READING EYE MOVEMENTS IN PATIENTS WITH NYSTAGMUS AND PROPOSED THERAPEUTIC PARADIGMS

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Abstract
Nystagmus is an involuntary, repetitive, to-and-fro movement of the eyes. It can be divided into two broad categories: jerk and pendular. Patients with nystagmus have decreased visual acuity due to the high velocity retinal-image motion which smears the image of the stationary target being viewed; and, in cases of the congenital idiopathic variety, in addition to any anatomical foveal malformations, they receive bilateral early abnormal visual experience due to this increased retinal-image motion. Reading becomes a difficult task secondary to the error-producing nystagmoid oculomotor component superimposed on the basic reading movements in addition to the reduced visual acuity. We provide a brief overview of the different types of nystagmus, the potential problems that may occur during reading in patients with nystagmus, and treatment options that may be helpful in such cases.

Key Words
reading, jerk nystagmus, pendular nystagmus, nystagmus vision therapy, eye movements

Reading is a complex, higher-level process which requires the oculomotor system to perform optimally and efficiently, frequently for extended periods of time. Reading becomes difficult in patients with nystagmus because of the error-producing abnormal nystagmoid oculomotor component added to the basic reading process over and above the reduced visual acuity. It is important for the clinician to understand the basic characteristics of nystagmus and how it may affect reading efficiency, as well as the range of treatment modalities available to such patients.

Nystagmus Overview
Nystagmus is an involuntary, repetitive, to-and-fro movement of the eyes. Classically, nystagmus is divided into two broad categories: pendular and jerk. Either can present in patients having a congenital or acquired etiology.

Pendular nystagmus is characteristically described by smooth horizontal or vertical sinusoidal movements, generally bilateral and relatively equal in velocity in both directions. The dynamic characteristics of pendular nystagmus may vary. Typically it has an amplitude of one to eight degrees, a frequency of two to six cycles per second, and a peak velocity of up to 100 degrees per second. Pendular nystagmus can sometimes have a jerk component with the fast phase occurring in the direction of extreme gaze.

Jerk nystagmus can be horizontal, vertical, or cyclorotary and is generally bilateral. It is characterized by a slow phase in one direction and a fast, saccadic phase in the opposite direction. The slow phase represents the pathological error-produc-
a linear, slow-phase component. It can result from either a central or peripheral vestibular nervous system dysfunction. It is also found during irrigation of the external auditory canals.

Both pendular and jerk nystagmus have a position of gaze where the amplitude and frequency is at a minimum, termed the null point. Thus, when nystagmus occurs, a patient that lies in front of them, they will frequently turn their head in the direction opposite to that of their null position. In this manner the extraocular motor innervation is similar to that found with the head straight and the eyes directed laterally into the null position.

The velocity of the nystagmus contributes to the reduction in visual acuity found in these patients because of the increased retinal-image motion producing a smearing effect. The constantly varying eccentric retinal locus may also contribute to the loss, but this factor has rarely been considered. The nystagmus presents a problem during reading, especially with smaller-sized print. It drives the eyes away from the word of interest, thus interfering with oculomotor positional and text processing. In cases of congenital idiopathic nystagmus, these sensory and motor-based aspects are superimposed on the bilateral amblyogenic sensory component due to early abnormal visual experience as a result of the increased retinal-image motion. Additionally, there are often anatomic foveal malformations. And, in cases of acquired etiology, the nystagmus produces oscillopsia, an illusory sense of movement of the world that is extremely disturbing to a patient. Thus, the effect of nystagmus has on a patient will vary considerably depending on the etiology.

Normal Reading

When reading, one maintains a complex level of oculomotor, sensory, cognitive, and linguistic activity. The oculomotor component involves the interaction of three primary types of eye movements.

The first eye movement is the saccade, which is the fastest of the eye movements. Its peak velocity is proportional to the size of the eye movement; the larger the movement, the higher the peak velocity. There are three categories of saccades that are present during reading. The first type is the progressive saccade, which moves the eyes from left to right over the words in a line of text. The second is the regressive saccade, which moves the eyes from right to left to reread a portion of text. And the last type is the return-sweep saccade, which is executed near the end of the line of text and moves the eyes from right to left near the beginning of the next line.

The second eye movement is disparity (fusional) vergence, which typically has a small amplitude of about 0.3 degrees. Disparity vergence is a reflexive, binocularly-corrective response following a saccade during the 200-300 ms fixation pause. It is compensatory for the transient dynamic divergence which occurs during each brief (e.g., 29-45 ms) saccade.

