Oscillopsia and the Influence of Stress and Motivation in Fusion Maldevelopment Nystagmus Syndrome

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Purpose. We examined factors influencing perceptual stability in observers with fusion maldevelopment nystagmus syndrome (FMNS). In addition, we also investigated the effect of visual demand, task-related physiologic stress, and motivation on the nystagmus waveform.

Methods. Perception of oscillopsia during daily activities was assessed via a questionnaire. Perception of oscillopsia in the laboratory was assessed using central and peripheral (10°) light emitting diodes (LEDs) in front of a background display of random, fixed-contrast shapes. Task-induced stress was achieved via a time restricted acuity task with or without concurrent mental arithmetic challenge, and motivation varied using a reward–penalty paradigm. The experiments have been previously described elsewhere.

Results. Six out of nine subjects reported experiencing oscillopsia in certain daily activities. In the laboratory, the percentages of trials with perceptions of motion of the LED and background were as follows: neither, 60% to 70%; background only, 20% to 30%; both, 5% to 15%, and LED only, 5% to 15%. Over all trials, six of nine experienced oscillopsia for both the low- and high-contrast image respectively (i.e., three subjects never experienced oscillopsia). The background was frequently seen moving for both images regardless of contrast and/or condition. Trials with and without oscillopsia did not differ when comparing foveation. In the second experiment, task-related physiologic stress and motivation were reflected in an increase in heart rate; nystagmus waveform intensity increased and foveation decreased. The magnitude of changes in heart rate was uncorrelated with changes in waveform parameters for all experiments, however.

Conclusions. Preliminary results suggest that the FMNS group does perceive spatially inhomogeneous oscillopsia, similar to infantile nystagmus syndrome (INS), in certain visual environments. In investigating the effect of stress and motivation on FMNS, a new, if tentative, finding suggests that task-induced stress and/or motivation may have a negative impact on the nystagmus. Taken together, our findings provide an insight into the particular environments and tasks that are likely to present particular challenges to persons with FMNS. (*Invest Ophthalmol Vis Sci.* 2013;54:2004–2010) DOI:10.1167/iovs.12-11326

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Fusion maldevelopment nystagmus syndrome[1] (FMNS) is a form of infantile nystagmus, which bears some similarities to infantile nystagmus syndrome (INS) and may coexist with it.[2,3] Whereas INS has a diverse range of waveforms,[4,5] FMNS slow phases are either decreasing velocity or linear.[4,6] FMNS encompasses both latent nystagmus and manifest latent nystagmus, which are mechanistically equivalent and coexist in all but the rare patient who has only latent nystagmus.[7]

While circumstances have been described in which individuals with INS, whose perceptual world is generally stable, may experience oscillopsia,[8–11] there have been few reported investigations regarding oscillopsia in FMNS. Simonsz[12] reported that in manifest latent nystagmus subjects, oscillopsia may come about when occlusion of one eye for the treatment of amblyopia leads to latent nystagmus. What is not known is how frequently oscillopsia is seen in what visual environments, and whether perceptual instability due to FMNS may be exacerbated during stressful situations (as may occur during driving or when taking examinations). We have recently developed methods to investigate oscillopsia frequency during daily tasks[8] and to investigate stress-induced changes in foveation[13] in INS, and so our aim was to extend these investigations to observers with FMNS. There is some evidence that cognitive factors can change the nature of FMNS[13]; for example, it has been demonstrated that some individuals with FMNS can volitionally control, which is the fixating eye,[14] even if one eye is prosthetic.[15]

In the current study, we investigated two aspects of FMNS. Firstly, we investigated the relationship between the nature of the visual stimulus and occurrence of oscillopsia in daily activities via a questionnaire, and also the relationship between waveform parameters, and the onset of oscillopsia in the laboratory. Our study was designed to assess the consistency of perceptual stability reports by repeatedly exposing subjects to the same stimulus multiple times. Secondly, we also assessed the influence of task-induced physiologic stress and of motivation on the FMNS waveform.

