Recording and Calibrating the Eye Movements of Nystagmus Subjects

L.F. Dell'Osso, Ph.D.

From the Daroff-Dell'Osso Ocular Motility Laboratory, Louis Stokes Cleveland DVA Medical Center and Depts. of Neurology and Biomedical Engineering, Case Western Reserve University, Cleveland OH, USA

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Send questions, comments, and suggestions to: lfd@case.edu

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Recording and calibrating the eye movements of subjects with nystagmus (or with saccadic intrusions or oscillations) is fundamentally equivalent to recording and calibrating normal eye movements. That is, one needs: 1) an accurate recording system; 2) calibration targets at known gaze angles; 3) a means to stabilize the subject's head; 4) real-time monitoring of stimulus and eye-movement signals; and 5) a means to verbally instruct and correct the subject. With a little experience, any of the currently available recording systems (infrared reflection, magnetic search coil, or high-speed digital video) is adequate to record horizontal eye movements while the latter two are better suited when both horizontal and vertical eye movements are required. Torsional eye movements require either the search-coil or digital-video methods equipped to sense torsion. Descriptions and specifications of available systems may be found elsewhere; this paper will concentrate on proper recording and calibration techniques that will ensure accurate data.

Calibration of normal subjects consists of: 1) establishing the zero position of each eye when the subject is *monocularly* fixating the 0° target and 2) establishing the required *monocular* gains in each gaze direction using targets at known gaze angles. The number of such targets depends on the desired accuracy and linearity and is dependent on the recording system. Binocular fixation is never advisable because even subjects presumed to be normal may have either intermittent or constant strabismus, especially under the usual recording conditions of dim light and LED targets; these tend to allow for phorias to become manifest.

The key to accurate and repeatable calibration of subjects with nystagmus is to use *only* the portions of their nystagmus waveforms known to be used for target foveation as the calibration points and to do so under *monocular* fixation conditions (i.e., the other eye must be behind cover). That is, align the foveation periods to the zero position and to each of the lateral gaze positions used in the calibration routine. Only in the case of pure pendular waveforms, containing neither braking nor foveating saccades nor visible foveation periods, should the midpoint of the oscillation be used for calibration purposes. Failure to calibrate using known foveation positions, including extended foveation periods, will result in inaccuracies ranging between 50% and 100% of the peak-to-peak amplitude of the nystagmus. The non-foveating portions of the nystagmus waveform are irrelevant to both accurate target foveation and high acuity and should be ignored during calibration. With a little experience, investigators can easily determine exactly where the subject with nystagmus is looking, which eye is fixating, and where the other eye is located vis-à-vis the target; they can also determine periods of inattention by the associated waveform changes. In addition, failure to calibrate monocularly will also introduce errors that depend on the (often variable) strabismus angle. Accurate calibration of subjects with saccadic intrusions and oscillations can be achieved using the same procedures as for those with nystagmus.

Infantile nystagmus and some types of adult, acquired nystagmus vary with attention and mental state (e.g., stress, anxiety, anger, etc.). Thus, it is incumbent to ensure that all recordings are made under the same conditions if one wishes to make time-separated intra- or intersubject comparisons. Even the simple task of reading a Snellen eye chart induces enough stress in some subjects that their nystagmus may double in amplitude. The implications of this stress-related variability are that the measured Snellen acuities of some subjects with infantile nystagmus do not reflect their maximum potential acuity (i.e., how well they see while calmly viewing the world around them). We have found that the simple task of looking at an LED in an otherwise dimly lit room satisfies the "calmness" requirement if the required fixation times are kept to a minimum (i.e., a few seconds per target). Records we have made of individual subjects taken many months or even years apart are essentially identical, ensuring that any changes recorded post-therapy reflect the therapy and not some artifact of our recording procedure.

Properly calibrated records make it relatively easy to detect boredom (longer slow phases taking the eyes farther away form the target), distraction (voluntary saccades off target), and changes in the fixating eye (the fixating eye shifts away from the target while the previously deviated eye shifts onto the target). The experimenter can easily detect boredom or distraction in real time and verbally encourage the subject to "look at the target" where upon the normal waveform will immediately return with the foveating periods on target.