The third eye movement refers to the fixational component itself. When fixating an object, the microsaccadic eye positional and drift velocity errors must be kept at a minimum to maintain maximum foveal visual acuity. This is assured in normals by the relatively brief fixation durations and the heightened attentional aspect. Absence of any relatively large oculomotor errors allows for more rapid and efficient text and positional processing.

Other oculomotor systems may also be activated during reading. The vestibular system with its very short latency (about 15 ms) compensates for head movements to maintain steady fixation on a word with maintained clarity of vision. The pursuit system may be activated to compensate for any smooth movement of the reading material itself; for example, slight slippage may occur while reading on a bus or subway. It may also be activated to compensate for the small fixational drift velocity errors, as mentioned earlier. And the optokinetic system may be stimulated by the surrounding Gibsonian visual flow patterns when reading in a moving vehicle. However, to maintain steady fixation, the optokinetic response must be suppressed.

The reading rate of an average college student ranges from 200 to 350 words per minute with good comprehension. Reading rate is related to level of difficulty of the text material. Reading difficult material results in a slower reading rate, while reading easier text can result in reading rates up to 500 or so words per minute.

Reading and Nystagmus

When objectively measuring eye movements during normal reading, one observes a staircase pattern of alternating saccades and fixation pauses. (See Figure 2.)

It represents the integration of all progressive and regressive saccades, return-sweep saccades, and fixation pauses (as well as the small and transient vergence movements during and immediately following each saccade). Under typical test conditions, the other possible oculomotor components play a relatively minor role.

Nystagmus also display a similar staircase pattern. However, the nystagmus is now superimposed upon the reading record. (See Figure 3.)

One can see how the presence of nystagmus will cause a problem when reading (as described earlier), which in itself is a complex process. For example, nystagmus may appear to make smaller and more frequent progressive saccades, tend to lose their place, and may have difficulty shifting to the next line of print. Hence, reading rate in nystagmics is typically reduced by 20-60 percent when compared with normals. In some unusual cases, however, the nystagmus is considerably reduced during reading. Perhaps the requisite reading-related saccades are able to suppress the jerk nystagmus-related saccades since only four or five saccades can typically be executed per second. The clinician must be aware of this when considering possible therapeutic interventions, as well as discussing potential problems and limitations regarding vocational and avocational aspects, especially with the younger patient.
although a much larger group of nystagmats is needed, probably in the context of a clinical trial, to determine in a more generalized manner the therapeutic outcome following such varied forms of vision therapy.

**Base-Out Prisms**

Use of base-out prisms is probably the simplest approach in the management of nystagmus in the absence of strabismus. Spectacles with equally divided amounts of base-out prisms before each eye stimulate convergence, which dampens the magnitude of the nystagmus (probably by interaction of the nystagmus and convergence oculomotor signals). It thereby reduces the retinal-image motion and increases text visibility. This is one reason why young nystagmats with ample accommodation tend to hold reading material at a closer working distance than normal; they stimulate convergence and reap the visual benefits. Composite prisms (i.e., base-out prisms of unequal amounts before each eye) have been used to create the same oculomotor innervational pattern in the “straight ahead” position as that found in the null position, with the added benefit of the simultaneous convergence innervation. Some clinicians believe that vision therapy should first be implemented, and only then prisms considered as a supplement, in all patients who show improvement during testing with prisms. However this philosophy remains a point of debate.

**Contact Lenses**

Rigid gas permeable lenses may also help patients with nystagmus. Contact lenses provide a wider field of view which may be beneficial to fusion and, in cases of high refractive error (especially the higher degrees of astigmatism typically found in these patients), can improve visual acuity by providing better optics than a spectacle prescription. Contact lenses may also reduce aniseikonia in cases of refractive anisometropia, and thus once again promote fusional ability in an already compromised system with its multiple sensory and motor disturbances. In addition, there is tactile feedback when nystagmats wear rigid gas permeable lenses. As nystagmus intensity increases, there is greater sensation of lens awareness with changing eye position as the rigid lens moves more vigorously against the sensitive palpebral conjunctiva. Patients fitted with rigid lenses are able to use the correlated lid tactile feedback to control and reduce their nystagmus in the normal environment once they are made aware of this novel source of oculomotor feedback. We feel that rigid contact lenses are a good supplemental treatment to be used in conjunction with vision therapy and oculomotor auditory biofeedback.

