. Only commonly known words were used. The verbal tasks were also administered under two conditions of target probability: a 50/50% probability condition and a 20/80% probability condition (20% same and 80% different responses) All stimuli were presented for a duration of 1000 msec on a video display. The inter-trial interval (ITI) had a range of 1.5–2.1 sec and an average of 1.8 sec (see Fig. 1).

The stimuli and their timing were generated by an LSI 11/23 computer which further coded the responses and measured the reaction times of the subjects. Each task consisted of 120 trials. After 60 trials a 20 sec break was included to rest the subjects' eyes. The experimental design (see Table I) thus contained 16 tasks (8 per instruction condition) for each subject, applied in random order between subjects and within subjects. Each task lasted about 4 min. The total duration of one experiment was approximately 4 h, with a 10 min break each 30 min. Subjects received 1000 trials of practice for both the speed and accuracy condition before commencing the experiment.

Instructions

In the accuracy condition subjects were instructed to respond as accurately and as quickly as possible, keeping a standard deviation with a maximum of 15% of the mean RT and no more than 10% errors. In the speed condition, subjects were required to respond as fast as possible. Strict control of speed was implemented by using a deadline procedure (Pachella et al. 1968). In this experiment subjects were under a deadline to respond faster than 400 msec. This was assured by providing subjects with feedback, a short tone, on those trials when they exceeded the 400 msec deadline.

EEG recording

Electrodes were placed at P_3 and P_4 following the international 10–20 system (Jasper 1958). Electrodes for electro-oculogram (EOG) were placed vertically (under and above the right eye) and horizontally (next to the left and right eye). The P_3 and P_4 electrodes were referred to A_1 and A_2 respectively. Ag/AgCl electrodes were used. The skin below the electrodes was punctured to reduce resistance (below 2 kΩ). Records were made with a 5000 van Gogh recorder with a bandpass filter (0.016–35 Hz, 6 dB). EEG and EOG signals were sampled at 125 Hz and stored on magnetic tape for off-line analysis.

Signal analyses

Signals were subjected to a digital low-pass filter (35 Hz 12 dB). All trials were checked visually for eye blinks and eye movements and removed whenever the EOG voltage exceeded 50 μV. The EEG was visually scanned for excessive deflections. Trials with artefacts and deflections were removed before further analysis. To control for fast-guesses or extreme accuracy (see Pachella et al. 1968) trials with RTs of 1.5 S.D. below or above mean RT (8%) were removed before further signal analysis. Within the speed condition, trials with RTs which exceeded 400 msec (15%) were also removed before further analysis. The signals were segmented into trials with an epoch of 2048 msec. The

TABLE I

The experimental design. S, same; D, different.

Instructions: accuracy/speed															
Verbal								Non-verbal							
Easy				Difficult				Easy				Difficult			
50/50		20/80		50/50		20/80		50/50		20/80		50/50		20/80	
S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D

epoch commenced 265 msec prestimulus. Separate analyses were conducted for same and different responses.

ERD analysis

Signals were filtered with a digital bandpass filter (8–13 Hz, 24 dB/oct). Alpha power was obtained by squaring each data point. Squaring data points of the ERD is a method proposed by Pfurtscheller (1977). The rationale is in analogy with power spectra where data points are squared in the frequency domain. For the ERD, however, we are interested in the time average of the signal. Thus the data from the alpha band frequency is transformed back to the time domain and squared to have an analog of power. Epoch length for averaging began 200 msec prior to stimulus onset and ended 1650 msec after stimulus onset, giving an epoch length of 1850 msec. With an ITI less than 1650 msec there would be an overlap between epochs (see Fig. 1). This overlap would, however, not influence the power in the following prestimulus interval since the return to baseline of the ERD was always in our research within 1300 msec (see also Van Winsum et al. 1984). The average of the data points was calculated with respect to the time of stimulus presentation. Averages were smoothed with a rectangle window of 40 msec. Finally, the morphology of the event-related desynchronization was characterized by the following parameters:

Level of prestimulus alpha power. This is the mean power (μV^2) in the 200 msec prior to stimulus onset.

Relative desynchronization. $100 \times$ maximal power decrease divided by the mean alpha power at baseline.

Latency of desynchronization. Time from stimulus onset (S) to instant at which alpha power desynchronization is maximal (B) (see Fig. 2).

