Optokinetic Nystagmus as a Measure of Visual Function in Severely Visually Impaired Patients

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Purpose. To evaluate the efficacy of using optokinetic nystagmus (OKN) as an objective measurement of vision in severely visually impaired patients, in whom it is difficult to measure visual function reliably. Objective visual acuity (VA) measurements would be useful in the pre- and postoperative assessment of severely visually impaired patients who are potential candidates for visual rehabilitation strategies, such as retinal prostheses, neural and stem cell transplantation, and molecular approaches.

Methods. Full-field visual stimuli were used to evoke horizontal OKN responses in 17 subjects. Eye movements were recorded and analyzed to determine the maximum stimulus velocity (V_{max}) at which subjects could maintain an OKN response. This endpoint was compared to logMAR VA and Goldmann visual field (VF) test results.

Results. V_{max} was dependent on VA, VF, and the spatial frequency (SF) of the stimulus, yielding the equation $V_{max} = 14.2 \cdot \log(VA) - 6.20 \cdot \log(SF) + 0.22 \cdot VF + 25.0$. The findings suggest that V_{max} in the presence of full-field OKN stimuli may provide an objective measure of VA and peripheral vision.

Conclusions. OKN testing may be useful as an additional, more objective means of assessing visual function in a select group of severely visually impaired patients who are being considered as candidates for new visual rehabilitative strategies. (*Invest Ophthalmol Vis Sci.* 2007;48:4542–4548) DOI:10.1167/iovs.06-1206

According to the American Foundation for the Blind, there are approximately 10 million blind and visually impaired people in the United States. In most industrialized countries, most patients with severe visual impairment unrelated to a systemic medical illness have retinal diseases such as macular degeneration and retinitis pigmentosa, for which there have not been treatments that restore vision.

The current and widely used methods of measuring central visual acuity (VA) in the severely visually impaired tend to yield highly variable and unreliable results.[1,2] Low-vision evaluations, which rely heavily on patients' subjective reports of changes in function, have been the mainstay of clinical assessment in these patients. The inadequacies of these visual testing methods were not especially problematic until fairly recent attempts were made to develop and test new forms of potential therapy for severely visually impaired patients, such as transplantation of photoreceptors or retinal pigment epithelium, stem cell transplants, and retinal prosthetics.[3–11] In the absence of reliable methods of testing vision, researchers must depend on subjective reports after therapeutic intervention. Subjective reporting can be notoriously unreliable, which could lead to spurious interpretations of the value of a proposed therapy. The purpose of this study was to determine whether OKN responses in severely visually impaired patients in the presence of full-field OKN stimuli correlate well with the standard clinical measurement of visual function as determined by logMAR VA and Goldmann VF testing.

OKN is a reflexive eye movement that is induced by movement of objects across one's visual environment and the "slip" of visual images across the retina. Subconsciously, the eyes initially rotate to follow the moving objects, but beyond a certain point the eyes return to the primary position. The neural pathways that mediate OKN extend from the foveal outflow path of the retina to the lateral geniculate body, occipital lobe, cerebellar flocculus, paramedian pontine reticular formation, and the ocular motor neurons. If the involved neural pathways are intact, the slow component velocity (SCV) of the OKN gradually increases (i.e., charges) and ultimately reaches a velocity close to that of the stimulus, up to a certain maximum stimulus velocity (V_{max}). If there is neural damage anywhere along the relevant neural pathways, the OKN response is affected.

Investigators in numerous studies have examined OKN responses in normally sighted patients and in those with visually significant lesions of the retina or cortical pathways, by using OKN drums or other devices.[12–14] In none of the earlier studies, however, has full-field OKN stimuli been analyzed across a range of spatial frequencies (SFs) in severely visually impaired patients. In this study we hoped to provide better correlations with standardly used measures of visual function, especially across a group of patients with a wide range of visual acuities.

