Factors Influencing the Experience of Oscillopsia in Infantile Nystagmus Syndrome

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Purpose. Perceptual instability in infantile nystagmus syndrome (INS) has been reported occasionally. This study was conducted to examine the factors that influence perceptual stability in 18 individuals with INS.

Methods. The subjects were instructed to look continuously at a fixation LED centered in an image (38° × 32°) at two luminance levels (3.25 and 0.46 cd/m^2, with 21% and 96% contrast, respectively) throughout all trials. A trial consisted of the fixation LED on, followed by a peripheral LED on, and then both LEDs off. Subjects then reported what they perceived. Five trials were conducted per contrast image. Eye movements were recorded with a limbal tracker. After testing, each subject completed a questionnaire to determine whether they ever had or were presently experiencing oscillopsia.

Results. Sixteen of 18 subjects reported experiencing oscillopsia on the questionnaire. In the laboratory, the percentages of trials with perceptions of motion of the LED and background were as follows: neither, 45% to 60%; background only, 15% to 30%; both, ~15%; and LED only, ~10%. Over all trials, 14/18 and 13/17 subjects experienced oscillopsia for the low- and high-contrast images, respectively (i.e., four subjects never experienced oscillopsia). The background was frequently seen moving when both images were displayed, regardless of contrast and/or condition. Trials with and without oscillopsia did not differ between the foveation periods.

Conclusions. Subjects with INS may experience spatially inhomogeneous oscillopsia under certain viewing conditions. The physical attributes of the stimulus, repeated trials, different conduction times, and the role of divided attention may influence a subject's perception differently. (*Invest Ophthalmol Vis Sci.* 2008;49:3424–3431) DOI:10.1167/iovs.08-1709

Under normal circumstances, individuals achieve perceptual stability if retinal slip does not exceed ~2 to 4 deg/s.[1,2] Above 4 deg/s, oscillopsia (illusory perception of environmental movement) may occur.[3–5] Infantile nystagmus syndrome (INS)[6] is an involuntary ocular motor oscillation that manifests at or shortly after birth[7]—or, rarely, in later life[8]—and persists throughout life.[9,10] Despite having a retinal slip exceeding 100 deg/s, individuals with INS seldom report oscillopsia, with fewer than 10 of more than 450 subjects with INS reporting it in a study by Leigh et al.[4] Indeed, the rarity of oscillopsia in INS has been stated in numerous studies.[1,11–14] Even when oscillopsia is observed, it is usually a transient or infrequent event. It is almost unknown for oscillopsia to be a presenting complaint of an INS patient, which bears witness to the efficacy of the mechanisms by which the visual system compensates for nearly incessant retinal image motion.

Visual stability in INS is not absolute, however, and precise questioning of subjects with INS reveals that sometimes the visual environment seems to be oscillating. A retrospective study of 224 INS/LMLN subjects by Abadi and Bjerre,[9] 39% occasionally experienced oscillopsia. Twelve of 16 (75%) subjects with INS encountered occasional oscillopsia in a study by Tkalcevic and Abel.[15] Oscillopsia is encountered under various conditions that may exacerbate INS, such as stress, illness, or fatigue, or when shifting gaze away from the null zone into a nonpreferred position.[4,16,17] Recent onset or deterioration of sensory deficits associated with INS can also precipitate oscillopsia.[18] Oscillopsia is also perceived when the visual field is of low contrast and relatively unstructured[19] or when the subject is viewing bright targets against dim backgrounds.[15] In a study investigating congenital periodic alternating nystagmus, oscillopsia occurred when the nystagmus attained peak velocity in its cycle.[11]

The mechanisms that contribute to perceptual stability in INS have been extensively studied. The most widely accepted mechanism involves an extraretinal signal to negate the effects of retinal slip.[3,12,13] This signal includes a copy of the efferent signal, and, to a lesser extent, proprioceptive input from the extraocular muscles. Evidence for such a signal includes the observation that in subjects with INS, who rarely perceived oscillopsia, artificial retinal image stabilization actually produces it.[4,20] More support for the efference copy hypothesis comes from Dell'Osso and Tomsak.[21] In this study, an INS subject perceived the motion of a migrainous aura superimposed on a stable visual environment, somewhat akin to a stabilized retinal image. In another instance, momentary hypertropia led to vertical diplopic oscillopsia due to the efference copy's failing to suppress motion in the vertical plane. The horizontal motion of INS remained unchanged, further supporting an efference copy in oscillopsia suppression.[22]

