Objective.—To determine cortical oscillatory changes involved in migraine visual aura using magnetoencephalography (MEG).

Background.—Visual aura in the form of scintillating scotoma precedes migraine in many cases. The involvement of cortical spreading depression within striate and extra-striate cortical areas is implicated in the generation of the disturbance, but the details of its progression, the effects on cortical oscillations, and the mechanisms of aura generation are unclear.

Methods.—We used MEG to directly image changes in cortical oscillatory power during an episode of scintillating scotoma in a patient who experiences aura without subsequent migraine headache. Using the synthetic aperture magnetometry method of MEG source imaging, focal changes in cortical oscillatory power were observed over a 20-minute period and visualized in coregistration with the patient's magnetic resonance image.

Results.—Alpha band desynchronization in both the left extra-striate and temporal cortex persisted for the duration of reported visual disturbance, terminating abruptly upon disappearance of scintillations. Gamma frequency desynchronization in the left temporal lobe continued for 8 to 10 minutes following the reported end of aura.

Conclusions.—Observations implicate the extra-striate and temporal cortex in migraine visual aura and suggest involvement of alpha desynchronization in generation of phosphenes and gamma desynchronization in sustained inhibition of visual function.

Key words: magnetoencephalography, scintillating scotoma, visual aura, cortical oscillations, event-related desynchronization

Abbreviations: SAM synthetic aperture magnetometry, ERD event-related desynchronization

(Headache 2004;44:204-208)
Synthetic aperture magnetometry (SAM) and spatially selective spectral measures were used to directly image the cortical electrical activity associated with migraine visual aura, demonstrating the time course of the frequency-specific cortical activity within the occipital and temporal regions implicated in visual aura.

PATIENT AND METHODS

Our patient experiences classical scintillating scotoma without subsequent migraine headache approximately twice per year. The Aston University Human Sciences Ethical Committee approved this research, and written informed consent was obtained from the patient before the study. We recorded an episode of scintillating scotoma (which typically lasts for approximately 20 minutes) using a 151-channel whole head magnetometer system (CTF Systems Inc, Coquitlam, BC, Canada). The patient experienced a classical arc of scintillations moving from the central to peripheral visual field in the upper right quadrant. Typically, a transient scotoma occurs in the region trailing the scintillations, but provision was not included for its observation on this occasion.

Recording.—The recording was taken continuously over a 20-minute period, at the beginning of which the scintillations had made a significant progression toward the periphery. The visual disturbance persisted for the first 5 minutes 22 seconds and was followed by disappearance of the scintillation with remaining temporary loss of local vision, which slowly returned over the next 5 minutes. There was, therefore, a 10-minute period of recording in which no visual abnormalities were reported. Throughout the recording, the patient fixated on a central point and made brief verbal reports of the location of the visual disturbance in the visual field.

Statistical Analysis.—The MEG data were analyzed using an adaptive beamformer technique known as SAM, which provides 3-dimensional images of power changes in cortical oscillations within specific frequency bands, termed event-related synchronization/desynchronization (ERS/ERD). Synthetic aperture magnetometry has been used previously to image ERD and ERS in various functional studies of motor cortex, sensory cortex, and midline theta rhythms. These changes have been shown to be spatially coincident with the locus of the fMRI hemodynamic response. Additionally, a spatially selective measurement of cortical activity derived from the SAM beamformer implementation called a virtual electrode (VE) was used to observe activity with high temporal resolution (Figures 1B and 2B). The VE data was filtered to frequency bands of interest and

![Image](https://example.com/image1.png)

**Fig 1.**—Alpha band desynchronization. A, Synthetic aperture magnetometry activation rendered on the patient’s magnetic resonance image. B, Time course of alpha band activity within maximally active extra-striate cortex. C, Reported end of scintillation observation (5 minutes 22 seconds). ERS indicates event-related synchronization; ERD, event-related desynchronization.
analyzed over the 20-minute duration at 2 cortical regions of interest, determined as the points of maximum ERD in the global SAM activation images, one in the left extra-striate cortex and one in the left inferior temporal lobe. The VE method also provides a basis for the computation of time-frequency spectrograms (Figure 3). Synthetic aperture magnetometry and spectrogram images were produced using successive 2-minute data segments partitioned into 2-second segments, each segment was contrasted with the 2-minute segment at the end of the recording period as a baseline. The segments were then assembled as a montage (Figure 3). The $z$ score for each time-frequency spectrogram element was computed with a Mann-Whitney test between the baseline and test segments, and is represented by the color bar in Figure 3.

**RESULTS**

Synthetic aperture magnetometry revealed strong focal ERD, most notably in the alpha band (7 to 13 Hz) in the lower left extra-striate and temporal
areas and also in the gamma band (30 to 80 Hz) in the left inferior temporal lobe. The extra-striate alpha source remained strongly desynchronized (30.4%, $P < .01$) with respect to baseline for approximately 5 minutes 30 seconds, corresponding to the period during which scintillations were reported by the patient. Following this period, there was a short episode of ERS with activity returning to baseline levels over the subsequent 10 minutes (Figure 1).

The temporal lobe exhibited the same pattern of alpha ERD as the extra-striate cortex (Figure 1A), however, it was weaker (19.4%, $P < .01$) and more diffuse. In the left inferior temporal lobe, strong focal desynchronization (49.7%, $P < .01$) was observed (Figure 1A) in the gamma frequency region, which was not observed in extra-striate visual areas. Temporal lobe gamma ERD was strongest in the first recorded minute and showed gradual reduction in the level of desynchronization to levels not significantly different from baseline after approximately 16 minutes (Figures 2B and 3). None of the phenomena reported above were observed in a control recording conducted with the same patient some weeks after the reported visual aura had been experienced.

**COMMENTS**

Results are spatially consistent with previous reports of extra-striate visual involvement in migraine visual aura, and the observation of visual anomaly in the presence of extra-striate ERD supports the hypothesis that this area is involved in the generation of phosphenes. Novel observations concerning the changes in oscillatory activity that accompany migraine visual aura were noted. The extra-striate and inferior temporal cortices exhibit identical alpha desynchronization commensurate with the reported visual disturbance (Figures 1 and 3) suggesting that alpha ERD is linked to the observed visual abnormalities.

Gamma desynchronization is restricted to the temporal region and displays gradual recovery over a 16-minute period (Figures 2 and 3), a time scale consistent with those reported in previous migraine studies, suggesting a connection with the scotoma following scintillations.

This study also demonstrates the ability of SAM to determine spontaneous changes in cortical synchrony without the need for driving stimuli and refutes suggestions of poor spatial resolution in migraine imaging using MEG.

Evidence from previous functional imaging studies would suggest that the ERD seen here is the result of underlying cortical hyperexcitability and subsequent asynchrony affecting prominent cortical rhythms of the visual system, results consistent with the theory of CSD.

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**REFERENCES**