Methods

The study was approved by the Human Studies Committee at the Massachusetts Eye and Ear Infirmary (MEEI), where all testing was performed, and complied with the tenets of the Declaration of Helsinki. Thirteen patients with visual impairment from retinitis pigmentosa or age-related macular degeneration were recruited from the neuro-ophthalmology service and screened for a history of neurologic disease. Their average age was 60 ± 16 years (mean ± SD). Five normally sighted volunteer subjects were recruited from hospital employees and associates with an average age of 29 ± 5 years; normal volunteers in the same age range as the patients were not readily available. Informed consent was obtained for all study subjects. In two patients, only one eye was tested; the second eye was capable only of perceiving light, making it difficult to assess VA or to calibrate eye movements. One patient exhibited a spontaneous nystagmus of 9 deg/s, which could have confounded the OKN response, and thus was excluded from the study. Monocular stimuli and recording were used to study 32 eyes.

In each subject, logMAR VA assessment was measured in a standardized environment by the same examiner immediately before the OKN testing. In addition, Goldmann visual field (VF) testing was

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performed in a standardized environment by the same examiner in 10 of the 12 patients with visual impairment, to document the location and size of any retained islands of vision. In those subjects with normal VA and no history of ocular disease, VFs were not tested.

The electrooculographic (EOG) recording system consisted of custom-built differential amplifiers having a common mode rejection ratio of 100 dB, a four-pole low-pass filter set to 40 Hz, and a 60-Hz narrow-band rejection filter. Silver-silver chloride electrodes were mounted on the inner and outer canthi of each eye after the skin was swabbed with alcohol and slightly abraded to remove surface grease. After at least 5 minutes was allowed for the electrode gel to reduce electrode impedance, the impedance was measured with an AC impedance meter to ensure it was below 10 kΩ. Eye movements were induced and recorded in a monocular fashion throughout testing. An eye patch was placed over the eye that was not being recorded.

Full-field optokinetic stimulation was achieved by having the subjects sit in the center of a cylindrical space 2 m in diameter surrounded by a white curtain 2 m in height. Projected OKN stripes were selected because of their ability to present a full-field surround in which the SF could be quickly and easily changed and the angular velocity could be precisely controlled. Suspended above the subject, the projector system was a 0.45-m tall by 0.25-m diameter hollow Plexiglas cylinder with a concentrically mounted halogen light filament. Striped patterns printed on Mylar film were mounted on the outside of the cylinder. The luminance of the projected light and dark portions of the stripes were measured on the cloth surround as 10.1 and 5.1 cm/m^2, respectively, yielding a contrast ratio of approximately 2:1 for equal-sized stripes.

EOG calibrations were performed after waiting at least 10 minutes to adapt to the light level of the OKN stripes so that changes in the corneoretinal potential were minimized. Calibration of normal-vision patients was performed using a laser beam projected onto the screen 10° temporally and nasally from fixation, producing a red dot subtending 0.3°. Calibration of low-vision patients required the use of a large target consisting of a white circle subtending 2°, within a dark green circle subtending 8°, with a black X through the center. A set of 35-mm slides was created to project the target onto the screen in the same positions as the laser dot. The EOG record was visually inspected to verify that all subjects were able to make consistent and appropriate gaze movements, and the investigator evaluated each subject for the presence of nystagmus. Calibrations were performed before and after a set of 6 to 10 trials with an intervening period of 20 to 30 minutes.

During each trial, the drum was rotated at progressively increasing velocities up to a V_{max} of 55 deg/s at a constant acceleration of 2 deg/s^2, maintained at that speed for 2 seconds, and then symmetrically decreased to 0 velocity. Separate trials were performed with the OKN stimulus moving to the left and to the right. Each eye was tested at multiple spatial frequencies ranging from 0.022 to 1.5 cyc/deg, but not all eyes were tested at the same spatial frequencies. Given the effect of mental attention on the quality of the OKN responses, it was deemed more appropriate to test spatial frequencies closer to the values of the response–nonresponse threshold of each subject, rather than to test every frequency for every subject. The decision of which spatial frequencies to test was based on the subject's responses at the extremes and the median of SFs that were tested.