Methods

Our study conformed to the declaration of Helsinki and was approved by the Human Research Ethics Committee of the University of Melbourne, and all subjects gave written informed consent before participating. Eye movement recordings were performed in nine FMNS subjects (three males and six females, mean age 25.8 ± 15.9). Mean distance visual acuity (logMAR) was 0.30 ± 0.25 and near 0.31 ± 0.27. The diagnosis of FMNS was primarily made by the referring ophthalmologist and later verified on the basis of clinical examination and eye movement recording analysis performed by the investigators. One subject had albinism, with no evidence of INS on waveform recordings; the others had no sensory abnormalities. All subjects had either an exotropia ($n = 4$) or esotropia ($n = 5$). The waveforms exhibited were jerk ($n = 9$). Baseline (i.e., subjects fixating an light emitting diode [LED] target in primary gaze) means and SDs of the waveform parameters for all subjects were: foveation periods (percent

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Table 1. Foveation, Amplitude, Frequency, and Intensity during Oscillopsia Trials for Both the Low- and High-Contrast Images as Assessed by Using Paired *t*-Tests

Waveform Parameters	Oscillopsia, Low-Contrast Image	Oscillopsia, High-Contrast Image
Foveation, percent ± 2° and ≤ 4 deg/s	36.14 ± 21.87	27.54 ± 20.14
Amplitude, deg	2.28 ± 1.26	3.16 ± 2.27
Frequency, Hz	3.93 ± 1.04	3.98 ± 1.43
Intensity, deg × Hz	9.70 ± 6.33	12.60 ± 8.52

Foveation showed a trend toward a difference between both contrast images.

± 2° and ≤ 4 deg/s), 53.6 ± 30.2%; amplitude, 1.82 ± 1.39°; frequency, 2.89 ± 1.08 Hz; and intensity, 5.69 ± 4.81 deg × Hz. All subjects were free of medications and drugs by self report. They were nonsmokers and were advised not to consume alcohol or coffee and to abstain from vigorous exercise at least 4 hours before the session. All subjects were naive with respect to the specific aims of the study. The instrumentation, design, procedure and the analyses of the experiments for (1) and (2) have been previously described in two related papers.[8,13] Briefly, in experiment (1), subjects viewed two images of random achromatic shapes and sizes of varying contrast presented on an LCD monitor (38° × 32°, width × height). A green fixation LED and another peripheral LED (10° above fixation) over laid the images. Subjects were told to fixate at the fixation LED and to report if anything happened to the LED or background images when the LED was illuminated or extinguished. To assess repeatability, images were presented five times. In experiment (2), we used a Landolt C visual acuity task under three conditions: unrestricted viewing (control), restricted viewing (100 ms presentation, unclear instructions, and simultaneous mental calculation, to induce physiologic stress), and the reward manipulation (100 ms presentation, plus monetary rewards or penalties for correct or incorrect responses, respectively) tasks. All FMNS subjects carried out the experiments monocularly, with the nonstrabismic eye as the viewing eye and the strabismic eye occluded during recordings. A comparison of monocular and binocular eye movement recordings (Microguide Corp., Downers Grove, IL) allowed us to see if the subjects had purely latent nystagmus or manifest latent nystagmus. None had purely latent nystagmus. We also took electrophysiologic recordings of heart rate in experiment (2), including a baseline measurement prior to commencing any task.[13]

We analyzed eye movement data for changes in the type and parameters of the waveform, in particular the foveation during experiments (1) and (2). In experiment (2), any changes in heart rate were also analyzed. For experiment (2), the data of subject A was removed due to repeated presence of artifacts in the electrocardiogram waveforms (e.g., spikes due to hand movement).

Results

Oscillopsia

Questionnaire Results. Six out of nine FMNS subjects (67%) perceived oscillopsia during their normal binocular viewing of the environment. Five of these subjects reported oscillopsia under dim lighting only, while one experienced motion under all conditions. When oscillopsia occurred, four subjects reported the surrounding scene as moving while one said that the viewed object moved. The remaining one perceived uniform motion. Fatigue was frequently associated with the experience. Most of the subjects were unable to prevent or minimize the perceived motion, although one of the six subjects reporting oscillopsia could stop it by looking away. This proportion was not significantly different (Fisher's exact test, $P = 0.65$) from the six of 16 INS subjects previously reported[2] who could stop their oscillopsia by either looking away or turning or tilting their head, and so presumably placing their eyes in their null positions. Results for all subjects are summarized in the Appendix.

Experimental Results

Experiment. Six out of nine subjects (67%) viewing the low-contrast (21% Weber) background image and six out of nine subjects (67%) viewing the high-contrast (96% Weber) image experienced oscillopsia. The level of contrast did not influence these subjects' responses (paired *t*-test, $P = 0.5$). During trials in which oscillopsia was reported, none of the waveform parameters differed significantly between the two contrast levels (paired *t*-test: foveation, $P = 0.07$; amplitude, $P = 0.33$; frequency, $P = 0.77$; and intensity, $P = 0.39$) (Table 1).