Other proposed oscillopsia suppression mechanisms include reduced sensitivity to retinal slip,[23] postsaccadic backward masking of motion signals,[4] suppression of vision during nystagmus phases other than during foveation periods (visual sampling hypothesis),[20,24,25] and perceptual adaptation to retinal slip.[26,27] The mechanism predominantly used to suppress oscillopsia may differ among individuals.[4,16] It remains to be established to what extent each mechanism contributes to preventing oscillopsia.

Observations made by Leigh et al.,[4] who used optical stabilization methods to induce oscillopsia in subjects with INS, reported that either the central target or the surround was seen moving. That they perceived oscillation in only part of their visual environment suggests that the suppression of oscillopsia is not spatially homogeneous, although the conditions used to stimulate oscillopsia in this study were highly unnatural. Tkalcevic and Abel[15] later reported that subjects with INS perceived spatially inhomogeneous oscillopsia under normal viewing conditions as well. However, as only one trial was performed per stimulus condition, the repeatability of the

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FIGURE 1. Schematic representation of the image viewed by the subject. *Two white circles*: fixation peripheral LEDs. The spatial configuration was identical for low (21%)- and high (96%)-contrast images, with contrast specified as the Weber's contrast between the shapes and the background.

perceptions was unknown. Also, the trial in Tkalcevic and Abel[15] took between 15 and 20 minutes, long enough that fatigue could influence the perceptual outcomes of the subjects. This possibility makes it difficult to determine whether oscillopsia was triggered solely by the stimulus characteristics in their study. Based on their preliminary findings, we sought to minimize fatigue as a contributing factor in subjects' perceptions and investigated further how specific aspects of visual stimuli can elicit oscillopsia in subjects with INS, and if so, what the nature of the perceived motion was. It is important to note that our study is designed to assess the consistency of perceptual stability reports by repeatedly exposing subjects to the same visual environment multiple times. We hypothesized that backgrounds with large luminance contrasts would provoke differential perception of motion in INS, independent of the location of an overlying LED (and, hence, attention to this LED). We analyzed waveform parameters, especially foveation periods, during viewing, to assess their association with the onset of oscillopsia.

METHODS

Our study complied with the Declaration of Helsinki and was approved by the Human Research Ethics Committee of the Department of Optometry and Vision Sciences, with all subjects giving written informed consent before participating. Eye-movement recordings were performed in 18 subjects with INS (7 men and 11 women, mean age 33 $\pm$ 13.6 and near uncorrected visual acuity 0.69 $\pm$ 0.64). The diagnosis of INS 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. Thirteen subjects were classified as idiopathic, and five had associated visual disorders. The waveforms exhibited were jerk ($n = 15$), pseudocycloid ($n = 1$), both jerk and pseudocycloid ($n = 1$), and pseudopendular with foveating saccades ($n = 1$). Means and standard deviations of the waveform parameters for all subjects were: foveation periods, 51.22% $\pm$ 29.27%; amplitude, 2.71 $\pm$ 2.03°; frequency, 3.22 $\pm$ 1.31 Hz; and intensity, 10.12 $\pm$ 9.75 deg · Hz. Subjects with aperiodic alternating nystagmus were identified during their initial examination by monitoring nystagmus direction during extended primary position fixation and were excluded. All subjects were naive with respect to the specific purpose of the study. No normal subjects were recruited, as Tkalcevic and Abel[15] reported that no normal subjects perceived motion in any of their presented conditions and so did not experience the autokinetic illusion (the apparent motion of a stationary light in complete darkness).[28,29]

Eye movements were recorded using a binocular infrared oculographic system (Microguide, Downers Grove, IL).[30] The bandwidth was DC-100 Hz, and the sensitivity of the system was 1 min arc. Horizontal eye-position data were digitized at 1000 Hz with a 12-bit analog-to-digital converter. Testing was performed without correction and in darkness. Head movement was minimized by cheek restraints, with residual movement monitored by a laser pointer strapped to the back of the head and projecting to a series of concentric circles spaced approximately 1° apart at 1.85 m. The cheek restraints allowed subjects to respond verbally without disrupting the eye-movement recordings. Eye movements were calibrated by consecutively presenting LEDs from $-20°$ to $+20°$ mounted on a 1.6-min arc radius at 1.6 m. Fixation data were scaled by using a best-fit regression line.

