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Brain Mechanisms Subserving Self-Generated Imagery: Electrophysiological Specificity and Patterning

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ABSTRACT

The present study was designed to assess the patterning of occipital and sensorimotor EEG activation during self-generated visual and kinesthetic imagery. Twenty subjects were requested to imagine, in separate trials, a flashing light, a tapping sensation on the right forearm, and both the light and the tapping together. Prior to the imagery trials, subjects were exposed to the stimuli which they were asked to subsequently imagine. EEG was recorded from the left occipital and left sensorimotor regions, filtered for alpha and quantified on-line. The results indicated that self-generated visual imagery elicited greater relative occipital activation than comparable kinesthetic imagery. The imagine-both condition fell predictably in between the two unimodal imagery conditions. The difference between visual and kinesthetic imagery was primarily a function of greater occipital activation during the former versus the latter task. No difference in overall alpha abundance among the three imagery tasks was found. These findings suggest that the self-generation of imagery in different modalities elicits specific changes in the sensory regions of the brain responsible for processing information in the relevant modalities.

DESCRIPTORS: Imagery, EEG patterning, Self-generation, Covert processes, Mode-specificity.

Many workers in both the cognitive (e.g. Neisser, 1967, 1970) and physiological (e.g. Zikmund, 1972) literature have commented upon the similarity in the mechanisms of imagery and perception. This suggestion has led to the search for neural concomitants of imagery using the scalp recorded EEG as a dependent measure. Research in this area has primarily been directed at determining whether the occipital alpha rhythm would be attenuated during the generation of visual imagery as was first described by Short (1953).

A number of investigators following Short (1953) have reported decrements in occipital alpha abundance during visual imagery versus imagery in other sensory modalities (e.g. Barratt, 1956; Mundy-Castle, 1957; Slatter, 1960). However, the interpretation of this finding has been called into question by a number of workers (e.g. Oswald, 1957; Simpson, Paivio, & Rogers, 1967) who conclude that the suppression of occipital alpha may be explicable solely in terms of differences between tasks in degree of general "arousal" elicited.

Recently, the EEG recorded from multiple scalp locations has been employed to assess patterning and specificity of activation. Such a research strategy involves the comparison of shifts in activation between two or more EEG sites from one task to another where overall alpha abundance is not found to differ significantly between the tasks. A growing body of data is accumulating which suggests that specifically designed tasks elicit predictable patterns of cortical excitation and inhibition in relevant brain regions, both interhemispherically (e.g. Davidson & Schwartz, 1976; Schwartz, Davidson, & Pugash, 1976) and intrahemispherically (e.g. Davidson, Schwartz, & Rothman, 1976; Lenson, Davidson, & Schwartz, 1976). Importantly, predictable

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shifts in EEG asymmetry have been found to accompany both overt, behavioral tasks (e.g. Galin & Ornstein, 1972; Davidson & Schwartz, 1977) as well as covert tasks requiring the self-generation of imagery in specific cognitive modes, i.e. verbal versus visuospatial or non-affective versus affective (e.g. Davidson & Schwartz, 1976; Galin & Ornstein, 1972; Robbins & McAdam, 1974).

Recent research from this laboratory has extended the application of EEG pattern analysis to the study of mode-specific selective attention. Two studies were performed which demonstrated that during selective visual versus tactile attention, the ratio of EEG activity recorded from occipital and sensorimotor brain regions shifted significantly (Schwartz, Davidson, & Margolin, Note 1; Davidson et al., 1976b) indicative of relatively greater occipital activation during the former versus latter attentional task. To date, this type of pattern analysis procedure, involving the recording of EEG activity from specific sensory regions, has not been applied to the study of the cortical concomitants of imagining in different modalities. Based upon behavioral research suggesting that imagery in different modalities is subserved by the perceptual apparatus specific to the modality in question (e.g. Segal, 1971; Segal & Fusella, 1970), the present study was designed to explore sensory-specific EEG patterning during the self-generation of imagery in two modalities. It was specifically hypothesized that visual imagery should result in relative occipital EEG activation while kinesthetic imagery should elicit relative activation in the motor region. Imagining simultaneously in both modalities was hypothesized to result in a pattern in between those elicited by the two unimodal imagery conditions.

Method

Subjects

Twenty female right-handed Radcliffe undergraduates served as subjects. All were paid volunteers and in good psychological and physical health.