**Eye Muscle Surgery**

Eye muscle surgery is another possible mode of treatment in the management of nystagmus, although diplopia may result, especially in the adult patient. Improvement of visual acuity has been found following extraocular muscle surgery consisting of the Anderson-Kestenbaum procedure as well as the artificial divergence procedure. The former procedure mechanically shifts the position of the eccentric null point to the “straight ahead” position, thus reducing the need for a head turn to improve vision. In contrast, the latter procedure creates a mechanical situation requiring convergence innervation at distance. Since convergence at near dampens the magnitude of nystagmus, then, surgically causing the binocular motor system to exert convergence innervation at distance results in a similar dampening effect. Post-operatively, patients demonstrated up to a two-line increase in Snellen visual acuity. In addition, if this is done at any early age (before 6 to 8 years), it may reduce the deleterious amblyogenic effects of the increased retinal-image motion. Subsequent active optometric vision therapy in such patients, by treating them as if they were bilateral amblyopes, should yield yet further improvement of overall vision function. Treatment of nystagmats in this way has been given little formal attention, and it would require considerable cooperation between the optometrist, ophthalmologist, and patient/parent.

**Pharmacological Intervention**

More recently, pharmacological agents injected directly into the extraocular muscles have been used to treat patients with nystagmus. Botulinum toxin A is used to paralyze to varying extents the extraocular muscles, thereby effectively reducing the magnitude of nystagmus. It affects the neuromuscular junction by chemoengeneration by preventing the release of acetylcholine. However, various side effects, such as diplopia and ptosis as well as forced innervational motor adap-
tive changes, may limit its use. Baclofen
has been successful in the treatment of
some forms of acquired nystagmus. Its
specific mechanism of action is not fully
understood; however, it inhibits monosyn-
naptic and polysynaptic transmission at
the spinal cord and also depresses the cen-
tral nervous system. However, these ef-
effects may be short-lived, and thus a more
permanent pharmacological agent in the
successful treatment of nystagmus re-
mains to be found.

NON-TRADITIONAL TREATMENT
Auditory and Associated
Biofeedback Techniques

The use of oculomotor auditory bio-
feedback was first reported nearly two
decades ago in the treatment of patients
with congenital nystagmus. The in-
frared limbal reflection technique was
used to monitor changes in horizontal eye
position. The reflected light detected by
the sensors varies as a function of eye
position. These changes are converted to
an auditory signal whose pitch alters sys-
tematically with eye position. Thus, pa-
tients actually "hear" their nystagmus.

While the patient fixates a target in
primary position, the nystagmoid eye move-
ment is represented as a jerky or waveling
tone. The patient attempts to reduce this
varying and unevetual quality by de-
veloping and invoking one or more higher
level control strategies. Different strate-
gies may be used, such as visual imagery
and relaxation, to gain control over the
nystagmus. For example, while fixating a
target at near in primary position, the pa-
tient is initially instructed to relax and
imagine looking "through" the target and
display screen into the distance. As the
patient relaxes and begins to exert some
control, the tone becomes more constant
in pitch as the nystagmus is reduced. The
patient may then use additional internal
control strategies to reduce the tonal vari-
ation to a minimum. For example, some
patients imagine that they are gazing into
their null position, while others imagine
looking with either one eye or the other
during binocular viewing of the target.
The ultimate goal is to reduce the tone to
a constant, unwavering pitch, as extending
foveation time will optimize visual acuity.
The patient is then gradually "weaned" off
the tone until eventually control can be
consistently exerted at will without audi-
tory assistance under more naturalistic
conditions and in the presence of purpose-
ful distractions. These techniques can then
be applied to the patient's own external
environment, such as the classroom, to
increase visual acuity at distance on the
blackboard and to enhance text visibility
at near as needed for short periods of time
(up to two minutes or so), thus effectively
functioning as a "spotting" device. At
home, the patient is asked to practice these
techniques and to monitor the oculomotor
variations either directly by tactile feed-
back (lightly touching the eyelid with a
finger) or by observing changes in very
low contrast test targets. Also, family
members may provide verbal feedback re-
garding the nystagmus intensity during the
home training periods.

Over the past 20 years, we have had
remarkable success with this technique.
With ongoing developments in this area,
including relatively simple and inexpen-
sive oculomotor auditory biofeedback de-
vice for in-office and home training, this
potent conditioning paradigm should be-
come more commonplace.

