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# VISUALIZING AND RHYMING CAUSE DIFFERENCES IN ALPHA SUPPRESSION

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## INTRODUCTION

Alpha rhythms of the EEG are strongest at the occipital regions of the head, and the visual cortex is apparently a major contributor. It has been suggested that visual cortex is involved in forming and processing mental images (Shepard and Metzler, 1971). The purpose of this experiment is to determine if a task that involves visualizing objects represented by words produces changes in alpha rhythms of the MEG that differ from changes associated with finding rhymes of the same or related verbal stimuli. By hypothesis, the visual areas of the cortex play a less prominent role in the latter task than they do in the visualizing task. This inference is consistent with the finding that visual imagery is accompanied by attenuation of the alpha rhythm over the occipital scalp, in the proximity of visual cortex (Golla et al. 1943; Slater, 1960). Pfurtscheller (1988) notes that cognitive factors, such as memorization and classification of words, affects the pattern of alpha blockage across the occipital and parietal area, but this does not establish that visual cortex *per se* is involved. Farah et al. (1989) presented words to subjects who responded by forming mental images of the objects represented by the words. The event related potentials associated with presentation of the words were larger in amplitude than they were when the subjects silently pronounced words that rhymed with the stimuli instead of forming mental images. This effect was more evident at occipital electrodes than it was at other locations.

Various types of analysis of neuromagnetic recordings indicate that magnetically detected activity in the alpha bandwidth (Chapman et al. 1984) as well as individual alpha spindles (Williamson et al. 1989), have sources within visual areas. Thus there may well be differential suppression of alpha activity depending on the degree to which visual resources are engaged in various mental tasks, such as imaging. This expectation motivated the present study.

## METHODS

A list of words was viewed by a subject (one word at a time) and the subject is instructed either to form an image of the object specified by the word if it is imageable or, to recite a word that rhymes with the presented word. In the rhyming condition imageable and non-imageable words were used, while in the imaging condition only the former one was used. To find how the visual presentation itself affects brain activity, a list of nonsense words were also presented to the subject. In this case the subject was required only to see/read the words without performing any task. The recordings were run by blocks. There were two blocks for the rhyming task and one block for each of the others. Each block contained 36 words that appeared for 200 msec on a screen inside a magnetically shielded room.

A 5-sensor SQUID system was placed over the occipital area in right or left hemisphere near the region where alpha activity is strongest. Measurements of the MEG during 6 seconds were taken for each word stimulus, beginning 2 second before the stimulus appeared and extending 4 seconds afterwards. The output of the SQUID electronics were bandpass filtered from 0.1-50 Hz and then digitally filtered from 8-12 Hz before computing the average response and the variance about the average. The variance represents brain activity that is not coherently related to the presentation of the visual stimulus (word). The variance in this sense is the mean power of spontaneous activity in the alpha bandwidth.

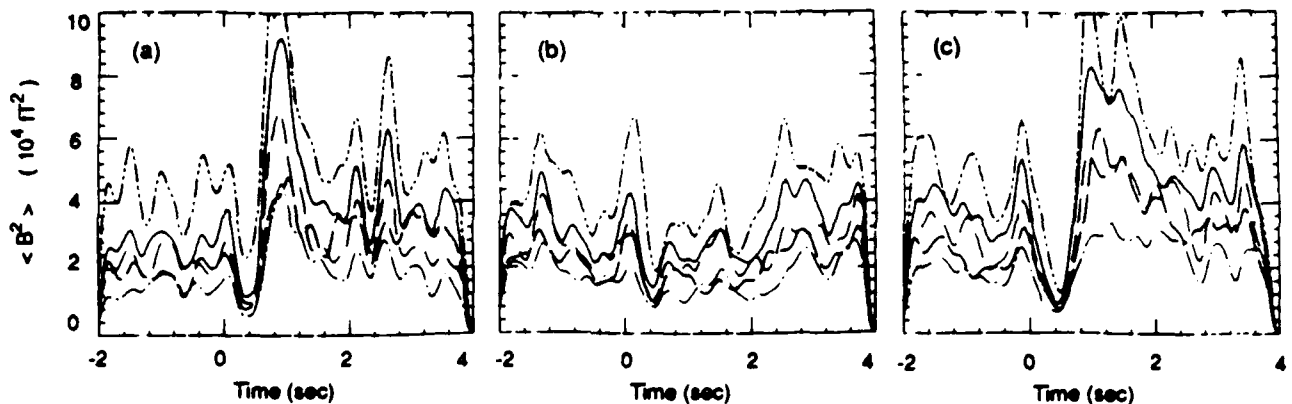


Figure 1. A representative plot of alpha power, detected by 5 channels, for the (a) rhyming, (b) imaging, and (c) reading tasks.

## RESULTS

Figure 1 shows alpha power as a function of time for the three conditions: rhyming task with non-imageable words, imaging task with imageable words, and reading non-sense words. The suppression of alpha in all cases started at about the instant of word presentation (time origin). What is notable is that for the rhyming and reading tasks the duration of this reduction is 0.60 sec while the period of suppression in the imaging task is about 1.5 sec. This shows that the visual presentation alone suppresses alpha activity but it is short-lived. There is rapid recovery for nonsense words and rhymable words. Finding rhymes by itself does not affect alpha activity in the occipital region.

