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EEG ALPHA RHYTHM, OCULAR ACTIVITY AND BASAL SKIN RESISTANCE

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Most hypotheses about the origin of the occipital alpha rhythm stress the specific influence of ocular activity.

In this study, the influence of eye-movement frequency and extreme upward deviation of the eyeballs (enlarging the corneo-retinal potential) on occipital alpha activity and basal skin resistance is investigated. Eye-movement frequency did not significantly influence alpha activity and basal skin resistance. On the other hand, extreme upward deviation of the eyeball resulted in alpha activity enhancement and BSR increase. A white noise stimulus, given while the eyeballs were in an extreme upward position lead to a significant decrease in both alpha activity and BSR. However, the influence of the white noise condition was relatively larger on BSR than on alpha activity.

The results of this study lead to the hypothesis that the extreme deviation of the eyeballs effects occipital alpha activity in two different ways; one is a direct influence from the eyes, along a low conductance pathway to the occipital region, according to Ennever; secondly, it is proposed that, during the extreme upward deviation of the eyeballs, inhibitory impulses from extra-ocular muscle receptors are sent down to the reticular formation leading to alpha activity increase (e.g. cortical arousal decrease).

In the search for neural correlates of behavior, much attention has been given to the electroencephalogram (EEG) and, in particular, to the alpha rhythm (8–12 c.p.s.) of the occipital region of the cerebral cortex.

The alpha rhythm correlates with a state of relaxed wakefulness. In particular, the lower alpha frequencies occur during the transition to sleep. The classical view is that occipital alpha activity originates from the activity of cortical neurons in the occipital region.

According to Mulholland (1965, 1971), variables such as eye-position and lens-accommodation influence alpha activity and Lippold (1970) supplies evidence for a significant influence of extra-ocular muscle (EOM) activity on occipital activity.

A detailed hypothesis about the origin of the alpha rhythm is presented by Ennever (1972), the main point being that alpha activity is dependent on the interaction of the corneo-retinal potential and EOM activity. In Ennever's hypothesis, alpha enhancement can occur by a direct action of the corneo-retinal potential on the occipital region through the nervus opticus.

A simple way of increasing the corneo-retinal potential is by turning the eyeballs to an extreme upward position. As a result of such turning, alpha enhancement can be observed, but the question can be asked whether such an arousal decrement is effected without any contribution of other central arousal regulating structures than the cerebral cortex. We therefore studied changes in arousal due to changes in eyeball position, but we measured arousal, not only through EEG recordings, but also through basal skin resistance (BSR), according to Greenfield and Sternbach (1972) the most sensitive index of autonomic arousal.

Autonomic arousal, as seen in BSR records, is supposed to be more under control of lower arousal regulating structures than the cerebral cortex. Thus a concomitant decrement in cortical and autonomic arousal would indicate that the enlarging of the corneo-retinal potential, besides the effect through the direct pathway, also has an arousal decreasing effect on lower central arousal regulating structures. This might also contribute to alpha enhancement.

Method

Subjects

Eighteen psychology students of the State University of Utrecht. All *S*s had normal or corrected vision. Those wearing glasses kept them on during the experiment.

Apparatus

Standard EEG electrodes were attached to the right parieto-occipital region P2–04 in the 10–20 system with a reference electrode at the hairline of the forehead. Each EEG electrode was attached with a 6% solution of collodium and filled with EEG electrode paste. Resistance was down to 2 kΩ for each electrode.

The EEG was recorded with amplifiers having high- and low-pass cut-off frequencies of 0.6 and 23.3 c.p.s., respectively. The signal was analyzed for the presence of alpha activity by means of a digital filter, whose output was true (positive logic) for the presence of alpha waves (8.3 – 13.2 c.p.s.), and false otherwise. (Detection criterion was one period.)

This output and the EEG were displayed as ink records on the polygraph.

The same type of electrodes were used for the electro-oculogram (EOG). They were placed at the outer canthus of each eye for the horizontal EOG. Infra-orbital and supra-orbital electrodes were placed in line with the pupil of the left eye for the vertical recording. Resistance was down to 2 kΩ for the horizontal electrodes and down to 3 kΩ for the vertical electrodes. The signals related to the horizontal and vertical movements of the eye were recorded, and the composition of both were filmed (16 frames per sec) as a two-dimensional representation from a storage oscilloscope (erasing every 2 sec, erasing time 243 msec).