Each subject viewed two images (Fig. 1) of random achromatic shapes and sizes and varying contrast. Each image subtended $38° \times 32°$ (width $\times$ height) on a LCD monitor at 60 cm. A green fixation LED ($\sim$0.1°) and a green peripheral LED 10° above fixation, each with a luminance of 794 cd/m^2, were mounted on a piece of clear plastic 42×35 cm. As background luminances were set at 3.25 and 0.46 cd/m^2, the resultant two contrast levels for the background shapes were 21% (low) and 96% (high), obtained by using Weber's contrast.[31] These two contrast levels matched the lowest and highest contrast values in the study by Tkalcevic and Abel[15] with their background luminances at 0.1 and 115.5 cd/m^2, respectively.

Each subject was instructed to look continuously at the fixation LED throughout the experiment, whether it was illuminated or not. A trial consisted of three conditions, (1) fixation LED on, peripheral LED off; (2) peripheral LED on, fixation LED off; and (3) no LED on. During each condition, the viewing time was 5 seconds. Subsequently, any illuminated LED was extinguished for 3 seconds. Subjects were then asked to report whether anything happened to the LED and background before the next condition was presented. They were not instructed in such a way as to lead to particular answers, although they were told that they did not have to report changes in which LED was illuminated. A green spot on the background highlighted the fixation LED when it was off. A practice trial was performed before the experiment, to ensure that the subjects fully understood the instructions.

We conducted five trials per image. The low-contrast image was always presented first to avoid afterimages. Subjects rested for 60 seconds between the two images to further ensure that afterimages did not invoke a perception of oscillopsia. All testing was done in primary gaze position. The whole study took between 4 and 8 minutes, minimizing the possibility of subject fatigue. After testing, each subject completed a questionnaire to determine whether they had ever experienced or were presently experiencing oscillopsia. This questionnaire was later used to compare the oscillopsia they encountered in their daily situations with the perceptions experienced in the laboratory (see Appendix).

We analyzed eye-movement data for changes in the type and parameters of the waveform, in particular the foveation periods, during the experiment. We defined foveation periods as those in which eye velocity was $\leq$4 deg/s and eye position $\pm$2° from the fixation point from cycle to cycle. This $\pm$2° position criterion was less stringent than the typical $\pm$0.5° position setting used in previous studies, to allow for albinos who lack a functional fovea.[15,24,32–34] Indeed, in some studies no position criterion have been used when examining foveation in INS, only a velocity criterion.[24,33,35] We manually identified foveation periods through the beginning of as many slow phases as possible in a given fixation interval. Blinks and nonfixation points (e.g., when the subject was looking off-target or appeared drowsy) during each 5-second viewing time in all trials of each image were excluded from analysis. One subject's data with the high-contrast image were removed due to the repeated presence of such problems.