Apparatus and Recording Procedure

The subjects were seated on a reclining chair in a sound attenuated room. Monopolar EEG was recorded from the left occipital area and left sensorimotor area (O_1 and C_3 respectively, Jasper, 1958) referenced to linked ears with Beckman miniature silver/silver-chloride electrodes and all electrode resistances were below 5000 ohms. Subjects were grounded with a plate electrode on the left forearm. All measures were recorded on a Grass Model 7 polygraph and each EEG channel was filtered for 8–13 Hz activity and displayed on two additional channels individually calibrated to yield a pen deflection of 1.5 cm for an average peak alpha burst. Grason-Stadler logic modules were employed to detect and automatically count bursts of criterion alpha on-line. An arbitrary criterion of .5 cm was utilized so that alpha activity had to be at least 33.3% of the average peak amplitude to be counted. Bursts of four alpha waves within a maximum of .5 sec were required to activate the counter and constituted one alpha unit; this effectively removed any movement artifact from being counted as alpha, and provided a reliable, conservative measure of alpha activity. Such a procedure has been successfully employed in previous research from the present authors' laboratory on both interhemispheric and intrahemispheric cortical patterning (e.g. Davidson & Schwartz, 1976; Davidson et al., 1976b; Lenson et al., 1976).

Heart rate was also recorded with plate electrodes from the right arm and left leg. These data will not be reported here.

Procedure

Subjects were required to perform in trials 30 sec in duration during which they were requested to imagine either a visual or kinesthetic stimulus, or both, to which they had been previously exposed. In a 30-sec trial prior to the presentation of a particular imagery condition, subjects were presented with the stimuli which they were asked to subsequently imagine.[1] The stimuli were presented randomly in the pre-task trial with a mean of 55 stimulus presentations per 30-sec trial. Kinesthetic stimuli were delivered by taping a miniature (3 in.) radio speaker to the right forearm of each subject and wrapping the forearm in sound-attenuating foam. A 6 V pulse was introduced across the speaker terminals thereby producing an inaudible pop which resulted in a mild tapping sensation that was easily discriminable to all subjects. The visual stimulus consisted of a small flashing light which was located approximately 7 ft from the subject, at eye level.

Subjects were exposed to two repetitions of each of the three task trials: Imagine Visual, Imagine Kinesthetic, and Imagine Both. During the Imagine Visual trials, they were asked to imagine the same flashing light they had previously seen. During the Imagine Kinesthetic trials, they were asked to imagine the tapping sensations that they had previously experienced. During the Imagine Both trials, they were requested to imagine both the light and the tapping. All trials were counterbalanced within and between subjects. The intertrial interval was approximately 30 sec. Subjects were instructed to keep their eyes open and fixated on a small point directly in front of themselves during all experimental trials. All subjects were monitored on closed circuit video to ensure compliance with instructions.

Data Analysis

EEG data were evaluated with two basic methods. To assess the relative activation of O_1 versus C_3, a ratio score was derived representing the difference in alpha units between O_1 and C_3 over the sum of alpha at O_1 and C_3

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[1] During these trials, when actual stimuli were presented, the subjects were asked to selectively attend to the stimuli in different modalities. These data are reported elsewhere (Davidson et al., 1976b).

(O_1-C_3/O_1+C_3). This ratio score served to "correct" the obtained values for individual differences in absolute amount of alpha activity. Similar ratios have been frequently employed in EEG studies of hemispheric asymmetry (e.g. Galin & Ornstein, 1972; Davidson, Schwartz, Pugash, & Bromfield, 1976). Higher ratios are indicative of greater relative C_3 activation. A one way analysis of variance with Condition (Imagine Visual, Imagine Kinesthetic, and Imagine Both) as a repeated factor was then performed. Two-tailed t-tests were employed to assess the significance of individual comparisons.

The second method of EEG analysis entailed the use of the "raw" EEG scores. An analysis of variance with EEG site (O_1 and C_3) and Condition as repeated factors was performed.

All analyses were computed on the mean EEG alpha score for the two repetitions of each condition. Unless otherwise indicated, the rejection region is $p < .05$ throughout.

Results

A one-way analysis of variance on the mean EEG ratio scores revealed a significant effect for Condition (Imagine Kinesthetic, Imagine Both, and ImagineVisual), $F(2/38)=3.20$, $MS_e=.031$. These data are illustrated in Fig. 1. Two-tailed t-tests revealed a significant difference between kinesthetic and visual imagery ($t(19)=2.50$) indicating greater relative occipital activation for the latter versus the former task. None of the comparisons with Imagine Both were significant though it is noteworthy that this condition fell predictably in between the other two unimodal imagery conditions.

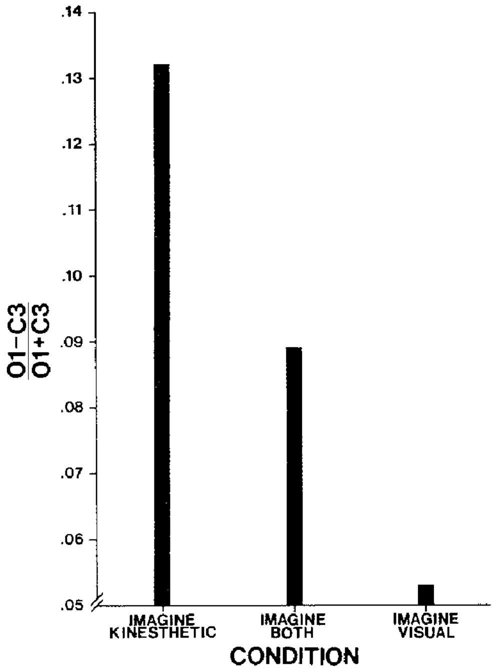

Fig. 1. Mean EEG ratio score (averaged across 2 trials) for each condition.