Two AgAg–Cl pellet electrodes (diameter 0.5 cm) were used for measuring the basal skin resistance (BSR) and the skin resistance reaction (SRR) with a constant current system (10 uA/cm^2). Current and voltage were measured to give the *S*s resistance. The electrode paste contained a 0.05 molar concentration of NaCl on an agar-agar base. White noise was presented with an intensity of 50 db.

A slide projector set up in the apparatus room projected onto a screen in front of the *S*s through an opening in the wall of the acoustically and electrically shielded room in which the *S*s were lying.

The presence of a stimulus was recorded on the polygraph and made visible on film.

The visual stimuli consisted of two slides. Slide 1 contained numbers of 1 to 21 scattered in a random order on the whole area. Slide 2 consisted of a row number from 2 to 7 placed horizontally across the middle of the slide.

Procedure

On arrival, the *S*s were familiarized with the procedure, and put at ease regarding the methods employed and their part in the experiment. While the electrodes were being attached in the instrument room, which adjoined the experimental room, the *S*s were given written step-by-step instructions to read through.

After entering the experimental room, the *S* lay down on a bed with an adjustable head support, facing a matt screen. The *S*s head was fixated by means of a head clamp. Calibration was carried out to ensure linearity of signals. Subsequently the door of the experimental room was closed.

The experiment started with an adaptation period lasting 7 min. After this period the first stimulus was presented, which formed the rapid search condition. The *S* was instructed to find the correct order (1, 2, 3 etc.) of the stimuli as quick as possible. Duration of the first stimulus was 7 sec. After a 20 sec interval, the second stimulus was presented, initiating a maintained fixation condition in which the *S* was required to fixate each of the 6 numbers during 2 sec. This was followed by another 20 sec rest period. The third condition consisted of the extreme upward deviation of the eyeballs during 7 sec. Following this condition, a 50 db white noise stimulus was given during 7 sec, during which the *S* was told to keep his eyes in the same upward position.

Throughout the experiment, skin resistance levels were recorded at every stimulus presentation.

Scoring

(a) EEG alpha time

During each of the 4 conditions, alpha activity was scored for 7 sec from the start of the condition. The total duration of α detected by the α-filter (true) was scored from the ink-record, in seconds.

(b) Eye-movement frequency

Eye-movements were scored from film. As the storage oscilloscope representation of the eye-movements was erased every 2 sec, a clear eye-movement pattern was visible. Scoring was done with an analysis projector, with which frame for frame could be scored. The number of eye-movements per sec was determined over the 7 sec.

(c) Basal skin resistance

At the beginning and at the end of each condition, the voltage and current values were noted. The skin resistance values could thus be determined and averaged.

Results

(a) Eye-movement frequency

There was a significant decrease in eye-movement frequency in the maintained fixation condition (condition II) relative to the rapid search condition (condition I), as indicated by a two-tailed t-test for dependent means (Ferguson 1966) (see table 1).

However, the decrease in eye-movement frequency is not accompanied by a significant change in alpha activity and BSR (see fig. 1).

(b) Extreme ocular deviation

There is a significant increase in alpha activity (table 2) during condition III (ocular deviation) relative to condition II (maintained fixation); there is no significant difference in eye-movement frequency between the two conditions. Basal skin resistance also showed a significant increase in condition III when compared with condition II.

(c) Effect of white noise

During the white noise condition (condition IV) there is no significant increase in eye-movement frequency, when compared with condition III (table 3). Both alpha activity and BSR show a significant decrease.

Table 1
t-values, two tailed. Condition I (rapid search) vs condition II (maintained fixation).

	Condition I – Condition II		
Alpha time	–0.8	$df = 18$	$p > 10\%$
BSR	–0.7	$df = 18$	$p > 10\%$
Eye-movement fr.	–9.2	$df = 13$	$p < 1\%$

Table 2
t-values, two-tailed. Condition II (maintained fixation) vs condition III (eyes upward).

	Condition II – condition III		
Alpha time	–3,21	$df = 16$	$p < 1\%$
BSR	–3,12	$df = 15$	$p < 1\%$
Eye-movement fr.	0.92	$df = 14$	$p > 10\%$

Table 3
t-values, two-tailed. Condition III (eyes upward) vs condition IV (eyes upward during presentation of a 50 db white noise stimulus).

