msec, or 102 Hz repetition rate. This difference in repetition frequencies was not caused by the difference in amplifier bandpass settings, since essentially the same differences were found when VECP and ERG were both recorded with a bandpass of 100 to 1000 Hz.

**Discussion.** Early wavelets observed in these VECP records exhibit the following properties: (1) monotonic relationship of peak-to-peak amplitude and implicit time to stimulus radiance; (2) substantially greater implicit times than ERG wavelets, ruling out the possibility that the VECP wavelets are volume-conducted from the retina, and (3) relatively constant wavelet repetition frequency across radiance (102 Hz), which is less than that for the ERG (139 Hz).

Our VECP wavelets share certain similarities with those described by Tsuchida et al.6 and Cobb and Dawson.7 However, some of the implicit times measured from occipital leads described by Cracco and Cracco8 (21, 30, 38, 52 msec) closely resemble the implicit times of our ERG wavelets (23, 30, 38 msec), and are similar to ERG wavelet implicit times reported by others.9 It is possible that volume-conducted ERG activity accounts for some of the very early VECP wavelets reported by others. We have not seen clear and consistent wavelets in our records that precede approximately 40 msec.

On the basis of these results we conclude that the VECP wavelets which are recorded from the occipital scalp are not volume-conducted from the retina. Since wavelets are ubiquitous throughout the visual system,10 we cannot with certainty ascertain the origins of these wavelets within the brain on the basis of the present evidence. However, their relatively early latency suggests that the wavelets may be generated by the initial arrival of optic radiation activity at the visual cortex, or by subcortical structures, and thereby may provide valuable data for the diagnosis of pathology and for basic visual functioning.

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**Alternating exotropia: temporal course of the switch in suppression.** Martin J. Steinbach.

The exotrope usually suppresses the input from the temporal retina of the deviating eye. Some exotropes can alternate the eye which is used to fixate. When this happens, the suppressing and fixating eyes trade roles in what appears to be less than 90 msec (about the time it...
takes to make a large saccade). The temporal course of this switch in fixating/suppressing eyes was measured by flashing patterned stimuli to the exotrope before, during, and after the eye movement used in making the switch. Polaroid lenses were used to dissociate the visual input to the two eyes, and binocular eye movements were recorded with a photoelectric technique. It was found in three alternators that the switch in suppression begins as soon as the eyes start to move and is completed before the end of the saccade used to make the switch.

The characteristics of suppression found in exotropia have been well described by Jampolsky. In the deviating eye the exotrope suppresses input from the temporal half retina. If the exotrope views through cross-Polaroids a complex scene that is cross-polarized so that light from the left half of the scene only enters the left eye and vice versa, then, when fixating the center of the scene with his good eye, he will see only one half of the picture. The portion of the scene falling on the temporal retina of the deviating eye will be totally suppressed. If the patient is an alternator, then he can, at will, view either the left half only or the right half only, by changing the eye he fixates with. These phenomena and dissociating techniques are admirably described by Pratt-Johnson and Wee.

When does this switch in suppression take place? Is it before, during, or after the eye movement when the eyes change roles? The answer can be obtained by flashing brief test patterns around the time of the fixation switch, with the techniques described below.

Subjects. Three subjects were used. M. N. was a 28-year-old man with an untreated intermittent exotropia of the left eye that had its onset at age 11 or before and was about 50 prism diopters at distance fixation. He had no amblyopia, and his refraction was RE plano + 0.75 × 180; LE +0.50 + 0.50 × 180. Three months prior to this test he had a recess/ resect surgical procedure carried out on his left eye, and this reduced his exotropia from about 50 to about 20 prism diopters at distance. He could alternate this residual exotropia at the request of the experimenter.

Apparatus

Stimulus material. The subjects viewed a large aluminized projection screen from a distance of 178 cm. Projected onto the screen was a checkerboard pattern within a square field with a side of 25° of visual angle. The checkerboard pattern was made up of squares with sides of 20 min arc. The luminances of the pattern and surround were measured with an SEI photometer and found to be 2 ft.-lamberts at the brightest region of the checkerboard, 0.2 ft.-lambert at the dimmest portion, and 0.1 ft.-lambert for the surrounding portions of the screen. The pattern was projected and viewed through Polaroid lenses arranged so that half the scene (divided vertically through the midline) was visible to the subject’s left eye and the other half visible only to the subject’s right eye. A non-polarized fixation target of 0.64° visual angle, visible to both eyes, was in the center of the screen. This arrangement enabled verification of the finding of Pratt-Johnson and Wee that when the patient alternated, one half of the field suddenly became visible while the field of the deviating eye disappeared.

The duration of the stimulus presentation was controlled by an electromechanical shutter (with an approximate 5 msec rise time and 2 msec fall time) placed over the lens of the projector, a 35 mm Leitz Pradovit. The shutter was tripped by a pulse from a timer and exposed the checkerboard pattern for 20 msec. A small unobtrusive photocell placed in the beam of the projector monitored the temporal characteristics of the illumination.