There were no significant interactions between subjects' responses and contrast level and condition (Friedman test: "LED moves," $P = 0.15$; "Background moves," $P = 0.33$; "All move," $P = 0.21$; and "Neither moves," $P = 0.75$. Dunn's multiple comparison test was not significant [$P > 0.05$] for all interactions). Trials with and without oscillopsia in both contrast levels did not statistically differ across subjects in terms of waveform parameters, except for frequency in the low contrast setting (paired *t*-test for low-contrast: foveation, $P = 0.89$; amplitude, $P = 0.45$; frequency, $P = 0.01$; and intensity, $P = 0.91$; for high-contrast: foveation, $P = 0.07$; amplitude, $P = 0.95$; frequency, $P = 0.94$; and intensity, $P = 0.71$) (Table 2). That is, the only change in waveform observed between trials with and without oscillopsia was that when subjects viewed the low-contrast image, frequency increased when oscillopsia occurred. Responses from all subjects are summarized in Figure 1.

Figure 2 illustrates the percentage of subjects consistently reporting the same perceptions for a given condition and contrast upon repeated testing. The subjects in the current study exhibited a high repeatability (hence, low variability) of the same perceptions in all five trials for both contrast levels.

Table 2. Foveation, Amplitude, Frequency, and Intensity of Trials with and without Oscillopsia for Both the Low- and High-Contrast Images

Waveform Parameters	Oscillopsia		No Oscillopsia	
Image Contrast	Low	High	Low	High
Foveation, percent ± 2° and ≤ 4 deg/s	43.23 ± 30.43	28.44 ± 19.75	43.61 ± 30.94	35.58 ± 23.44
Amplitude, deg	2.14 ± 1.39	2.70 ± 2.23	2.42 ± 1.52	2.89 ± 2.00
Frequency, Hz	**3.65 ± 1.07**	3.96 ± 1.43	3.32 ± 1.18	4.03 ± 1.32
Intensity, deg × SHz	8.83 ± 7.05	10.84 ± 8.56	8.96 ± 6.61	12.34 ± 9.12

Only changes in frequency were significant in the low contrast setting (shown in bold), as assessed by using paired *t*-tests.

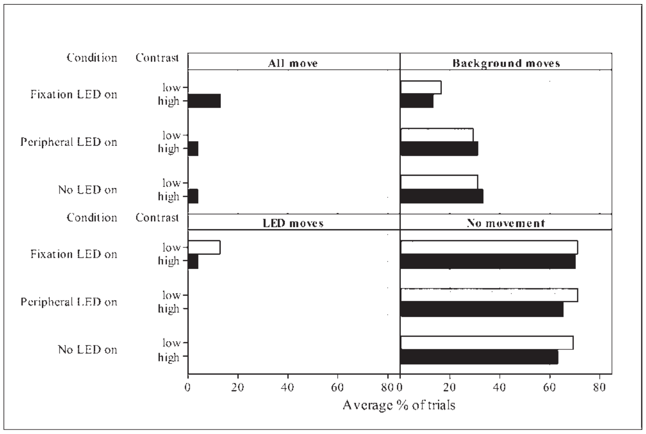

FIGURE 1. *Individual bar* represents the percentage of trials averaged across all subjects for a particular condition and contrast. All bars of the perceptual outcomes (all move, background moves, LED moves, no movement) for a particular condition and contrast add up to 100%. For some subjects, they noticed the unlit fixation LED in instances of either the background or LED moved when no LED was on. The peripheral LED was never seen by the subjects when no LED was on.

Of the trials when oscillopsia was perceived, three subjects consistently reported that the same part of the stimulus moved (i.e., LED, background, or both) regardless of the condition and/or contrast presented. The responses of the remaining subjects varied depending on the condition. Age did not correlate with oscillopsia at either contrast level (Spearman rank correlation: low contrast, $r = -0.11$; $P = 0.78$; high contrast, $r = 0.24$; $P = 0.52$). No change in waveform type was observed when compared with baseline.

Stress and Motivation

We compared the waveform parameters and heart rate in the baseline, unrestricted viewing, and restricted viewing tasks using a one-way ANOVA with repeated measures. Unlike visual acuity, significant alterations were seen in all waveform parameters (Fig. 3). Heart rate was also significantly increased (Fig. 3), indicating our restricted viewing condition evoked a significant amount of physiologic stress.

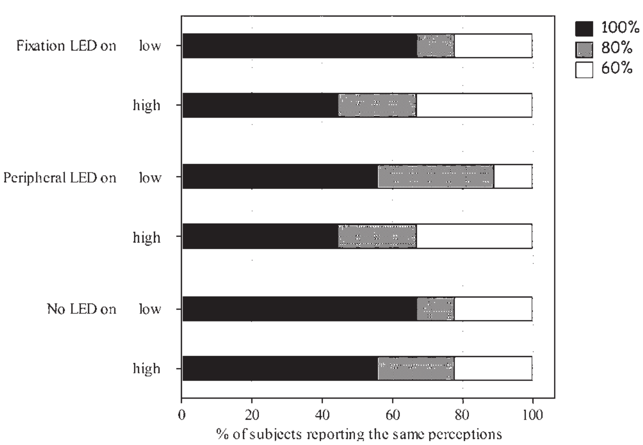

FIGURE 2. *Individual bar* represents the percentage of subjects consistently reporting the same perceptions (i.e., LED moved, background moved, both moved, or neither) of a particular condition and contrast for all trials.