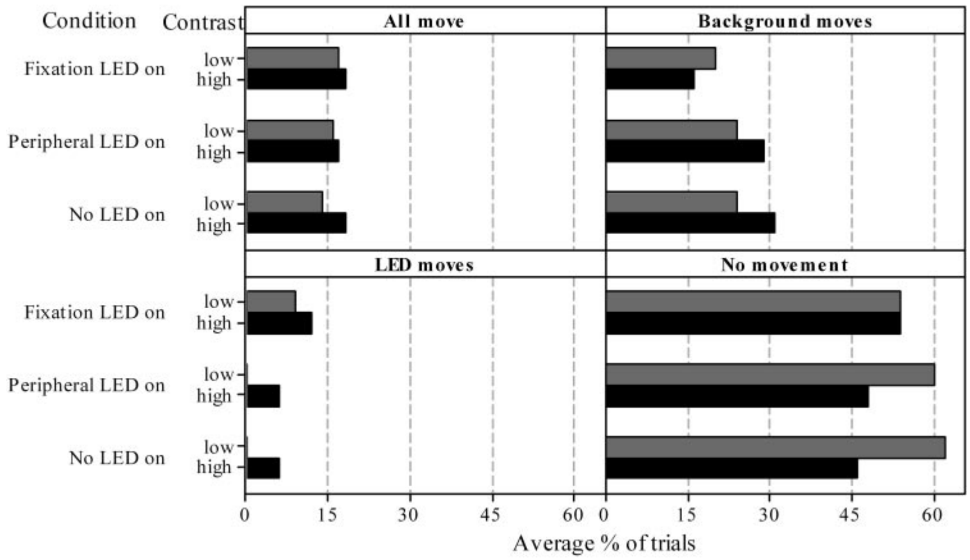

Figure 2. Individual bar represents percentage of trials averaged across all subjects for a particular condition and contrast. All bars of the perceptual outcomes (all move, background moves, LED moves, no movement) for a particular condition and contrast add up to 100%. Some subjects noticed the unlit fixation LED in instances of either the background's or the LED's moving when no LED was on. The peripheral LED was never seen by the subjects when no LED was on.

Results

Questionnaire Results

Sixteen (89%) of 18 subjects with INS perceived oscillopsia. Eight subjects reported oscillopsia under dim lighting, whereas the other eight experienced motion under no particular condition. When oscillopsia occurred, four subjects reported the surrounding scene as moving, whereas five said that the viewed object moved. The remaining seven perceived uniform motion. Fatigue and stress were frequently associated with the experience. Looking away from the fixation point or turning/tilting the head could prevent or minimize oscillopsia in some subjects. Results for all subjects are summarized in the Appendix.

Experimental Results

Fourteen (78%) of 18 subjects viewing the low-contrast image, and 13 (76%) of 17 subjects viewing the high-contrast image experienced oscillopsia. The level of contrast did not influence these subjects' responses (paired *t*-test, $P = 0.27$). During oscillopsia trials, none of the waveform parameters differed significantly between the two contrast levels (paired *t*-test: foveation periods, $P = 0.51$; amplitude, $P = 0.49$; frequency, $P = 0.47$; and intensity [amplitude $\times$ frequency], $P = 0.70$). There were no significant interactions between subjects' responses and contrast level and condition (Friedman test: LED moves, $P = 0.18$; background moves, $P = 0.25$; all move, $P = 0.98$; and neither moves, $P = 0.68$. Dunn's multiple comparison test: not significant at [$P > 0.05$] for all interactions). Trials with and without oscillopsia in both contrast levels also did not statistically differ across subjects in terms of waveform parameters (paired *t*-test for low contrast: foveation periods, $P = 0.47$; amplitude, $P = 0.41$; frequency, $P = 0.70$; and intensity, $P = 0.19$; for high contrast: foveation periods, $P = 0.75$; amplitude, $P = 0.38$; frequency, $P = 0.83$; and intensity, $P = 0.31$). Responses from all subjects are summarized in Figure 2.

Figure 3 illustrates the percentage of subjects consistently reporting the same perceptions of a given condition and contrast. The subjects in the present study exhibited a high repeatability (hence low variability) of the same perceptions in all five trials for both contrast levels.

Of the trials in which oscillopsia was perceived, eight 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 correlation: low contrast, $r = -0.002$; $P = 1.0$; high contrast, $r = 0.04$; $P = 0.89$). A change in waveform direction was noted in one subject (subject A: baseline, jerk left; low- and high-contrast image, jerk right).

Figures 4A and 4B illustrate the INS waveform of a subject whose perceptions varied with condition and contrast and whose waveform, especially foveation periods, varied somewhat, but not in a way that would support the idea that oscillopsia is provoked by reduced foveation. When viewing the low-contrast image, the subject foveated the least (14%) on the trial in which no LED lit up, reporting that no movement occurred. In the high-contrast image, he foveated the most (25%), now reporting that the LED and background moved when the peripheral LED lit up. The questionnaire responses of this subject showed that he encountered oscillopsia in dim conditions, away from his preferred head position, and that either the viewed object or the background could be seen as oscillating.