Eye position and drum tachometer velocity were digitized at 120 samples per second and stored on disc for subsequent analysis. An automated algorithm that detects nystagmus slow and fast components by using the smoothed first derivative (velocity) and median filtering[15] made regularly spaced estimates of SCV. Biological and electrode noise was reduced by time averaging the data to determine an estimate of the SCV for each interval of 1 second. Based on EOG calibration runs from our laboratory, we estimated the short-term baseline drift to be less than 0.1 deg/s (taken over a calibration run that typically lasts 20 seconds)—much less than the measurement noise. RMS noise was typically less than 0.5° for the recorded eye position, and less than 5 deg/s for eye velocity. Because we used averages over one second to estimate eye velocity, the velocity error was reduced to ±1 deg/s (95% confidence interval [CI]). All these errors are less than those currently specified by the ANSI standard for vestibular function tests.[16]

Results

Figure 1 compares the drum velocity and the SCV response of one patient at four spatial frequencies. In the case of this particular subject, a decrease in SCV was observed as the SF of the stripes increased, which is indicative of an inability to track images at higher spatial frequencies. (This phenomenon is similar to a patient's inability to resolve lines with spatial resolution that are greater than the patient's "measured" VA on an eye chart). This trend was apparent among most of the subjects, although one eye in one patient demonstrated no OKN response at any SF.

The OKN gain was calculated as the ratio between the SCV and the drum velocity. It was typically highest at the beginning of the trial when the drum speed was low, decreased as the drum accelerated, and increased again as the drum decelerated. Figure 2 demonstrates this behavior in a single trial with an SF of 0.094 cyc/deg. An OKN response was present initially, but it then disappeared when the drum velocity reached 38 deg/s, which suggests that the patient's visual system could no longer discern the visual pattern at higher velocities. Consistent OKN responses did not reappear until the drum had decelerated to 17 deg/s.

In a previous study (Wall C, unpublished data, 1987) in the laboratory using the same equipment, we measured the OKN responses of 50 normal subjects to a 0.067 cyc/deg, 50 deg/s stimulus and calculated a mean gain of 0.76 ± 0.15. The 5th percentile of 0.46 is used as the threshold for classifying abnormally low gain. In many cases in our study, the OKN gain remained above the threshold throughout the trial, which indicated good OKN performance at all drum speeds. This finding was especially true in subjects with the best VA. In the case demonstrated in Figure 2, the gain dropped to 0 for sufficiently high velocities.

As the drum accelerated, the maximum drum velocity (V_{up}) at which the OKN gain remained above threshold was determined. When the gain fell below threshold, the deceleration portion was analyzed to determine the drum velocity (V_{down}) at which the gain returned to and remained above the threshold. Analysis of drum rotations in both directions yielded up to four separate velocity parameters for each SF (V_{up} and V_{down} for leftward rotations, and V_{up} and V_{down} for rightward rotations). Overall, V_{up} tended to be larger than V_{down}, particularly in patients with lower VA, but this difference was inconsistent even within individual subjects. There were no differences observed between leftward and rightward rotations. As such, the maximum (V_{max}) of these four velocities was selected as the descriptor of the subject's best performance at that SF.

The relationship between V_{max}, SF, and VA was initially examined by grouping the data according to the VA of the corresponding eye. Within each group, the average V_{max} was calculated at each SF (Fig. 3). Eyes with the best VA were almost always able to maintain normal OKN responses throughout the entire trial. In eyes with lower VA, there was a decrease in V_{max} at higher spatial frequencies. In eyes with severe vision loss, there was a decrease in V_{max}, even at lower frequencies. The data from these studies showed substantial variability, but the trends in the results are clear. These data also suggest that subjects with better VA would continue to produce OKN responses at higher drum speeds.

An analysis of variance (ANOVA) on the complete data set (175 observations) showed a highly significant effect of VA on V_{max} ($P < 0.0001$) but a surprisingly insignificant effect of SF. A major contributing factor was probably a "saturation" effect in the data—namely, that the majority of the trials (96/175)