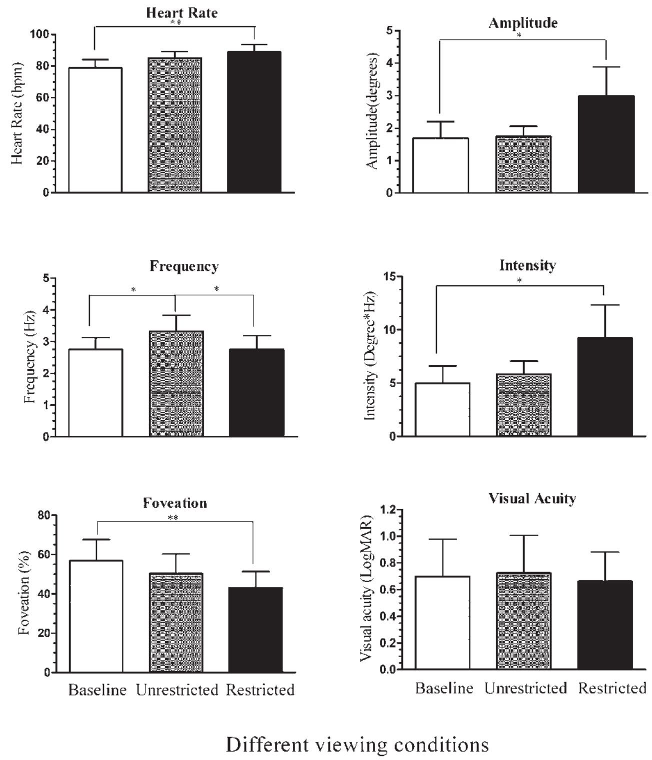

FIGURE 3. Heart rate and waveform parameters for the baseline, unrestricted, and restricted viewing tasks. Pairwise interactions were investigated using Tukey's multiple comparison test. $^{**}P < 0.001$–0.01; $^{*}P = 0.01$–0.05. Results for the repeated measures one-way ANOVA were as follows: heart rate: $F\,(2,7) = 7.8$, $P = 0.007$; amplitude: $F\,(2,7) = 4.4$, $P = 0.03$; frequency: $F\,(2,7) = 4.74$, $P = 0.03$; intensity: $F\,(2,7) = 4.05$, $P = 0.04$; foveation: $F\,(2,7) = 8.08$, $P = 0.005$; and visual acuity: $F\,(2,7) = 0.3$, $P = 0.75$. *Error bars* = standard error of mean.

For the reward manipulation task, paired *t*-tests illustrated significant changes only in heart rate and foveation when compared with baseline (Fig. 4).

When examining the heart rates and waveform parameters during minimum (largest optotype read) and maximum (smallest optotype read) visual demand, significant differences were found using paired *t*-tests only for foveation in the unrestricted viewing and for heart rate in the restricted viewing tasks (Table 3). No significant differences were found for any other parameters in the three tasks.

When comparing the restricted viewing and reward manipulation tasks, heart rate increased significantly more (paired *t*-test: $t = 4.46$, $P = 0.003$) and foveation decreased significantly more ($t = 4.02$, $P = 0.01$) in the restricted viewing task. Table 4 shows the effects of increased visual demand on FMNS parameters (i.e., decreased, that is, deteriorated, foveation) during the unrestricted viewing and of increased heart rate during the restricted viewing tasks. Considerable intersubject variability can be seen.

A Pearson correlation was performed to investigate the relationship between changes (restricted viewing minus unrestricted viewing) in heart rate and changes in waveform parameters between the unrestricted and restricted viewing tasks. The correlation was done separately for each subject. Changes in heart rate were uncorrelated with changes in waveform parameters (amplitude, $r^2 = 0.23$, $P = 0.23$; frequency, $r^2 = 0.05$, $P = 0.6$; intensity, $r^2 = 0.18$, $P = 0.3$; and foveation, $r^2 = 0.15$, $P = 0.3$).