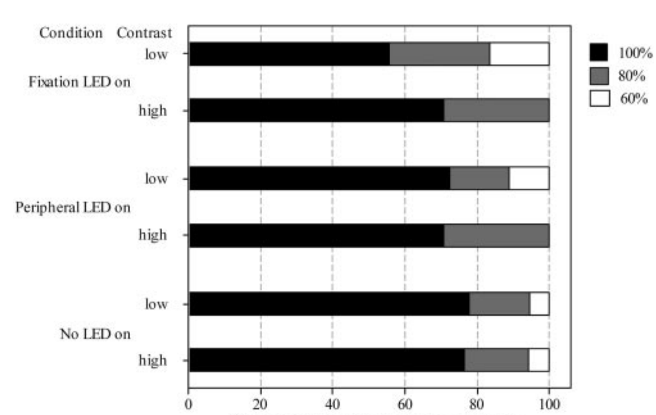

Figure 3. Individual bar represents the percentage of subjects consistently reporting the same perceptions (i.e., LED moved, background moved, both moved, or neither) for a particular condition and contrast for all trials.

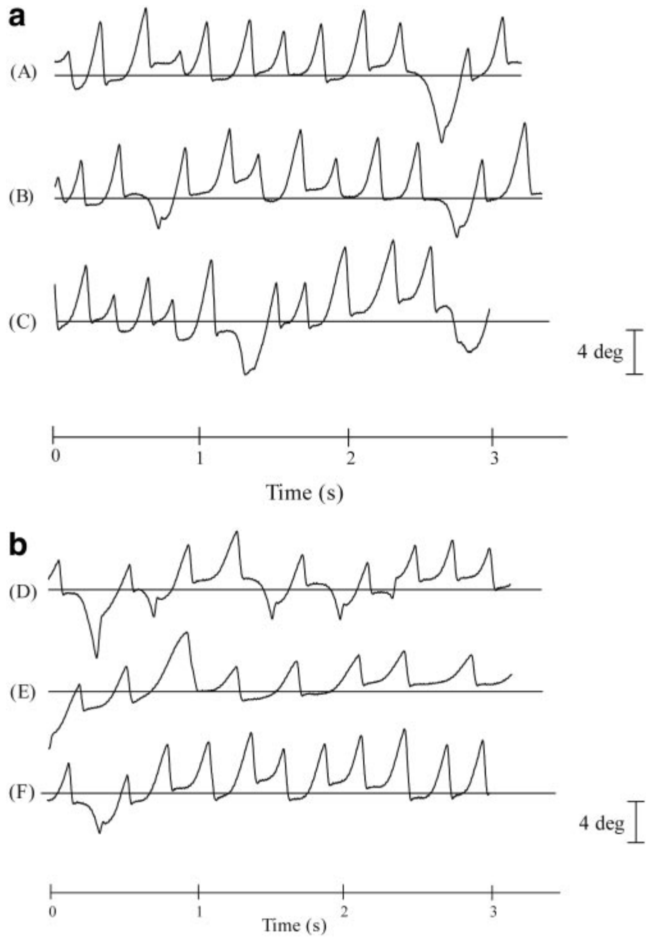

FIGURE 4. (**a**) Recordings of a subject showing slight waveform changes, which did not predict how perceptual stability differed. Viewing the low-contrast (21%) condition: (**A**) When the fixation LED lit up, subject reported, "LED moved." Foveation criteria were met 18% of the time; (**B**) when the peripheral LED lit up, he reported, "LED moved." Foveation criteria were met 20% of the time; (**C**) when no LED lit up, he reported, "No movement." Foveation criteria were met 14% of the time. *Horizontal lines* across the waveforms: fixation. The time origin is arbitrary. (**b**) Recordings of the same subject, again showing minimal waveform changes not predictive of perceptual stability. (**D**) Viewing the high contrast (96%) condition, when the fixation LED lit up, he reported, "No movement." Foveation criteria were met 16% of the time; (**E**) when the peripheral LED lit up, he reported, "LED and background moved." Foveation criteria were met 25% of the time; (**F**) when no LED lit up, he reported, "Background moved." Foveation criteria were met 17% of the time. *Horizontal lines* across the waveforms: fixation. The time origin is arbitrary.