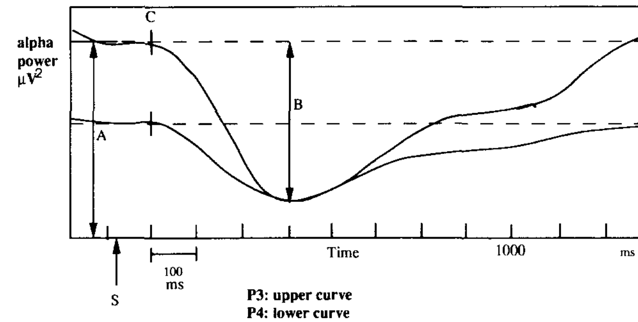


Fig. 2. Mean event-related desynchronization, recorded at P3 and P4; S, time of presentation of stimulus; A, level of prestimulus alpha power; B, maximal power decrease with respect to level of prestimulus alpha power; C, beginning of desynchronization.

These measures were calculated by an interactive computer program under visual control.

Statistical analysis

All measures were entered into a multivariate analysis of variance (MANOVA) with repeated measures. The within-subject factors were: speed instructions, code (verbal/non-verbal tasks), task difficulty, response probability, type of response (same or different) and electrode site. Separate MANOVAs were performed for the dependent measures: amplitude and latency of the ERD, level of prestimulus alpha power, reaction times and errors.

Results

Performance data

Two measures of performance were used in this study: reaction times (RT) and percentage errors. All task variables had strong main effects on RT. RTs

TABLE II

Means and standard deviations for instruction (accuracy/speed), code (verbal/non-verbal), task difficulty (easy/difficult), probability (50/50–20/80), response (same/different) and electrode placement (P3/P4) as a function of reaction times (RT, msec), error percentage (%), relative amplitude of the ERD (%) and latency of the ERD (msec).

	RT		Errors		Amplitude ERD		Latency ERD	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Task variables								
Accuracy	515	84	4	5	72	17	388	149
Speed	327	20	26	17	68	18	392	193
Verbal	432	126	16	12	67	18	397	178
Non-verbal	411	96	14	10	66	19	382	167
Easy	391	73	10	7	64	19	343	155
Difficult	452	134	20	11	69	17	437	178
50/50	426	112	15	7	65	17	395	173
20/80	415	113	15	14	67	19	385	173
Same	434	118	19	13	70	17	411	176
Different	408	104	11	8	63	19	371	168
P3	–	–	–	–	63	18	384	174
P4	–	–	–	–	70	18	396	171

became longer when accuracy was required rather than speed (F (1, 7) = 198.1, $P < 0.0001$), with non-verbal tasks compared to verbal tasks (F (1, 7) = 25.50, $P < 0.005$), with increasing task difficulty (F (1, 7) = 149,75, $P < 0.0001$), within the 20/80 probability condition (F (1, 7) = 12.19, $P < 0.05$) and when a same response was required (F (1, 7) = 40.38, $P < 0.0005$), for means see Table II. Instruction (accuracy vs. speed) interacted significantly with response type (F (1, 7) = 6.24, $P < 0.05$), task difficuly (F (1, 7) = 99.83, $P < 0.0001$) and verbal/non-verbal tasks (F (1, 7) = 26.25, $P < 0.005$). The results indicated that differences in RTs are primarily found in the accuracy condition and not in the speed condition. That is, when accuracy is stressed RT was 45 msec longer during verbal than during non-verbal tasks, easy tasks showed a decrease of 125 msec compared to difficult tasks. Same responses were 41 msec longer than different responses. When speed was stressed differences in RTs were minimal, that is, none of the RT differences during type of response, task difficulty and verbal/non-verbal tasks exceeded 10 msec.

Most errors (26%) were committed in the speed condition (F (1, 7) = 83.99, $P < 0.0001$). Error percentage also increased with increasing task difficulty (F (1, 7) = 147.90, $P < 0.0001$) and when a same rather than a different response was required (F (1, 7) = 52.57, $P < 0.005$; see Table II). The instruction by task difficulty interaction (F (1, 7) = 88.81, $P < 0.0001$) revealed that error percentages increased with increasing task difficulty, for accuracy as well as speed instructions. However, increases in error percentages were more pronounced during speed (16%) than during accuracy (5%). A similar effect was found for the instruction by response interaction (F (1, 7) = 58.45, $P < 0.0005$). When accuracy was stressed, same responses (compared to different responses) showed a small increase in error percentages (1.7%), whereas during speed same responses showed an error increase of 13%. In the case of the probability by response interaction (F (1, 7) = 175.99, $P < 0.0001$) same responses led to more errors in the low probability condition (17%) than in the equal probability condition (3.5%).