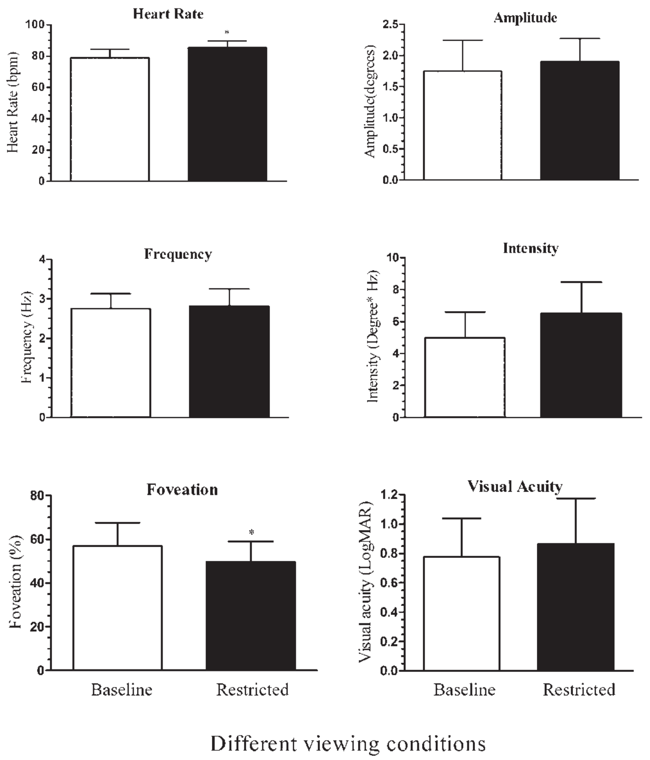

Figure 4. Heart rate and waveform parameters for baseline and the restricted viewing tasks in the reward manipulation paradigm. $^*P = 0.01$–0.05. Results for the paired *t*-test were as follows: heart rate: $t = 2.84$, $P = 0.02$; amplitude: $t = 0.59$, $P = 0.58$; frequency: $t = 0.3$, $P = 0.77$; intensity: $t = 1.3$, $P = 0.22$; foveation: $t = 2.37$, $P = 0.04$; and visual acuity: $t = 0.82$, $P = 0.44$. *Error bars* = standard error of mean.

When evaluating task performance (change from baseline heart rate versus number of correct responses in the mental arithmetic task or the number of skipped optotypes), Pearson correlation was significant for the mental arithmetic ($r^2 = 0.47$, $P = 0.04$) in the restricted viewing task, but not for the skipped optotypes ($r^2 = 0.013$, $P = 0.77$). No significant correlation was found for the reward manipulation task (skipped optotypes, $r^2 = 0$, $P = 1.0$). No change in waveform type was observed when compared with baseline. The subjects were not asked explicitly about the experience of oscillopsia, but no one reported any movement during all experimental components in experiment (2).

Discussion

Oscillopsia during Daily Activities

Six out of nine subjects (67%) perceived motion in their daily life, with the majority reporting this to occur under dim lighting; however, oscillopsia was occasional and usually lasted only seconds. Four subjects reported the viewed background moved. We have previously reported[8] that 89% of subjects with INS perceived either uniform or nonuniform oscillopsia either under dim lighting or unrelated to any particular viewing condition. This proportion is not significantly different from that found in the current study for FMNS (Fisher's Exact test, $P = 0.30$). Fatigue was commonly associated with oscillopsia in FMNS, while stress was more often identified as an additional factor in INS.[8] Looking away from the fixation point or turning/tilting the head could prevent or minimize oscillopsia in a small number of INS subjects,[8] and a similar proportion of FMNS subjects in the current study could minimize oscillopsia by turning away. Since FMNS generally obeys Alexander's law,[12] one might expect a gaze shift, which reduced nystagmus intensity to work similarly to adoption of a null position in INS. The experience of oscillopsia in FMNS subjects was uncorrelated with age, although the limited range and the number of subjects in this study would make finding such a correlation difficult.

Oscillopsia under Laboratory Conditions

In the current study, neither the LED nor the background was reported to move (i.e., oscillopsia was absent) in the majority of the trials. In trials where motion was reported, spatially inhomogeneous oscillopsia was observed, with the background often seen moving. The LED was rarely seen as oscillating. Two subjects consistently reported the same stimulus elements moved regardless of contrast and condition. In their questionnaire results, they frequently perceived oscillopsia.