DISCUSSION

Questionnaire Results

Responses obtained from the current questionnaire are consistent with recent studies[9,15] that, although it is not a major complaint of patients, oscillopsia is not as uncommon in INS as previously thought.[1,4] With careful questioning, 16 of 18 subjects experienced oscillopsia—some under dim lighting and others in any condition—with seven subjects experiencing it frequently. When frequent, oscillopsia was nearly always present for hours at a time. Nine subjects reported that either the viewed object or background moved. Though some subjects with INS appear to perceive motion more frequently than others, oscillopsia is rarely a presenting complaint in these subjects. A subject's psychological state may be critical in eliciting oscillopsia, with fatigue and stress being the most common triggers, as was reported by Abel et al.[16] The effect of these triggers has yet to be examined by experimental manipulation of such factors, however.

Our subjects with INS who had normal or near-normal visual acuity experienced oscillopsia in the same way as subjects with sensory deficits. Several investigators have suggested that oscillopsia may decline with advancing age.[3,36] However, we failed to find any significant correlation between subjects' age and oscillopsia, perhaps because of the limited age range and the number of subjects in our study.

Perceptual Results

Most studies have been investigations of oscillopsia under highly unnatural conditions using afterimages[4,12,37] or mechanical or optical stabilization techniques.[3,4] Tusa et al.,[19] under normal viewing conditions, found that oscillopsia occurred when the nystagmus waveform slow phase velocity reached its maximum value, although the subjects had atypical INS, if they had it at all. Uniform oscillopsia over the entire stimulus was reported in all these studies.

Tkalcevic and Abel[15] were the first to provide evidence for the perception of spatially inhomogeneous oscillopsia encountered by typical subjects with INS when viewing bright fixation targets against dim backgrounds. In the present study, the two contrast levels (but not mean background luminances) were chosen to match the contrasts in Tkalcevic and Abel,[15] to see whether their findings could be replicated. Neither the LED nor the background was reported to move (i.e., no reported oscillopsia) in most of the trials. In trials in which motion was reported, spatially inhomogeneous oscillopsia was again observed; however, the part of the stimulus seen to be oscillating was unlike that previously reported. Regardless of age, waveform type, clinical diagnosis, or visual acuity, the background was most often reported moving at both contrast levels. The low-contrast image did not provoke more oscillopsia. A considerable number of trials elicited uniform oscillopsia, and the LED was rarely reported to oscillate. Another finding was that five subjects consistently reported the same stimulus elements moving, irrespective of conditions and contrasts. Of the five subjects, two reported uniform oscillopsia. Relating to their questionnaire responses, both subjects constantly experienced oscillopsia. The remaining three saw the background move during testing and reported occasional oscillopsia on their questionnaires. Although these three reported that the background moved when oscillopsia occurred, two suggested that, in daily life, viewed objects sometimes moved, as well.

No changes in the waveform parameters were noted when oscillopsia occurred. In this study, several subjects had good foveation periods and yet still perceived oscillopsia. This finding suggests that good foveation periods do not prevent the breakdown of perceptual stability, in agreement with Dell'Osso et al.[12] However, nystagmus exacerbation is known to precipitate oscillopsia.[4,9,11,16] In our study, testing was done only in primary-gaze position and not in the nystagmus maximum or minimum (null) zone, because of the limited range of the infrared oculographic system and the need to limit testing time to minimize fatigue. Those subjects reporting no oscillopsia may have done so when looking into their maximum zone and thereby may have aggravated their nystagmus. Future studies should consider the comparison between different gaze positions to examine whether the oscillopsia that occurs because of a deterioration in foveation stability would be spatially inhomogeneous as well.

No mechanisms proposed for perceptual stability in INS (see the introduction) can easily explain why the oscillopsia experienced by participants in this study was nonuniform. The waveform characteristics cannot explain the perceptual results reported in this study, as no parameters, especially foveation periods, affected the subjects' perceptions. Perceptual stability in INS is vulnerable and may collapse under degraded viewing conditions.