Level of prestimulus alpha power

Instruction (F (1, 7) = 5.02, $P < 0.06$) yielded a marginal and electrode side (F (1, 7) = 7.7, $P < 0.05$) yielded a significant effect for the level of prestimulus alpha power (see Fig. 3). Speed instructions compared to accuracy instructions resulted in a decrease in prestimulus alpha power by 75 μV^2. Prestimulus alpha power recorded over the left hemisphere was found to be 62 μV^2 lower than over the right hemisphere.

There were considerable individual differences in prestimulus alpha power and the correlation between prestimulus alpha power and maximum power de-

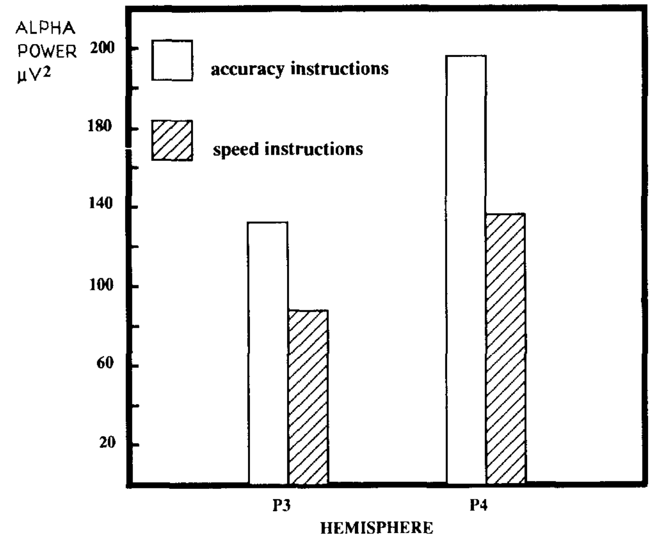


Fig. 3. Level of prestimulus alpha power, for accuracy and speed instructions, recorded at P3 and P4.

crease was high: r (512) = 0.988, $P < 0.005$. Thus, the amount of ERD depends mainly on the amplitude of the prestimulus alpha power. In view of this, as in previous reports (Van Winsum et al. 1984), the relative measure of desynchronization was chosen for further analyses. This measure resulted in a decreased correlation (r (512) = 0.47, $P < 0.005$) between prestimulus alpha power and relative ERD, and significant main effects for task difficulty and response; for statistics see next paragraph.

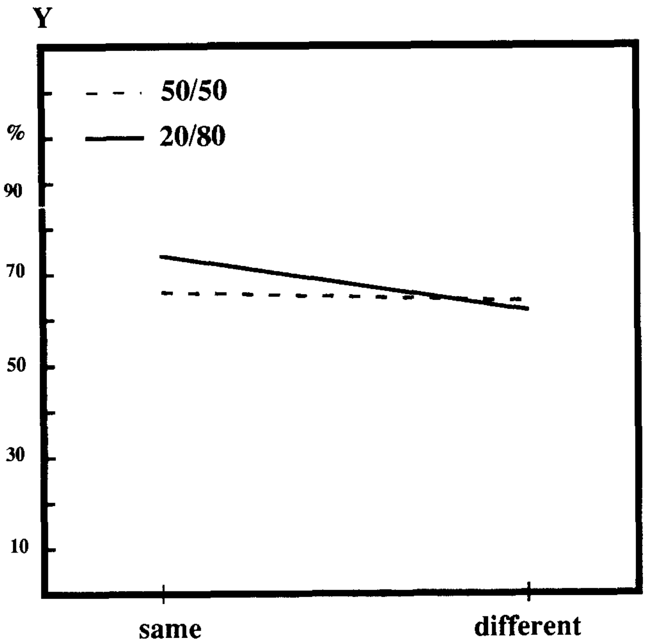
Relative event-related desynchronization

There was a positive correlation between the latency and the amount of relative ERD (r (512) = 0.47, $P < 0.005$). Relative ERD was smaller in the speed than in the accuracy condition (F (1, 7) = 5.67, $P < 0.05$). Increasing task difficulty led to an enhanced relative ERD (F (1, 7) = 10.09, $P < 0.05$). When subjects were required to give a 'same' response ERD was larger than when subjects were required to give a 'different' response (F (1, 7) = 30.39, $P < 0.01$). Relative ERD was larger over the right than over the left hemisphere (F (1, 7) = 5.9, $P < 0.05$). This effect was independent of the other task variables.