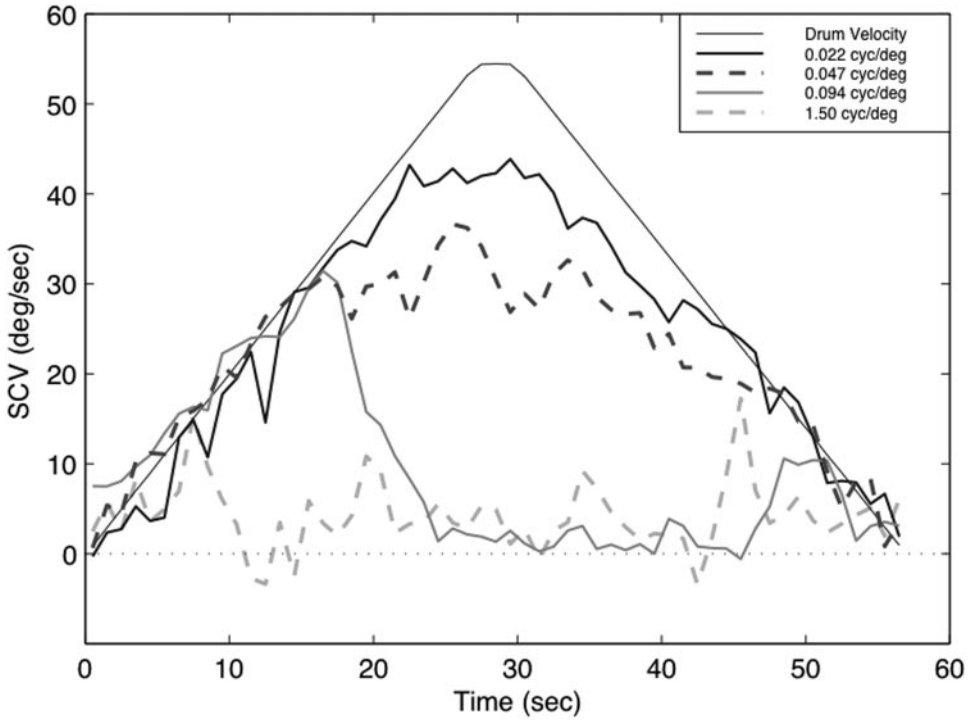

FIGURE 1. SCV of the OKN response of one eye of one patient (who had VA 20/125 in the tested eye) to four different spatial frequencies that corresponded to 8, 17, 34, and 540 stripes. The velocity of the OKN drum is also shown in relation to time.

resulted in a V_{max} of 55, indicating that the OKN response persisted throughout the trial. It is likely that the OKN responses would have continued if higher drum speeds had been used, indicating that these V_{max} scores have been artificially reduced. The normal subjects scored a 55 in almost all the trials (64/69), and two of the subjects (patients 10 and 11) scored a 55 in all trials with both eyes. Exclusion of these subjects produced a nonsaturated data set which consisted of 79 data points from 10 patients (17 eyes). A subsequent ANOVA showed significant effects of both VA and SF ($P < 0.05$).

A two-parameter linear regression model was fit to this nonsaturated data set, producing a root mean square error (i.e., the difference between the observed values and the predictions of the model) of 15.5 deg/s for the overall fit, which was higher than anticipated. This difference was consistently large in some patients, suggesting the presence of another contributing factor. In particular, the model tended to underestimate the responses of patients with large islands of peripheral vision and to overestimate the responses of those with poor peripheral vision.