The notions of spatially variable motion thresholds[27] and differences in perceptual latency due to large contrast differences[38] were both suggested by Tkalcevic and Abel[15] to account for instances in which participants perceived the background as moving behind a stable-fixation LED for the low-contrast image. However, our main finding that the background is seen as moving in most of the trials for all the experimental conditions still requires explanation. We now propose some additional explanations for why motion perception may be spatially inhomogeneous, as well as for why the background may be more commonly seen as moving.

Stimuli

A possible reason could be the differences in the physical characteristics of the stimuli used in our study. Tkalcevic and Abel,[15] showed that the number of trials of only the fixation LED moving was greatest only when the background luminance was dimmest (20% contrast). Although we maintained the same contrast level in the existing study, our background luminance was brighter; in fact, it more closely resembled the second dimmest background luminance that they used (2.7 cd/m^2), for which the LED was seldom reported to oscillate. This finding could explain why the fixation LED was rarely seen to move in the present study. Their use of variably crossed Polaroid filters allowed the luminance of their background stimuli to be reduced to nearly 0, which was not possible for the adjustment range of our monitor.

It should be noted that the fixation LED used by Tkalcevic and Abel[15] radiated stray light, producing an annulus of light surrounding it that reduced the contrast of neighboring shapes. This phenomenon may have made shapes close to the fixation LED difficult to see, making it hard for subjects to tell whether the background was moving. Also, with no structured background immediately adjacent to the fixation LED, the fixation LED could have been favored when motion was perceived by the subjects. We were careful not to produce a similarly inhomogeneous background by using a sharply focused fixation LED that did not radiate light back onto the LCD monitor; thus, the contours of the peripheral shapes of the background remained distinct and structured. With our larger, sharper, brighter background, we found more oscillopsia trials in which only the background was seen to move.

We conducted five trials each for both contrast images, addressing the trial-by-trial variability in this phenomenon. The results from our study suggest that an INS subject's perception is rather stable within a given stimulus condition/contrast.

Conduction Time

In addition to the dimmer stimuli's having increased conduction times,[38] conduction time also increases as retinal eccentricity increases.[39] Different conduction times of the fixation target and background could affect the spatial relationship between them. Therefore, when subjects looked at the fixation LED, it would always be processed faster than the background, as it was both more central and brighter, at least while the LED was on. However, it may also be that the visual processing speed is different, with increasing speed as eccentricity increases.[40] Although all can explain why there would be differential motion, neither explains why the background rather than the LED moved. A possible explanation may relate what the subject is attending, as discussed next.

Attention

Attention may be defined as the selective processing of some aspect(s) of the environment to the relative reduced processing/exclusion of other information.[41] In the present study, subjects had to look at the fixation LED for 120 seconds per contrast image. If whatever oscillopsia suppression mechanism is operating is presented with conflicting image motion signals from the center and periphery, we speculate that by making an effort to try to fixate at a small target, its apparent motion can be suppressed, thus stabilizing the fixation LED. The periphery, which is not attended to, will then oscillate. This proposal is supported by questionnaire responses from several subjects who often had to concentrate to eliminate movement of the fixated object. Also, several subjects had experienced the background's moving against a stable fixation target before, as reported in the questionnaire. Their previous encounters may predispose them to expect to see a similar effect during testing.

However, such an explanation would not a priori favor seeing a stable peripheral LED placed above fixation, as occurred in our study, since the subjects were told not to fixate it. One reason to account for the steady peripheral LED could be that the subjects actually fixated the peripheral LED when it lit up. Under such circumstances, changes in waveform parameters (e.g., decrease in amplitude) would be seen due to crosstalk between the channels. We found no evidence of crosstalk. Alternatively, the peripheral LED may be ignored and hence not seen to move. However, it is unlikely, since the peripheral LED is more visually salient than the background, yet subjects reported the background to be moving. It is possible that the motion of the peripheral LED was somewhat different from that of the background but that without its being covertly attended to, this difference was not noticed. Another possible explanation involves how subjects segregate their attention between different stimulus elements. The visual stimulus in our study was complex (fixation LED, peripheral LED, and background). When the peripheral LED lit up, subjects had to make an effort not to look at it and instead to concentrate on the fixation spot straight ahead, which may have made it harder for some subjects to tell whether the peripheral LED remained still or moved. Beyond instructing subjects to fixate the central target, we did not explicitly control how subjects divided their attention among the fixation LED, peripheral LED, and the background. Whether manipulation of covert attention can determine what part of the stimulus is seen to move and what portion appears to remain stationary would merit further study.