Eye movement recording. A Biometrics SG/H photoelectric system was used to monitor the horizontal movements of both eyes. The calibration was taken with the eyes in primary or straight-ahead position, and thus the exotropic eye was frequently outside the linear range of the recording system (about ±10°). However, the critical information for this study concerned the onset of the switch, and this could be clearly determined from the records. The output of the eye movement system was displayed on a pen recorder that ran at a paper speed of 100 mm/sec, enabling the experimenter to determine onset of eye movement times to within 10 msec. Only the data from trials

He had no amblyopia, and his refraction was RE plano + 0.75 × 180; LE +0.50 + 0.50 × 180.
Fig. 1. A, Experimental set-up for testing suppression, using cross-Polaroid to dissociate the visual input to the two eyes. When the exotrope fixates the center of the pattern (the black dot) with the left eye, input to the right exotropic eye is suppressed, and the subject reports seeing only the left half of the pattern. When fixation is switched (by a saccade) and the right eye now fixates, the left eye goes exotropic, and the subject reports seeing only the right half of the pattern. The solid and dashed lines represent, respectively, the visual axes of the left and right eyes. B, Time at which suppression switched, relative to the change in fixation, was assessed by briefly flashing the test pattern around the time of the switch. The traces depict horizontal eye position and the conjugate saccade (of between 60 and 80 msec duration) that occurred when there was a change in fixation. The magnitude of the vertical displacement of the traces would be determined by the amount of the deviation. For M. N. it was 25°, for L. H. it was 10°, and for P. H. it was 17.5°.

Method. The method used for this study is described in Fig. 1. The subjects usually changed fixation from one eye to the other by a conjugate saccade, whose duration was about 60 msec for M. N. and 80 msec for L. H. and P. H. (These durations are reasonably close to values reported for normal subjects.3) At the end of the saccade the formerly deviating eye would now be fixating, and the formerly fixating eye would be deviating by the amount of the saccade (matching the angle of deviation). In order to determine the time at which the switch of suppression occurred, the checkerboard pattern was flashed at various times around the time of the switch, and the subject asked to indicate which half of the stimulus was visible (corresponding to the half of the pattern not suppressed and therefore identifying the seeing eye). The subject was asked to switch fixation after he heard a warning tone. There was a variable delay period between the warning tone and the flashed presentation that the experimenter manipulated in order to bracket the time of the saccade. The tone onset, the binocular eye movement traces, and the flashed stimulus onset and duration (monitored by a photocell) were all recorded on the pen recorder, and the records were analyzed afterward to relate flash time to saccade onset and subject’s response.

Procedures. The subject was fitted with the Biometrics frames and comfortably seated facing the aluminized screen. His head was steadied by a forehead/chin rest, and calibration of the eye movement system completed before any suppression data were collected. The experiment was run in two to four separate 45 min sessions separated by at least 24 hr.

Results and discussion. The basic result, consistent across all three subjects, is that the switch in
suppression began as the eyes began to move and was completed even before the eyes stopped moving. For 98% of the judgments made at or before the onset of eye movement (195 out of a total of 198 judgments for all three subjects) the reports of the subjects indicated that the initially fixing eye was seeing. After the eyes began to move, only 4% (11 out of a combined total of 278 judgments) of the reports were that the initially fixing eye saw; 96% indicated that the soon-to-be-fixing eye, even while it was still in motion, had taken over visual functioning.

There were no differences across subjects or within subjects according to which eye initially fixated, so the data were combined and can be seen in Fig. 2. The subjects were usually very confident in their judgments about which half of the stimulus pattern was visible. Even for those judgments made while the eye was in motion, the subjects had little difficulty in responding, although this was the time when uncertainties sometimes occurred.

The mislocalization of very-short-duration targets that sometimes accompanies saccades did not occur systematically, although the few instances when the subjects expressed uncertainty might have been due to this. The subjects most always reported that they were able to see the test flash clearly and in the proper spatial location. The field was bright enough so that the small amount of suppression that normally accompanies saccadic eye movements was overcome.

The fact that all subjects produced identical results suggests that their patterns of suppression were very similar even though one was not a true alternator (M. N.) and one had had recent surgery (L. H.). The surgery, at least within the 3-month period that had passed before the time of testing, did not seemingly alter the suppression patterns, although long-term follow up data are not available.

Considerable pilot work had to be done in order to find a flashed stimulus that would still be suppressed. It was the author’s intention to use small test probes flashed into suppressed regions in order to carefully map the scotoma. This turned
out to be impossible because any target of small (less than 5°) dimension would be immediately visible to the subject as long as it was flashed. The large field targets (28° square) were effectively suppressed by the subject, but the relationship between areal size and suppression is a complex one and remains to be investigated.

None of the subjects ever noticed any diplopia or the simultaneous appearance of both halves of the test field. This indicates that in these adult subjects diplopia plays no role in the switching of suppression. That is, the suppression did not develop in response to a confusing or diplopic scene, but rather was determined centrally, and was tightly coupled to the oculomotor signal that produced the saccade.

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