No changes in the waveform parameters were observed when oscillopsia occurred in the high-contrast condition. However, when viewing the low-contrast image, nystagmus frequency increased when oscillopsia occurred. In FMNS, there are no explicit foveation periods; slow phases are either decreasing velocity exponentials or linear. Most often, the fast phases place the image of the point of regard on the fovea, immediately followed by the highest velocity portion of the slow phase. At times, however, the fast phase may carry the fovea past the target; as the slow phase velocity decays, the target image drifts onto the fovea.[16] There is no part of the waveform where the eye is stationary for a brief period while

Table 3. Amplitude, Frequency, Intensity, Foveation, and Heart Rate during Minimum and Maximum Visual Demand for All Three Tasks

Task	Visual Effort	Amplitude, deg	Frequency, Hz	Intensity, deg × Hz	Foveation, Percent ± 2° and ≤ 4 deg/s	Heart Rate, beats/min
Unrestricted viewing	Min	1.8 ± 0.7	2.9 ± 1.4	5.9 ± 5.2	53.1 ± 32.0	82.8 ± 13.3
	Max	1.8 ± 1.0, $P = 0.99$	3.2 ± 1.5, $P = 0.32$	5.5 ± 3.4, $P = 0.71$	41.4 ± 32.0, $\mathbf{P = 0.016}$	85.7 ± 13.8, $P = 0.3$
Restricted viewing	Min	3.1 ± 1.8	2.9 ± 1.7	9.0 ± 6.9	46.9 ± 31.9	80.5 ± 13.9
	Max	2.5 ± 1.6, $P = 0.15$	2.8 ± 1.1, $P = 0.71$	7.3 ± 5.2, $P = 0.1$	45.0 ± 27.1, $P = 0.68$	88.9 ± 11.0, $\mathbf{P = 0.007}$
Reward manipulation	Min	2.6 ± 1.8	3.4 ± 1.5	10.4 ± 10.1	53.1 ± 30.3	83.4 ± 12.7
	Max	2.0 ± 1.6, $P = 0.36$	3.2 ± 1.8, $P = 0.49$	7.2 ± 6.8, $P = 0.25$	50.6 ± 25.9, $P = 0.57$	83.2 ± 10.6, $P = 0.97$

Only changes in foveation during the unrestricted viewing and heart rate in the restricted viewing tasks (shown in bold) were significant, as assessed by using paired *t*-tests.

TABLE 4. Mean Foveation during the Unrestricted Viewing and Heart Rates during the Restricted Viewing Tasks at Times of Minimum and Maximum Visual Demand

	Foveation, Percent ± 2° and ≤ 4 deg/s – Unrestricted Viewing		Heart Rate, beats/min – Restricted Viewing	
Subject	Min	Max	Min	Max
B	74.50	51.00	95.78	96.39
C	17.32	16.50	95.14	94.13
D	83.34	73.00	83.57	94.76
E	98.00	97.80	93.44	104.67
F	48.30	33.00	64.56	70.63
G	60.13	43.00	66.67	79.41
H	6.83	6.40	81.18	90.00
I	36.42	10.10	63.83	81.30
Mean ± SD	53.11 ± 31.98	41.35 ± 32.00	80.52 ± 13.88	88.91 ± 11.01

Group means and SD are also shown for each measure.

the target image falls onto the fovea, as is the case in many INS waveforms. Hence, foveation in the present context is that percentage of the slow phase, which meets specific position and velocity criteria.

It seems that good foveation did not prevent the breakdown of perceptual stability at either contrast level. It appears there is not a simple relationship between perceptual stability and foveation, and so the role of waveform parameters in influencing FMNS subjects' perceptions requires further investigations. Some relationship must exist, however, as it is known that occlusion therapy for amblyopia in an FMNS patient can provoke oscillopsia as it elicits a greater nystagmus[12]; something analogous occurs in congenital periodic (or aperiodic) alternating nystagmus, where oscillopsia is common during the most intense portions of the cycle.[17]

Influence of Stress and Motivation

This study is the first to provide evidence for the negative impact of stress and/or motivation upon the characteristics of the FMNS waveform. Task-induced physiologic stress, as evident by an increase in heart rate when performing the restricted viewing task, led to an increase in the intensity of the nystagmus waveform, and decreased foveation in FMNS. This suggests that FMNS increases with psychologic factors (such as stress and anxiety) that affect visual performance, similar to INS.[13] It is curious that such internal influences have not been previously commented upon for FMNS, unlike INS. Perhaps most FMNS patients have sufficiently minimal nystagmus with binocular viewing that a statistically significant deterioration of foveation still does not noticeably compromise acuity to the extent that it does in INS; that is, there may be a greater "safety margin." We do not fully understand the mechanisms that underlie FMNS and INS, although this influence of internal state may reflect the role of inputs from stress and motivation-modulated brain regions on a common component of the smooth eye movement pathway. Such brain regions may include the amygdala and the anterior cingulate cortex, which are known to influence emotion and affective behavior.[18] Various brain regions have also been implicated in motivation. The brain–reward circuit involves the mesocorticolimbic dopamingeric network that regulates motivation, spanning the frontal cortex, amygdala, mesencephalon, nucleus accumbens, striatum, thalamus, and cerebellum.[19–21]

Maximum visual demand decreased foveation in the unrestricted viewing and increased heart rate in the restricted viewing tasks. It is rather surprising that foveation decreased at maximum visual demand during the unrestricted viewing and not in the restricted viewing task, since the latter is more stressful (evident by elevated heart rate) than the former. Since foveation was lower in the restricted viewing task even for minimal visual demand, it may be that there was less scope for further change in this task.