The interactions difficulty by response (F (1, 7) = 17.88, $P < 0.005$) and probability by response (F (1, 7) = 18.64, $P < 0.005$) revealed that same responses, given within the difficult condition and 20/80 probability condition, led to larger relative ERD than same responses given within the easy and 50/50 probability condition (see Fig. 4).

Latency of maximal event-related desynchronization

Task difficulty led to a strong increase of the maximal ERD latency (F (1, 7) = 58.62, $P < 0.0005$). When same responses were required the ERD latency was



y- axis= relative decrease alpha power (ERD)

Fig. 4. Mean event-related desynchronization as a function of response probability (50/50% probability dashed line, 20/80% probability solid line) and response type.

longer than when a different response was required (F (1, 7) = 6.67, $P < 0.05$). The probability by response interaction showed that same responses given during the 20/80 probability condition led to a longer latency of the ERD (85 msec) than same responses given during the 50/50 probability condition (6 msec). The results indicate that differences in latency and amplitude of the ERD for same and different responses are primarily the result of the 20/80 probability condition.

Discussion

The main findings of this experiment suggest that the prestimulus level of alpha power is sensitive to the subject's activation state. Relative ERD is mainly influenced by task difficulty and type of response. The lateralization data show that prestimulus alpha power and relative ERD are asymmetrically distributed over the left and right hemispheres, both being higher in the right hemisphere. The verbal/non-verbal distinction did not result in asymmetries of ERD.

The prestimulus level of alpha power decreased bilaterally when speed was stressed. The prestimulus level of alpha power was not affected by computational demands. This indicates that the prestimulus level of alpha power is mainly influenced by variables which manipulate the subjects activation state. In order to explain the relation between speed emphasis, activation and prestimulus processes, it might be argued that, when subjects are required to perform under a time pressure they need to apply more effort to maintaining a tonic readiness (activation) for action. Under this assumption, effort in preparing to act increases cortical activation, and hence alpha power suppression even before the stimulus is presented. Klimesch et al. (1988) have also reported that energetic variables such as readiness and expectancy affected prestimulus alpha power. That attentional processes might be monitored by the level of prestimulus alpha power has been shown by Miltner et al. (1988), who investigated the effects of prestimulus attention levels on the size of the N100-P200 complex. The attention levels prior to painful stimulation were estimated by means of the alpha power in the prestimulus interval. It was found that there was a more pronounced N100-P200 complex after prestimulus periods with high alpha power.

The laterality data (electrode site) indicate that there was less prestimulus alpha power on the left than on the right hemisphere. Since this effect is independent of the various task variables, it is suggested that this phenomenon is a structural or subject-related effect. Similarly, this result suggests that, independent of the type of task subjects perform, the left hemisphere is more activated than the right hemisphere. However, a more definite statement on this issue can only be made when the distribution of prestimulus level of alpha power is also recorded during a rest or non-respond condition. This was not done in this study.

In contrast to the prestimulus level of alpha power, the latency and amount of relative ERD have been shown to be sensitive to task demands. Difficult tasks and same responses led to an increase in latency and to an increase in the amount of relative ERD. The increase of relative ERD due to task difficulty replicates an earlier finding (Van Winsum et al. 1984). Same responses were more difficult in our study than different responses, probably because in the 20/80 probability condition subjects were required to respond more often with a different response than with a same response. Therefore, same responses were more difficult to predict than different responses. This is supported by the response by probability interaction of the performance measurements. These data suggest that the latency and amount of relative ERD might be used as indices to differentiate between cognitive processing. Furthermore, the relative ERD, as a phasic response to input, seems to correspond with the notion of arousal (Pribram and McGuinnes 1975). An increase in ERD is accompanied by an increase in reaction time and error percentages, which is in line with the notion that arousal is augmented with increasing complexity of the stimuli (Berlyne 1969).