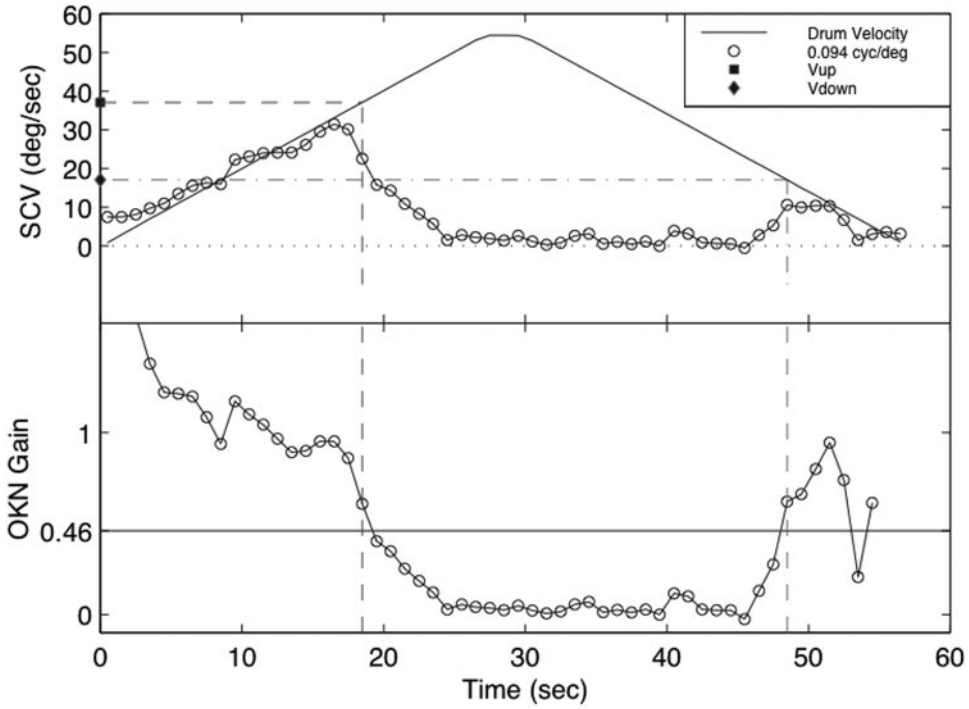

FIGURE 2. Analysis technique illustrated by the OKN responses of a single eye of a single patient (VA of 20/125) to a single SF (0.094 cyc/s). *Top*: velocity of the rotating drum over time and magnitude of the average SCV at 1-second intervals; *bottom*: corresponding gain (i.e., ratio of SCV to drum velocity) and the threshold gain (0.46) that was used to classify a normal response. V_{up} (or V_{down}) refers to the maximum drum velocity at which the SCV was above the threshold during the acceleration (or deceleration) phase.

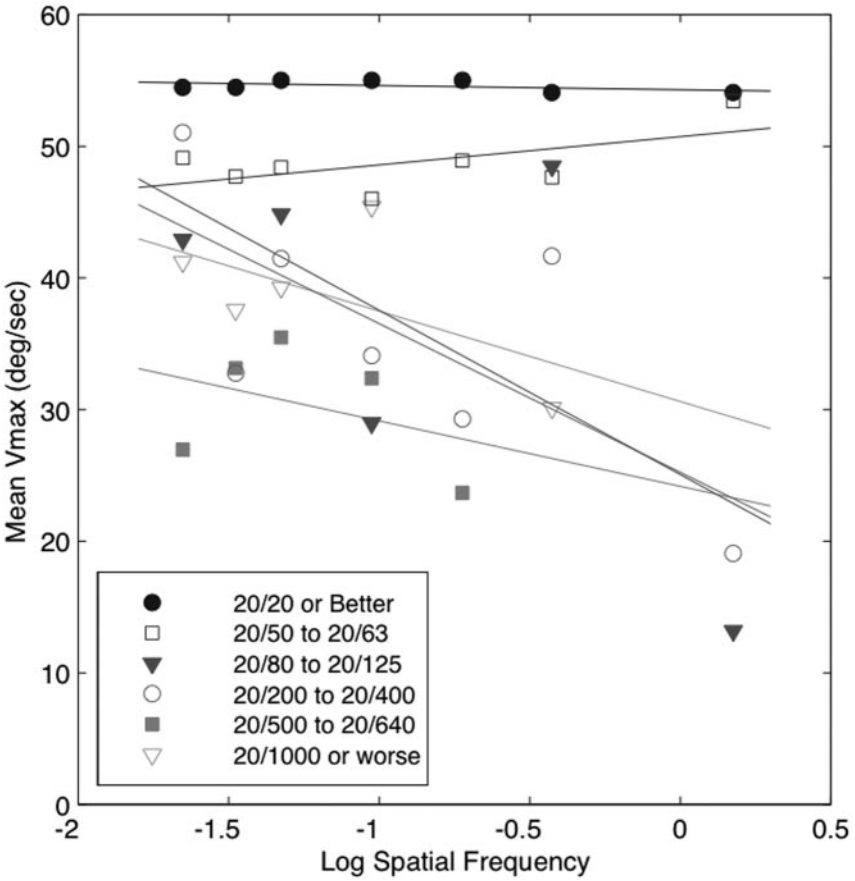

FIGURE 3. Relationship between maximum drum velocity and the SF of the visual stimuli. The subjects are grouped according to the VA of the eyes that were tested. Best-fit lines for each group show a general decrease in V_{max} with decreasing VA and increasing SF.