Even though foveation decreased significantly during the visual tasks, visual acuity remained relatively unchanged. As mentioned previously in our study on INS,[13] our methods were not primarily designed to measure visual acuity, but rather to produce a stressful visual environment by briefly presenting optotypes. This unconventional visual acuity task might account for the increased variability (and hence, nonsignificant) in visual acuity among the visual tasks. The infrared limbus eye tracker also precluded the use of patients' spectacles for refractive errors correction, thus, further limiting our ability to evaluate best-corrected visual acuity.

In the reward manipulation paradigm, foveation decreased significantly when compared with baseline. Concurrently, heart rate increased, but not as much as it did in the restricted viewing task. This reflects a greater motivational role compared with stress in the current task.

Although heart rate, nystagmus amplitude, and foveation were significantly associated in our ANOVA, we failed to find any significant correlation between the magnitude of these changes when subjects performed different visual tasks, possibly due to reasons as mentioned previously regarding INS.[13] It is possible that although both observed changes covary with stress, they do not covary with each other. It is also possible that the variability of the data in our study results in insufficient power to illustrate the correlation, or the nature of how both changes vary cannot be demonstrated by correlation, or both. The underlying functional relationship between stress, changes in heart rate, and changes in nystagmus parameters is unknown. Furthermore, recording heart rate over a short period of time is a coarse measure. Being an episodic rather than a continuous measure, heart rate is less robust and less sensitive than other measures such as galvanic skin response or pupil size to detect subtle changes when monitoring the psychologic state of the subjects in this study. Again, the use of additional, more continuous measures such as galvanic skin response or pupil diameter might better quantify the psychologic state of an individual compared with heart rate. Monitoring pupil diameter in oscillating eyes, of course, presents its own difficulties.

CONCLUSIONS

Limited research on perception in FMNS exists. In the current study, preliminary results suggest that people with FMNS do perceive spatially inhomogeneous oscillopsia, similar to individuals with INS. In investigating the effect of stress and motivation on FMNS, a new, if tentative, finding suggests that task-induced stress and/or motivation may have a negative impact on this form of nystagmus as well. Appreciating how nystagmus and its perceptual effects may change in response to the type of visual environment and the presence of psychologic stressors is important in predicting how and what daily activities may present particular challenges to persons with FMNS.