	Condition III – Condition IV		
Alpha time	2.65	$df = 17$	$p < 1\%$
BSR	3.80	$df = 17$	$p < 1\%$

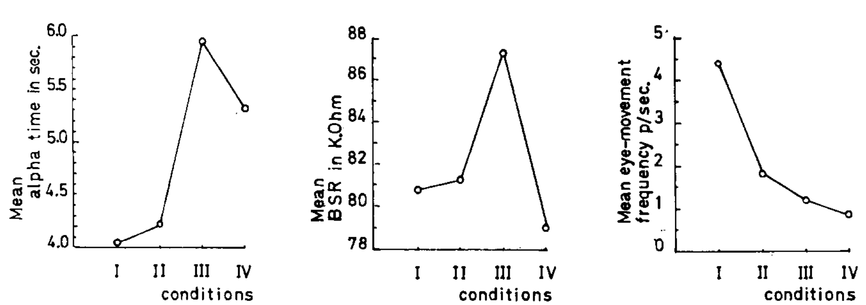

Fig. 1. Mean alpha time, BSR and eye-movement frequency scores during the 4 conditions.

Table 4
t-values, two-tailed. Condition I (rapid search) vs condition IV (eyes upward during presentation of a 50 db white noise stimulus)

	Condition I – Condition IV		
Alpha	–2.59	$df = 16$	$p < 2\%$
BSR	1.59	$df = 15$	$p > 10\%$

There is, however, a difference between the alpha change and the BSR change: during the white noise condition the BSR dropped to the level of the rapid search condition, whereas alpha activity was still significantly higher in this condition than in the first condition (see table 4).

Discussion

Although there is a significant difference in eye-movement frequency between the rapid search condition and the maintained fixation condition, no significant difference in amount of alpha time is found, and it is to be concluded that eye-movement frequency does not significantly influence the EEG alpha rhythm under the conditions used.

Comparing the data of condition II (maintained fixation) and condition III (extreme upward ocular deviation), it is observed that extreme upward deviation of the eyeballs leads to a significant increase in amount of alpha time. The latter data are in accordance with those reported by Mulholland (1965). It is of interest that in condition III the BSR also showed a significant increase compared with condition II. The observed increase in BSR is interpreted (Greenfield and Sternbach 1972) as a decrease in sympathic activity.

Contradictory to the expected dissociation of cortical and autonomic arousal during condition III, we find a concomitant decrease in cortical and autonomic arousal.

These results lead to the assumption that the extreme upward deviation of the eyeballs has an effect on arousal regulating structures lower than the cerebral cortex. However, although there are also indications that the upward ocular condition has an arousal decreasing effect not restricted to the cerebral cortex, there are indications that alpha activity is at least partly influenced in the way proposed by Ennever (1972), e.g. via a direct pathway from the eyes to the occipital region.

Both variables, BSR and amount of alpha time, show a significant decrease during the white noise condition. However, it is important to note (see fig. 1) that, during the white noise condition, amount of alpha time is still significantly higher than in the arousing condition I, while the BSR shows a decrease during the white noise condition to the level of condition I. In this sense there is a dissociation between cortical and autonomic arousal. This could mean that, despite the observed arousing effect of the white noise condition on amount of alpha time, the extreme upward deviation of the eyeballs still has a significant effect on alpha activity in the way proposed by Ennever.

The results of this study suggest that the increase in amount of alpha time following the extreme upward deviation of the eyeballs is effected in two different ways.

First, there is the way proposed by Ennever, according to which the enlarged corneo-retinal potential, interacting with EOM activity, causes an increase in alpha activity by way of a low conductance path leading from the eyes to the occipital region.

In the second way, suggested by the decrease in sympathic activity on the one hand, and the significant effect of the white noise condition on amount of alpha time on the other hand, the extreme upward deviation of the eyeballs has an effect on lower arousal regulating structures (e.g. the reticular formation) that results in an arousal decrement that is both cortical and autonomic.

There is some evidence supporting a central inhibitory influence of extra-ocular stretch receptors. Cooper (1953) recorded afferent impulses from extra-ocular stretch receptors in the reticular formation and Gernandt (1968) and Euston (1970) demonstrated that these impulses exert inhibitory effects on ascending vestibular and skeletal muscle activity, respectively.

A possible explanation for the observed decrease in sympathic activity during the extreme upward deviation of the eyeballs is that eye-muscle receptors, which are identified in the extra-ocular muscles of several animal species as well as in those of man (Bach-y-rita 1971), are activated by the extreme position of the eyeballs, and send down inhibitory impulses to the reticular formation.

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