Goldmann VF tests were quantified by recording the average extent (in degrees of visual angle) of the horizontal dimension of the largest island of retained VF. These data were not available for two patients or for any of the normal subjects and were only available for one eye of a third patient, which further reduced the nonsaturated data set to 54 observations from 12 eyes. A three-parameter ANOVA showed highly significant effects for both VA and VF ($P < 0.0001$) and a trend toward significance for SF ($P = 0.06$). A linear regression model produced the following equation:

$$V_{max} = 14.2 \cdot \log(VA) - 6.20 \cdot \log(SF) + 0.22 \cdot VF + 25.0$$

It should be emphasized that the VA and SF were transformed by their base 10 logarithms. Visual inspection of the data showed a clear logarithmic dependency on these two parameters, but no such behavior was observed for the VF data.

Second- and third-order effects were examined throughout the statistical analyses. The second-order interaction between SF and VF was borderline significant ($P = 0.049$) in the final analysis of 54 observations, for which there is no immediate explanation. No other significant interactions were found. There was also no significant correlation between any of the three parameters.

The root mean square error from the equation was 12.5 deg/s. A mean error was calculated for each eye by averaging the difference between the model prediction and the observed V_{max} across all spatial frequencies (Table 1). The average results agree fairly well with the model prediction, with the exception of two patients. Patient 12, who had a very narrow VF, had a much lower response than expected in the left eye, and had no OKN response in the right eye. Although this patient had a narrow VF (10°), the results for patient 4 (who had an even narrower VF of 2°) had a good model fit. Conversely, the V_{max} scores of patient 10 were much higher than expected. This patient had central scotomas in both eyes but excellent peripheral vision. These results suggest that the dependency of V_{max} on VF may not be linear.

DISCUSSION

This study was designed to determine whether OKN responses could provide a more objective and reliable means to assess visual function in patients with significant visual impairment, for whom current testing modalities have a limited ability to reliably quantify changes in visual function. The study was motivated by our desire to develop better testing methods for patients who may eventually receive a retinal prosthesis that is currently under development,[11] and by the results of previous studies, which indicated that measures of OKN may provide a means to quantify visual function objectively. Our results showed that the stimulus V_{max} for an above threshold OKN response was dependent on both the VA and VF of the subject and the SF of the OKN stimulus (see the equation).

As early as 1958, researchers demonstrated that OKN responses may provide additional information on visual function in patients with normal or subnormal vision.[12] Millidot et al.[17]

TABLE 1. Test Results and Quality of Model Fit

Subject	Age	VA	VF	Error	Subject	Age	VA	VF	Error
Patient 1 OD	85	20/200	NA	—	Patient 11 OD	52	20/50	105	0.2
Patient 1 OS	85	20/400	NA	—	Patient 11 OS	52	20/63	135	8.3
Patient 3 OD	76	20/125	80	4.7	Patient 12 OD	49	20/63	10	—
Patient 4 OD	68	20/25	2	−5.7	Patient 12 OS	49	20/80	10	−22.0
Patient 4 OS	68	20/25	2	5.3	Patient 13 OD	58	20/63	115	−6.6
Patient 5 OD	68	20/400	30	−4.6	Patient 13 OS	58	20/80	90	2.0
Patient 6 OD	48	20/500	25	6.6	Normal 1 OD	26	20/12.5	NA	—
Patient 6 OS	48	20/640	30	0.3	Normal 1 OS	26	20/12.5	NA	—
Patient 7 OD	78	20/80	60	8.5	Normal 2 OD	37	20/63	NA	—
Patient 7 OS	78	20/640	NA	—	Normal 2 OS	37	20/50	NA	—
Patient 8 OD	34	20/2560	55	1.0	Normal 3 OD	26	20/20	NA	—
Patient 8 OS	34	20/1280	110	−5.9	Normal 3 OS	26	20/20	NA	—
Patient 9 OD	77	20/1600	NA	—	Normal 4 OD	27	20/20	NA	—
Patient 9 OS	77	20/400	NA	—	Normal 4 OS	27	20/20	NA	—
Patient 10 OD	42	20/800	95	26.1	Normal 5 OD	26	20/20	NA	—
Patient 10 OS	42	20/800	65	32.5	Normal 5 OS	26	20/16	NA	—