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References

1. *A National Eye Institute Sponsored Workshop and Publication on The Classification Of Eye Movement Abnormalities and Strabismus (CEMAS)*. Bethesda: National Eye Institute, 2001.
2. Abadi RV, Scallan C. Manifest latent and congenital nystagmus waveforms in the same subject. *Neuro-Ophthalmol*. 1999;21: 211–221.
3. Dell'Osso LF. Congenital, latent and manifest latent nystagmus–similarities, differences and relation to strabismus. *Jpn J Ophthalmol*. 1985;29:351–368.
4. Abadi RV, Bjerre A. Motor and sensory characteristics of infantile nystagmus. *Br J Ophthalmol*. 2002;86:1152–1160.
5. Dell'Osso LF, Daroff RB. Congenital nystagmus waveforms and foveation strategy. *Doc Ophthalmol*. 1975;39:155–182.
6. Dell'Osso LF, Schmidt D, Daroff RB. Latent, manifest latent and congenital nystagmus. *Arch Ophthalmol*. 1979;97:1877–1885.
7. Abadi RV, Scallan C. Waveform characteristics of manifest latent nystagmus. *Invest Ophthalmol Vis Sci*. 2000;41:3805–3817.
8. Cham KM, Anderson AJ, Abel LA. Factors influencing the experience of oscillopsia in infantile nystagmus syndrome. *Invest Ophthalmol Vis Sci*. 2008;49:3424–3431.
9. Abel LA, Williams IM, Levi L. Oscillopsia suppression in congenital nystagmus: dependence on foveation stability and duration. *Invest Ophthalmol Vis Sci (Suppl)*. 1990;31:122.
10. Abadi RV, Whittle JP, Worfolk R. Oscillopsia and tolerance to retinal image movement in congenital nystagmus. *Invest Ophthalmol Vis Sci*. 1999;40:339–345.
11. Tkalcevic L. *Influence of visual stimuli on perceptual and fixation stability in congenital nystagmus. Orthoptics*. Bundoora, Australia: La Trobe University; 2004. Thesis.
12. Simonsz HJ. The effect of prolonged monocular occlusion on latent nystagmus in the treatment of amblyopia. *Doc Ophthalmol*. 1989;72:375–384.
13. Cham KM, Anderson AJ, Abel LA. Task-induced stress and motivation decrease foveation periods in congenital nystagmus. *Invest Ophthalmol Vis Sci*. 2008;49:2977–2984.
14. Abadi R, Clement R, Theoodorou T, Scallan C. Manifest latent nystagmus: a case of sensori-motor switching. *Prog Brain Res*. 2008;171:497–502.
15. Dell'Osso LF, Abel LA, Daroff RB. Latent/manifest latent nystagmus reversal using an ocular prosthesis: Implications for vision and ocular dominance. *Invest Ophthalmol Vis Sci*. 1987;28:1873–1876.
16. Erchul DM, Dell'Osso LF, Jacobs JB. Characteristics of foveating and defoveating fast phases in latent nystagmus. *Invest Ophthalmol Vis Sci*. 1998;39:1751–1759.
17. Abadi RV, Dickinson CM. Waveform characteristics in congenital nystagmus. *Doc Ophthalmol*. 1986;64:153–167.
18. Cardinal RN, Parkinson JA, Hall J, et al. Emotion and motivation: the role of the amygdale, ventral striatum, and prefrontal cortex. *Neurosci Biobehav Rev*. 2002;26:321–352.
19. Breiter HC, Aharon I, Kahneman D, et al. Functional imaging of neural responses to expectancy and experience of monetary gains and losses. *Neuron*. 2001;30:619–639.
20. Delgado MR, Locke HM, Stenger VA, et al. Dorsal striatum responses to reward and punishment: effects of valence and magnitude manipulations. *Cogn Affect Behav NeuroSci*. 2003; 3:27–38.
21. Volkow ND, Wang GJ, Ma Y, et al. Activation of orbital and medial prefrontal cortex by methylphenidate in cocaine-addicted subjects but not in controls: relevance to addiction. *J Neurosci*. 2005;25:3932–3939.

Appendix: Responses to the Oscillopsia Questionnaire

Do you ever see things moving, which are not supposed to move? ☐ Yes ☐ No

FMNS – Yes: 6/9; No: 3/9

If **yes**,

Can you describe by giving an example(s)?

FMNS

LEDs, backlights of cars, clock radio display, taillights (2)

Light on the computer screen

LEDs in the experiment

Shapes on the computer

Lights

Writing on the whiteboard at school

When was your first experience?

FMNS – years ago: 4/6; today: 2/6

How often do you encounter it? ☐ Rarely ☐ Sometimes ☐ Frequently

FMNS – Rarely: 3/6; Sometimes: 2/6; Frequently: 1/6

How long does it usually last? ☐ Seconds ☐ Minutes ☐ Hours

FMNS – Seconds: 6/6

How do you think it has affected your life? ☐ No ☐ Minimal ☐ Moderate ☐ Major

FMNS – No: 6/6

Were there any other symptoms when you see things moving (e.g., blurred vision, double vision)?

FMNS – No: 4/6; Blurred vision: 1/6; Blur & Double vision: 1/6

What is the speed of the movement? ☐ Slow ☐ Moderate ☐ Fast

FMNS – Slow: 1/6; Moderate: 1/6; Fast: 4/6

What is the direction of the movement? ☐ Horizontal ☐ Vertical ☐ Both

FMNS – Horizontal: 1/6; Vertical: 1/6; Both: 4/6

Can you try to stop it? If yes, how?

FMNS

No, can't stop it (3)

When the lights go off

Focusing

Look away

What triggers the movement (e.g., fatigue, illness, etc.)?

FMNS

Tired (5)

Lights

When the movement occurred, what moved? ☐ Viewed object ☐ Background ☐ Both

FMNS – Viewed object: 1/6; Background: 4/6; Both: 1/6

Does it occur when looking ☐ straight ahead ☐ off to one side or ☐ both?

FMNS – Straight ahead: 3/6; Both: 3/6

Does it happen in a particular lighting condition? ☐ Dim ☐ Bright ☐ Any condition

FMNS – Dim: 5/6; Any condition: 1/6

Who else in the family has nystagmus? Do they complain of seeing things moving?

FMNS – No one: 6/6

Have you undergone any form to treatment to decrease the movement of things? If so, was it effective?

FMNS

No (6)