In addition it is clear that the recovery of alpha has a different appearance in these two cases. When the subject performs the rhyming task there is a marked rebound of alpha power that often exceeds the original level of power just before word presentation. Such a "rebound" is not evident when the subject engages in forming an image. We suggest that the *rebound effect* reflects the involvement of non-visual portions of the cortex in language related tasks, thus "freeing" visual cortex from activity that otherwise constrains the level of alpha activity.

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## ALPHA SUPPRESSION RELATED TO A COGNITIVE TASK

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### INTRODUCTION

When subjects are in a resting but alert state, alpha activity (8-12 Hz) predominates in the spontaneous EEG. It has been reported (Kaufman and Locker, 1970; Pfurtscheller, et al., 1977, 1987) that alpha suppression coincides with presentation of visual stimuli and that its time-course is much longer than that of the classic evoked response. In this paper we report that MEG activity during a visual memory task shows a dramatic amplitude reduction in the alpha range lasting 500 to 2000 msec, following which the amplitude recovers despite continuous visual fixation on the display.

Previous MEG studies (Chapman, et al., 1984; Ilmoniemi, et al., 1988) showed that alpha spindles have multiple sources in occipital and perhaps in parietal areas. This raises the possibility that in addition to global suppression of alpha activity, mental activity may result in local suppression of some alpha sources. To test this hypothesis, we gave subjects a variation of a classic memory search task (Sternberg, 1969) in which memory load is varied systematically and reaction times are predicted according to a simple model. We observed "evoked" alpha suppression along with the averaged responses. In this paper we present the analysis of data from one 41 year old male subject. Data analysis from other subjects will be described in detail in subsequent publications.

### METHODS

The subject, seated on a chair in a magnetically shielded room, maintained fixation on a small cross and viewed a sequence of three white outline, irregular polygon shapes on a dark background in the lower right quadrant of his visual field. Each shape was seen for 1 sec, followed by a 0.3 sec dark interval; 3.0 sec after the disappearance of the last image a fourth "probe" shape was presented for only 0.1 sec. In one block of trials ("choice reaction", CR) the subject pressed one of two buttons after seeing the probe, indicating whether it belonged in the memory set or was new. Each block of trials consisted of a sequence of 30 epochs (1 epoch = 3 + 1 shapes) and responses. In a second block of trials ("simple reaction", SR) the subject saw all the forms but simply had to press one button as soon as he saw the probe.

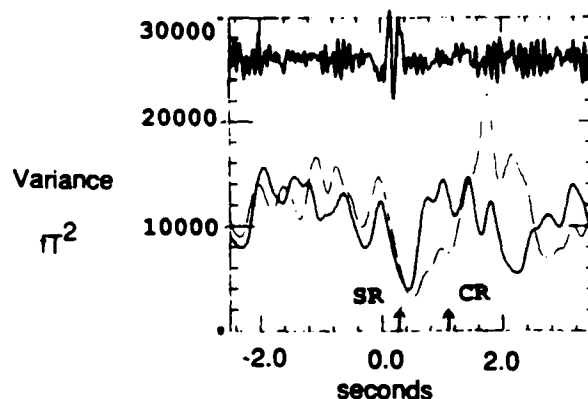
The component of the magnetic field normal to the subject's head was recorded over posterior and parietal areas on about 74 different locations by means of a 5-channel SQUID-based Neuromagnetometer (Williamson, et al., 1983; Buchanan, et al., 1988) The outputs of the SQUIDs were bandpassed between 0.1 - 50 Hz. The recording epoch lasted 7 sec, 3 sec prior to and 4 sec following the onset of the (100 msec) visual probe.

Visual evoked potentials were extracted after digitally filtering the MEG between 1 and 20 Hz and then averaging over the 30 recording epochs. Alpha activity was isolated by filtering each epoch of data between 8 and 12 Hz, and computing the variance across the 30 trials in each block as a function of time for each SQUID channel. This variance is the mean square field (power), which excludes the evoked response. Temporal changes in this variance are due to changes in amplitude, not to incoherence across the epochs since the alpha activity is clearly not time-locked to the stimulus.

## RESULTS

Our results support the notion that MEG power in the alpha band undergoes a systematic reduction during the performance of visual memory-search tasks. The evoked responses are much briefer than either the power variation or the reaction times (RT's). The variance in fact diminishes dramatically just after the onset of the probe and recovers after a duration characteristic of the task. In the SR task, the drop is generally much steeper than in the CR task and the average RT nearly coincides with the time at which the alpha power reaches its minimum, suggesting that the subject was prepared to respond as soon as the stimulus appeared. The longer duration of the suppression in the CR task is consistent with the interpretation that the visual cortex is engaged during a search of memory. Simple RT's were always much shorter than the choice RT's.

Fig. 1. A representative plot of variance across epochs. The darker trace is the SR condition, the lighter trace is the CR condition. Reaction times are indicated by arrows. An averaged evoked response is shown for temporal comparison (upper trace, arbitrary units). This evoked field is a grand average of 10 groups of 30 trials for all 5 sensors, as it was impossible to obtain a sharply defined evoked field averaging only 30 trials.



The reduction in alpha is due either to changes deep in visual cortex or to a more widespread pattern of activity of visual cortex nearer the surface. The duration of the suppression clearly depends upon the mental load required by the task, and is commensurate with the RT's. The effect is not restricted to the alpha band, but is also present in the beta band (16-24 Hz) of the MEG. Evidence is accumulating that although the suppression of alpha is a widespread phenomenon, local suppression is superimposed on it, depending upon the location of the visual stimuli in the visual field. We believe the above procedure may be useful for direct tests of hypotheses about the roles of various areas of the brain during different types of mental acts.

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