LogMAR VA was assessed immediately before optokinetic testing. Goldmann VF tests were performed in 10 of the 12 patients. The designation VF refers to the maximum horizontal extent of the VF (expressed in degrees of visual angle) that was demonstrated with Goldmann perimetry. Error (in deg/s) refers to the average difference between the observed V_{max} and the value predicted by the model in the equation. No error was calculated for subjects who lacked VF results or, in the case of patient 12 OD, lacked an OKN response.

studied OKN eye movement responses to a sinusoidal-moving grating and found that, at higher stimulus SFs, there was a point at which eye movements could no longer be generated. Later, Khan et al.[18] compared OKN responses to a Catford apparatus with VA in normally sighted subjects, normal subjects with blurred vision from optical "fogging," and patients with ocular disease that reduced central VA. They found that subjects with a VA of 20/50 or better had a good correlation between the traditional, subjective measure of Snellen acuity and the objective measure of vision made by recording OKN responses. Other studies have also demonstrated this correlation, at least at VAs as low as 20/400.[19–22] More recently, Shin et al.[23] evaluated eye movements in the presence of horizontal OKN stimuli in 89 patients with a variety of ocular diseases and found that OKN induction and suppression methods provide a satisfactory means of determining objective VA. Their study, however, did not use full-field OKN stimuli, varied the stimuli only between 0.2° and 0.6°, and used only one velocity (10 deg/s) for each trial run. Our study is distinctive in that we (1) studied OKN responses of severely visually impaired subjects (lowest VA measured was 20/2560, and smallest measured VF size was 2°); (2) used full-field OKN stimuli[24]; and (3) correlated OKN responses to measures of both central acuity (using the logMAR acuity paradigm) and peripheral vision (assessed with Goldmann perimetry). We analyzed OKN responses by measuring the SCV responses of subjects across a range of stimulus spatial frequencies and across a range of OKN drum velocities.

We analyzed our data individually for each patient in an attempt to identify outliers from the overall trends that we observed for both VA and VF results. Two subjects (patients 4 and 12 in Table 1) had good central VA but extremely restricted VFs. Both patients had a low response rate with inconsistent OKN responses, one of which fit the model well and one of which did not. There were periods of consistent OKN response in patient 12, but the amplitude was usually lower than our threshold, resulting in a lower V_{max} than expected. The response in patient 4 agreed well with the model. These findings are consistent with literature, which has demonstrated the important contribution of peripheral retinal stimulation for the generation of OKN responses. Specifically, Miyoshi[25] evaluated the role of the fovea and peripheral retina in generating OKN responses by using a masking cylinder to separate the VF into peripheral and foveal retinal stimulation and found that, as central VF narrowed, nystagmus elicitation was more difficult.

At the other extreme, one of our subjects had low central VA (5/200 bilaterally) because of central scotoma (30° and 40°, respectively), but normal peripheral vision. Even though this patient could not identify characters on the logMAR VA chart, he had an OKN response that approximated that of the normal patients. Previous studies have analyzed OKN responses in patients with central VF defects and have revealed similar findings.[26,27] For example, Valmaggia et al.[13] and Valmaggia and Gottlob[14] analyzed OKN responses in patients with large central scotomas of various sizes secondary to AMD. They found that there was no significant difference in the OKN gain between the control group and patients with central scotomas of less than 20° of visual angle.

These outlier cases highlight the previously studied variation between OKN stimuli that target specifically the peripheral and foveal areas of the retina by using the fogging technique to target the area of interest. Although our study demonstrated this effect through full-field OKN stimulation in patients with peripheral and central scotomas due to underlying retinal disease, future studies could examine this by using OKN stimuli with spatial masking so that only the foveal or peripheral areas of the retina are stimulated.