Rapid Serial Visual Processing
(RSVPA)

The primary way to read more rapidly
and efficiently is to minimize the number
of saccadic eye movements. The maxi-
mum number of saccades made is control-
led by the neurological sampled-data
system, which limits it to four or five per
second. Thus, during simple positional
tracking, its 180 ms or so latency/refrac-
tory (fixational) period is activated; how-
ever, during reading, an additional 70 ms
or so is used for text processing during
each 250 ms fixation pause. Elimina-
tion of saccades during reading can there-
fore effectively result in a savings (~75%)
of at least 180 ms per saccade, in addition
to the 20 to 45 msec saccade duration
itself. However, even with the elimination
of the saccades related to reading, the
nystagmus component is still present in these
patients. Therefore, it is first necessary to
use other modes of treatment to improve
oculomotor control and enhance text visi-
bility, and then use additional techniques,
such as the RSVP methodology, to in-
crease reading speed even further.

Basically, rapid serial visual process-
ing, or RSVP, refers to a computer-con-
trolled text with a fixed spatial location
within which text is presented one word at
a time. Since saccades are not required
during such RSVP reading, it can be a
useful tool for those patients who have
already attained good fixational control
over their nystagmus, therefore increasing
reading efficiency and reading rate even
more. RSVP can also be used in conjunc-
tion with oculomotor auditory biofeed-
back to maintain improved gaze stability
for longer periods of time.

Discussion

It is clear that nystagmus control is
essential for more rapid and efficient read-
ing in these patients. The act of reading
requires a sustained and high level of cog-
nitive, linguistic, sensory, and oculomotor
processing and interaction. It is easy to see
how the abnormal nystagmoid oculomo-
tor component can cause havoc to the
complex reading process. The staircase
pattern found in normal reading is also
present in patients with nystagmus, but
with the aberrant nystagmoid eye move-
ments superimposed, overall reading effi-
ciency is reduced.

Our present training protocol in a pa-
ient with nystagmus has multiple sequen-
tial components which may take several
months to complete. First, we conduct
8 sessions of eye movement auditory
biofeedback. Most of this involves
midline fixation; the latter sessions in-
clude some saccadic and pursuit tracking.
Once relatively consistent control has
been established with these initial ses-
sions, additional sources of feedback are
incorporated concurrent with the ongoing
clinical auditory biofeedback sessions.
This includes visual feedback using com-
puter tracking tasks and the pegboard ro-
tator. It also includes tactile feedback
involving placement of the patient's index
finger against the upper lid. During these
times, they attempt to invoke the higher-
level control strategies learned previously
with the auditory biofeedback training.
We plan to incorporate afterimage training
in the future, using a device that helps
sustain the percepct for up to five minutes.
At this time, some of the patients are also
fit with RGP contact lenses, which typi-
cally improves their vision as well as pro-
vides an additional source of tentative
feedback related to their nystagmoid
movements. Then home training is insti-
tuted. The patient can use tactile feedback
from a finger and/or contact lenses, verbal
feedback from a family member trained to
detect and assess the patient's eye move-
ments, and visual feedback using very low
contrast stimuli (near threshold) such as
sinusoidal grating patterns. In this last
case, when the nystagmus worsens, the
grating pattern disappears, whereas if the
nystagmus decreases, the pattern becomes visible. In the future, we anticipate having a simple eye movement auditory biofeedback device for home training, which will provide reinforcement of the clinical sessions.

It is important for the clinician to consider all viable options in the treatment and overall management of the patient with nystagmus. Whether such treatment is invasive or non-invasive, traditional or non-traditional in nature, or some combination, it is the responsibility of the clinician to educate the patient regarding all interventions as well as any potential problems or side effects. With the variety of treatment options available, as well as others currently being investigated, including more experimental modes such as acupuncture and afferent stimulation, the clinician and patient should be able to formulate an appropriate and beneficial rehabilitative program.

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References


EDITORIAL continued

Further, the present system of health care reimbursement is not conducive to healing the patient. Managed care seeks to reduce the number of procedures performed and minimize the time the doctor spends with the patient. Consequently, the doctor's ability to fully understand the disease in order to fully treat, and to gain the knowledge and insights about the patient as a person that are prerequisites for healing, are both compromised. This is the antithesis of Galland's method of "patient centered diagnosis" and "integrated medicine."

Finally, a system of integrated optometry would require the doctor to, at once balance a superb knowledge of the diseases that afflict his/her patients with the knowledge and sensitivity to understand them as unique individuals. This means that the healer must be doctor, psychologist and clergy person all at once, indeed a challenging task. Perhaps Galland's system is utopian, yet it is reminiscent of the old time family doctor. Hopefully, what goes around will come around in the near future.

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