Recording Conditions

Subjects must be comfortably seated with their heads stabilized in a dimly lit room to eliminate any distracting targets. Head stabilization by means of a headrest and chin cup is usually adequate for cooperative subjects. A V-shaped headrest will hold the head with minimal tendency to turn if the subject is instructed to keep the head still and pointed straight ahead while looking at the targets only with the eyes. The experimenter at the strip chart or other real-time eye-movement display must be able to verbally instruct the subject to look at the targets, reassure him of compliance, and immediately correct any loss of concentration evident by the failure of the eye traces to follow the target. Once calibrated, if the subject turns his head slightly, both horizontal traces will be displaced and the subject can be instructed to return his head to the straight-ahead position while the experimenter uses the horizontal traces to ensure realignment.

Calibration Paradigms

We use an experimental paradigm whereby the LED target is made to appear at 0° for 5 sec, then at ±15°, ±20°, ±25°, and ±30° horizontally, each for 5 sec; this is repeated twice during the record for right-eye fixation (left eye behind cover) and also for the left-eye fixation (right eye behind cover) record. If vertical data are being taken, the target appears at 0° and ±10° vertically following the horizontal target positions. The same paradigm is then repeated during binocular viewing; this demonstrates any tropias present. The remaining records taken during the experiment are usually under binocular viewing conditions and depend on the particular study we are making. The use of 5-sec epochs allows the subject to refixate the new target (usually less than 1 sec) and to fixate it for a time long enough to determine calibration (4 sec which is about 12 cycles of 3-Hz nystagmus) but not long enough for boredom to set in and with it, a loss of fixation on the target. Also, once calibrated using one of the target sets in the monocular record, calibration can be checked against the second set. If the patient/subject does not fixate targets in the first set, data from the second set provide a backup to ensure measurement of each calibration point.

Calibration Software and Procedures

Infrared reflection and high-speed digital video: Once the monocular data are taken, the two files are used to zero, calibrate, and linearize the data from the respective eyes in each plane using a MATLAB m-file called, "cal.m" that is part of the "OMtools" software downloadable from this site. This interactive program is used to set the zero position and the positions of gaze (settable from 1, when the data are linearly related to gaze angle, to 4 for non-linear data) in each direction. Its outputs are manually placed in a text file, "adjbias.txt" that was previously generated using the program, "biasgen.m" and placed in the same folder (directory) as the data files. The values in "adjbias.txt" automatically adjust the data of each channel in each data file of the experiment as the data file is read into MATLAB by the OMtools program, "rd.m." This provides bias-adjusted, calibrated, and linearized data for subsequent analysis. The outputs from the right-horizontal cal procedure are used on all right-horizontal data channels, the right-vertical outputs for all right-vertical channels, and the same is done for the left eye. Thus, all data from an experimental recording session use the same calibration numbers derived from the first two monocular fixation records. Indeed, once calibrated in this manner, the phorias behind cover during the first two records can also be accurately determined if the recording system in use can record data from the occluded eye. Such properly calibrated records provide a dynamic documentation of the variation of phorias and tropias, not appreciated from static clinical determinations.

NOTE: To avoid having the same "adjbias.txt" name for the files from different patients/subjects or from different recording sessions of the same person, we name the file, "adjbias_fml.txt" (where "fml = first, middle, and last initials) or, "adjbias_fml#.txt" (where # = the recording session number, when # >1).

Scleral search coils: Each coil can be precalibrated using a protractor device in the magnetic field. However, the zero-position bias cannot be set equal to the value it will have once the coil is placed over the eye of the subject. Also, for Robinson-type systems, the induced signal varies as the sine of the gaze angle. We use the data from our monocular records to set the zero position of each eye individually and to apply an arcsine function to the data; for Collewijn coils, this latter step is not needed.

What NOT to do
Following the above recording and calibration procedures ensures accurate, repeatable data. Unfortunately, many of the built-in commercially available software programs and some investigators with little or no experience in recording humans (or animals) with nystagmus fall victim to the type of shortcuts based on false presumptions that effectively reduce their highly sophisticated and potentially accurate recording systems (of all types) down to the level of bitemporal EOG, a method that is anathema to research-quality data. Such poor calibration techniques reflect a lack of knowledge of target foveation in the presence of nystagmus and preclude both accurate rendition of the eye movements and meaningful conclusions as to their underlying mechanisms.

Do NOT attempt to calibrate from data taken with both eyes viewing the target. As stated above, many commercially available monitoring systems come with calibration software based on the erroneous assumption that eye movement data can be accurately calibrated under binocular viewing conditions; *do not use such software*. Rather, follow the steps outlined above to bias-adjust, calibrate, and linearize the monocular data from each eye off line.

Citation

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