Besides the retinal area of stimulation, two other variables of the OKN stimulus can affect the magnitude of the response: the SF of the stripes (or grating) and the velocity of the entire pattern. In this study, both variables were examined. The results demonstrate that patients with extremely poor vision require testing at low velocities and low SFs. In contrast, higher velocities and SFs are necessary for evaluating subjects with visual acuities better than 20/80.

Although our method of recording OKN, electrooculography, has limitations including signal-to-noise ratio, baseline drift, resolution, and dependence of corneoretinal potential (CRP) on ambient light level, we thought it was the most appropriate recording method for this study. Scleral search coils have 1 minute of arc resolution over a bandwidth of 1000 Hz, and a linearity of 0.25% over a range of ±30°,[28] but typically cannot be used for more than approximately 30 minutes in one session.[29] Our sessions exceeded 1 hour. There is also the risk of corneal abrasion and disease transmission if the fairly costly coils are reused. Video oculography has a resolu-

tion for horizontal eye movements of 0.01°, with an accuracy (horizontal) of 0.18 ± 0.15° over a ±30° range.[30] Despite the greater resolution of search coils and video compared to EOG, the three methods produce very similar estimates of human OKN gains by using horizontally moving stripes. In their comparison of coil with video techniques, Teiwes et al.[30] estimate the OKN gain to be 0.78 ± 0.14 with the use of coils and 0.77 ± 0.14 on the same three subjects with video. Our estimate on 50 normal vision subjects is 0.76 ± 0.15. We argue that the EOG, although less accurate than video and search coils, is still adequate for this study because the estimates of OKN gain does not differ significantly from the video and search coil techniques.

To increase the signal-to-noise ratio, we tried to decrease the electrode impedance via thorough skin preparation before mounting the electrodes. Digital filtering and time averaging of the data reduced the noise to a level much less than the response changes we saw among the different stripe patterns. Baseline drift is more of a limitation when measuring gaze position over long periods. This effect was not a factor in the EOG calibration, because it involved only short periods. Our analysis focused on SCV, rather than absolute gaze position, and the velocity resolution of our system was much greater than the magnitude of the slow drift. Since the CRP depends on ambient light level, we attempted to keep the level relatively even during the test runs, provided ample time to adjust to any changes, and made EOG calibrations at the beginning and end of each set of trials. With these modifications, the use of EOG in this study produced statistically significant differences in V_{max} as a function of SF and VA.

Future studies would benefit from a larger sample size that includes age-matched controls, a higher contrast ratio, inclusion of subjects with light-perception vision, and testing of the same subjects on multiple days. Previous studies have found that OKN gain decreases and OKN gain variability increases with age.[31] Although there was a disparity between the ages of our normal and patient groups due to selection criteria (as outlined in the methods section), there was no reduction in V_{max} with increasing age in our study. Future studies, nonetheless, would benefit from age-matched controls to eliminate this potential confounder. In addition, previous researchers such as Wang et al.[32] have shown that threshold luminance for OKN triggering increases as target velocity increases. The projection system used in these experiments has the advantages of being full-field and easy to change in SF, but the relatively low contrast ratio of approximately 2:1 may have increased the variability of the OKN responses. Future studies could be conducted to evaluate the effects of luminance, contrast sensitivity, and sinusoidal gratings on OKN responses in this patient population.

The inclusion of patients with light-perception vision would allow further investigation of how well the model applies to other diagnoses, such as optic neuropathy, end stage glaucoma, and retinal artery occlusions. The reproducibility of OKN testing in individual patients could be studied for multiple testing days and compared to the reproducibility of routinely used measures of central acuity and peripheral VFs that would be performed on each of the testing days.

In conclusion, our results reveal that V_{max} assesses a combination of central VA and peripheral vision. As such, full-field OKN testing may provide potentially useful information on visual function in severely visually impaired patients, who may be candidates for emerging therapeutic initiatives. In practice, the approach developed herein could be used as a new parameter (V_{max}) to evaluate vision, or alternately the model equation could be solved for VA in terms of V_{max} and SF, and thus could be used to estimate VA. OKN testing may be especially useful to test the ability of a retinal prosthesis to drive the retina, because the device can be turned on and off while the OKN responses are recorded.

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