No single explanation is sufficient to account for the perceptions reported in this study. From our findings, it is possible that volitional "top-down" attention may determine the saliency of the stimulus and thus influence its perceptual stability. The fact that the peripheral LED was rarely reported to oscillate, despite being more visually salient than the background may support this notion. In addition, in the condition where no LED was lit up, only some subjects could differentiate between the unlit fixation LED and background, reporting either one or the other moved. It is tempting to speculate that subjects who could detect the unlit fixation LED with its colored background were more attentive than those who could not. When compared with their questionnaire results, these subjects frequently perceived inhomogeneous oscillopsia. Whether their regularly encountered oscillopsia could be attributed to their being more attentive remains to be explored. Much more remains to be determined about the role of attention in perceptual stability in INS.

Conclusions

Nothing in this study overturns the idea that oscillopsia is seldom a presenting complaint in subjects with INS who experienced it. In the present study, we found the commonest response to our stimuli was that nothing moved. However, perceptual instability in INS is not as infrequent and simple as previously thought. Regardless of the viewing conditions, the experience of oscillopsia can vary across subjects and may also be either spatially uniform or inhomogeneous. Of course, many may not even perceive it at all, whereas others will constantly experience illusory motion regardless of the visual environment. However, in trials in which motion was perceived, we found the most common percept to be that of a stable fixation target against a moving background. We propose that a combination of factors, both external and internal to the subjects, may account for these perceptions. These include the physical attributes of the stimulus, repeated trials, different conduction times, and the role of divided attention. Each may influence a subject's perception differently. Decoupling ocular instability from cognitive and physiological factors can be challenging. The mechanisms behind this phenomenon remain to be determined. Future research may also provide more insight into the stability of such perceptions, their association with nystagmus waveform, and the influence of psychological states (e.g., stress and attention) on oscillopsia.

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Appendix

Responses to the Oscillopsia Questionnaire

The number of subjects who chose the response follows each answer.

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

INS (n = 18)
Yes, 16
No, 2

If *yes*, can you describe by giving an example(s)?

INS (n = 16)
Everything, if I have to strain/focus to see it—TV, cars at a distance, people, objects, 8
Shapes on a computer screen, 2
Green lights on the arc, 2
Green spot on a computer, 1
LEDs on trucks and bikes, scrolling message board, 1
LCD lights, 1
Lights in a dark room, 1

When was your first experience?

INS (n = 16)
Years ago, 12
Today, 4

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

INS (n = 16)
Rarely, 4
Sometimes, 5
Frequently, 7

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

INS (n = 16)
Seconds, 9
Minutes, 1
Hours, 6

How do you think it has affected your life?
☐ Not at all ☐ Minimal ☐ Moderate ☐ Major

INS (n = 16)
Not at all, 5
Minimal, 3
Moderate, 6
Major, 2

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

INS (n = 16)
No, 5
Blurred vision, 4
Double vision, 2
Blurred and double vision, 5

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

INS (n = 16)
Slow, 3
Moderate, 6
Fast, 7

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

INS (n = 16)
Horizontal, 8
Vertical, 2
Both, 6

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

INS (n = 16)
No, 4
Look away, 3
Concentrate, 3
Turning/tilting my head, 3
Blinking, 2
Close eyes, 1

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

INS (n = 16)
Tired and/or stress, 9
Trying to concentrate, 2
Sick, 2
Moods (e.g., angry), 2
Lights, 1

When the movement occurs, what moves?
☐ Viewed object ☐ Background ☐ Both

INS (n = 16)
Viewed object, 5
Background, 4
Both, 7

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

INS (n = 16)
Straight ahead, 8
Off to one side, 2
Both, 6

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

INS (n = 16)

Dim, 8

Any condition, 8

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

INS (n = 16)

No one, 11

Parents/siblings, 5

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

INS (n = 16)

No, 10

Baclofen, not effective, 2

Contact lenses, effective, 1

Glasses, effective, 1

Vision therapy, not effective, 1

Botox injection and bimedial recession, not effective, 1