An analysis of variance with Condition and Site (O_1 and C_3) as factors was next performed to determine the precise locus of the imagery effect. As predicted a significant Condition × Site interaction was obtained ($F(2/36)=3.78$, $MS_e=86.76$) and is illustrated in Fig. 2. It can be seen that during kinesthetic imagery, subjects have more occipital and less sensorimotor alpha than during visual imagery. On occipital alpha, the Imagine Both condition was in between the other imagery conditions while on sensorimotor alpha, the three means were all very similar. Two-tailed t-tests revealed that during kinesthetic imagining, subjects had significantly more occipital alpha than during both visual imagining ($t(19)=2.92$) and imagining both ($t(19)=2.34$). There was no significant difference in occipital alpha between the Visual and Imagine Both conditions. When task effects upon sensorimotor alpha were examined, no significant differences were obtained. It thus appears that occipital alpha is more labile and is more sensitive to covert imagery task demands.

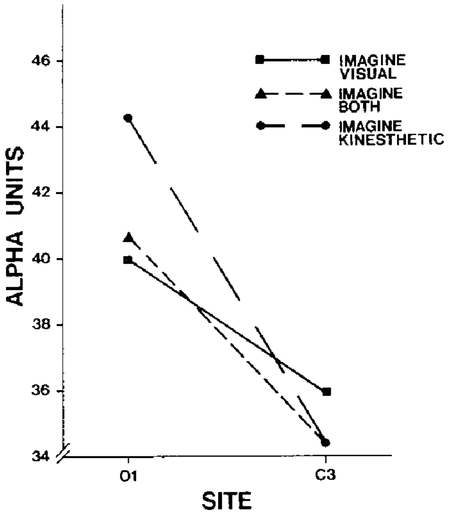

Fig. 2. Mean number of alpha units for each condition by EEG site (left occipital and left sensorimotor).

Importantly, there was no significant main effect for Condition ($F(2/38)<1$) indicating that the different imagery tasks did not differ in the overall amount of alpha (across O_1 and C_3 sites) elicited ($\bar{X}$ total alpha for visual = 37.9; for Kinesthetic = 39.4; and for Imagine Both = 37.6). A significant main effect for EEG site was obtained ($F(1/19)=8.13$, $MS_e=1336.67$) indicating that across conditions, greater alpha abundance was obtained at O_1 versus C_3 ($\bar{X}$ alpha for $O_1=41.64$; for $C_3=34.97$).

Discussion

The results of this study support the general hypothesis that self-generated imagery in different modalities elicits predictable patterning of EEG activity at primary sensory regions. Significantly dif-

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ferent patterns of occipital and sensorimotor alpha activity were observed during kinesthetic versus visual imagining, indicative of greater relative occipital activation during the latter versus the former task. The requirement to imagine both visual and kinesthetic events produced a pattern in between the other two unimodal imagery conditions.

When the raw EEG data were examined to locate the locus of the effect seen with the ratio score, it was found that differences in occipital alpha between the unimodal conditions were significant while no condition effects were seen for sensorimotor alpha. One possible interpretation of these findings is that subjects, on the average, experience visual imagery more vividly and consequently showed greater task dependent shifts in occipital alpha. An attempt was made to get an independent measure of vividness of imagery by administering the Betts' Questionnaire Upon Mental Imagery (Sheehan, 1967) to all subjects. Separate scores were derived for visual and kinesthetic imagery from this questionnaire. The results indicated a trend, across subjects, for vividness ratings of visual imagery to be higher than for kinesthetic imagery (on a 7 point scale, $\bar{X}$ visual rating = 4.08, $\bar{X}$ kinesthetic rating = 3.79; $t(19)=1.86$). Future research might specifically select subjects scoring high on kinesthetic versus high on visual imagery vividness and look for individual differences in mode-specific EEG patterning during the self-generation of imagery in different modalities. Such a strategy has proved successful in the behavioral literature where individual differences in vividness of imagery have been found to be associated with cognitive and perceptual differences on a variety of tasks (e.g. Marks, 1972).

It is important to note that no main effect for Condition (across O_1 and C_3 alpha) was obtained. This indicates that the three imagery tasks employed in the present study did not differ in overall amount of alpha activity. The fact that a condition by EEG site interaction was obtained suggests that the EEG shifts associated with imagery self-generation in the present study were not simply a function of differences in overall "arousal." Significant differences between the Imagine Visual and Imagine Kinesthetic conditions were obtained on EEG *patterning,* but not on overall differences in alpha abundance. These data help clarify the interpretation of previous findings in the literature on electrocortical concomitants of imagery (see Zikmund, 1972) and suggest that the generation of an image in a particular modality is associated with relative activation in the cortical region involved in information processing in that modality.

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