An interaction between prestimulus level of alpha power and the amount of ERD was found in the speed condition and was associated with laterality. Both prestimulus level of alpha power and relative ERD decrease bilaterally, when speed is stressed. This is coupled with decreasing reaction time and increasing error rates. There are two possible lines of explanation for this finding. One explanation is that the positive correlation between prestimulus level of alpha power and relative ERD is due to the law of initial values (Wilder 1957). That is, when speed is stressed ERD starts at a lower level of alpha power than when accuracy is emphasized. A second possible explanation is that the ERD not only reflects stimulus specific but energetic processes as well (Klimesch et al. 1988). The more difficult a task the more attentional resources must be allocated to performing it. Resource allocation in cognitive tasks has been studied by using the amplitude of the P300 and the ERD (Sergeant et al. 1987). It was found that ERD amplitude became larger and P300 amplitude smaller with a larger load or task difficulty and a slow event rate. Furthermore, ERD duration and P300 latency became longer with a slow event rate and a higher processing load. This suggests that ERD amplitude and P300 amplitude are different cortical indices of the same attentional processes, both capable of monitoring the degree of resource allocation. It might be argued that subjects allocate their attentional resources to maintain a high state of activation in order to beat the speed deadline. This is done at the expense of allocating attention to computational processing, monitored by a decreased ERD. If a subject's activation system is viewed as a resource pool (Sanders 1983; Sergeant et al. 1987), which demands that attention be allocated to maintain a high speed of responding, this will result in a smaller ERD than when accuracy is stressed. Or, as the data suggest, when speed is stressed, there is less alpha power left over to desynchronize, which results in a decreased relative ERD. Thus, different levels of prestimulus activation affect the poststimulus ERD.

The greater relative ERD over the right than over the left hemisphere may be related to the positive correlation between the prestimulus level of alpha power and the relative ERD. Since the prestimulus level of alpha power is greatest over the right hemisphere, one might expect a greater relative ERD. Assuming that ERD is an index of arousal, this result implies that during cognitive processing the right hemisphere is more aroused than the left hemisphere. This has been advocated by Tucker and Williamson (1984); based on lateralized neurotransmitter pathways, they reviewed the evidence that the arousal and activation systems can be distinguished from one another. They proposed that the two cerebral hemispheres have become specialized for the attentional controls underlying these functions. The left hemisphere uses the regulatory properties of activation, and the right hemisphere relies on arousal. For instance, Tucker and Williamson showed that there is substantial evidence that the right hemisphere is more involved in emotional processes than the left, while in turn emotions are rooted in the phasic arousal mechanisms (Pribram 1981). The laterality effect of relative ERD and their proposed indication of arousal require replication before definite conclusions may be drawn.

No verbal/non-verbal task dependent asymmetries were found for phasic ERD. Others have found when using theta, beta and alpha spectral bands in cognitive tasks, that asymmetries in the electroencephalogram could be attributed to efferent limb movements (Gevens et al. 1979). One possibility for the absence of asymmetries here is that the tasks were not powerful enough to induce laterality effects, although they were clearly effective in the information processing demands. An alternative explanation may be that, if one accepts the idea that the left and right hemispheres are differentially involved in cognitive processing, then the duration of stimulus processing should be considered. Rebert and Mahoney (1978) indicated that it is doubtful whether alpha asymmetries may be observed when tasks do not continuously engage a subject for some minimum amount of time. This is consistent with the present study. The duration of trials was short (about 2 sec). Another explanation may be that in most studies on asymmetries of alpha power, the experimental design is different from the design used here. Asymmetrical suppression of alpha power during, e.g., mental arithmetic is considered as evidence of a lateral specialization of the brain compared with a baseline (non-processing) condition. In the present study, (phasic) suppression of alpha power was stimulus locked and compared with the prestimulus alpha power level for accuracy as well as speed instructions. The advantage of this method is that phasic and tonic differences in alpha power can be monitored during task performance.

In conclusion, the data suggest that prestimulus alpha power is mainly influenced by the activation state of the subject. The relative ERD, as a phasic response to input, seems to correspond with the notion of arousal. The study also demonstrates the importance of prestimulus activation processes of the brain on the size of the poststimulus ERD amplitudes. The present method might therefore be used to resolve issues concerning arousal and activation and contribute to the study of cognitive demands and EEG asymmetries.

This research was performed in the Laboratory for Experimental Clinical Psychology in Groningen.

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