Editorial

The Musical Intellect of Infantile Nystagmus

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Cause and effect—there is probably no such duality; in truth. A continuum stands before us, two segments of which we isolate, just as we perceive movement always as isolated points and, so, do not really see but infer it…an intellect that saw cause and effect as a continuum and not, as we do, as arbitrary division and fragmentation—and which saw the flux of events, would reject the concept of cause and effect and deny all causal interpretation.

Friedrich Nietzsche[1]

As we recently proposed an integrated neurologic mechanism for infantile nystagmus,[2] a recent article in the *New York Times* caught our attention. Gregory Hickok from the Department of Cognitive Sciences at the University of California, Irvine, presented evidence that the commonly accepted human "stream of consciousness," first introduced to the western world in 1890 by the American psychologist and philosopher William James,[3] is incorrect; and that we actually perceive the world in rhythmical pulses rather than as a continuous flow.[4]

Brain waves, as measured by electroencephalography, have a rhythmical contour that changes according to perceptual or cognitive events such as concentrating or shifting attention. Although these rhythmical electrical currents have always been considered to be a reflection of our mental activity, there is new evidence that they are a cause of it, and that they influence a variety of cognitive processes such as perception, memory, and consciousness. Perceptual evidence can be found in the "wagon wheel" illusion, wherein spokes of a wheel are sometimes perceived to reverse the direction of their rotation when a stroboscopic light is being flashed. In this instance, the stroboscopic light may capture the position of a spoke that differs from the previously captured position in a direction that indicates a backward direction of wheel rotation. However, this effect can also be observed by normal people in the absence of any stroboscopic stimulus (when perceptual sampling captures the necessary freeze-frame images of a spoke that would correspond to a backward wheel rotation).

According to Hickok, these perceptual phenomena provide empirical evidence that we are "cycling between better and worse perceptual sensitivity several times a second."[4] He proposes that "the brain samples the world in rhythmic pulses, perhaps even discrete time chunks, much like the individual frames of a movie. But rather than the brain being entrenched in its own rhythms, it appears that rhythms in the environment can draw neural oscillations into their tempo, and thereby synchronize the brain's rhythms with those of the world around us."[4] Accordingly, the brain's sensory experience is quantized rather than continuous. Experimental evidence for this counterintuitive premise is accumulating. Within the human auditory system a faint auditory tone is best heard when it falls into synchrony with a just-heard 3-beat-per-second rhythm.[5] Our ability to "feel" and enjoy music may similarly reflect the highjacking of our brainwaves by its pulsatile rhythms of sound.[4,5] Vision detection thresholds also fluctuate with the phase of electroencephalographic activity and these intrinsic oscillations can entrain to ambient stimulus rhythms.[6–8]

So what does this have to do with infantile nystagmus? Infantile nystagmus is a conjugate horizontal oscillation of the eyes that develops early in infancy and persists throughout life.[2] It can present as an isolated hereditary condition or be facilitated by a variety of disorders that diminish central vision in both eyes.[2] The intensity of infantile nystagmus increases during visual attention or fixational effort.[2] Unique to infantile nystagmus is the presence of foveation periods, which punctuate each cycle and impart a transitory stillness to the eyes that provides optimal visual acuity for any given patient.[9] These short foveation periods follow saccadic refixation and last approximately 0.04 seconds, but they may last up to 0.5 seconds. Foveation periods are not visible to the clinical observer, but they are the *sine qua non* of this condition on eye-movement recordings. Because individuals with infantile nystagmus do not experience oscillopsia, it was once erroneously inferred that such individuals experience stroboscopic vision, with "on" periods corresponding to the foveation periods. However, such individuals see throughout the entire nystagmus cycle—they just see more clearly during their foveation periods.[10] Although anxiety, anger, fear, excitement, and fatigue are believed to exacerbate infantile nystagmus, increased visual demand

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provides prolonged foveation and a reduction in the intensity of infantile nystagmus.[11]

The discovery that visual perception and attention have intrinsic rhythmicity begs the question of whether there are natural foveation periods in all of us. If we are only aware of visual images in a pulsatile fashion, do the foveation periods of infantile nystagmus simply lay bare what is normally happening at the perceptual level? So when the system gets thrown into oscillation, perhaps we simply continue to display our rhythmical pulses of visual attention in the form of foveation periods. To the contrary, it appears more likely that "Rhythms in the environment… can draw neural oscillations into their tempo, effectively synchronizing the brain's rhythms with those of the world around us."[4] This kind of synchronization may underlie communication between the brain's neural networks.[4] In infantile nystagmus, there is a steady perception of a clear and stable image despite the cycle-to-cycle sampling of clear images only possible during the foveation periods. According to this model, the sensory-perception brain signals in a person with infantile nystagmus synchronize with the motor foveation periods to facilitate that perception of steady clarity. In normal individuals, the same type of perceptual stability is achieved despite a sampled visual input. Thus, individuals with infantile nystagmus are not really doing anything remarkable or even very different from normals; they are just synchronizing their sensory inputs with those of motor stability (ie, the foveation periods).

The brain samples both visual clarity (not vision per se) and stability, and preserves both from one foveation period to the next.[12] That allows, in the time domain, the same thing as we all perceive in the spatial domain, where we perceive a totally clear picture of the visual field despite the known degradation of the visual input at all retinal positions away from the fovea. The brain imposes clarity in places (spatial clarity) and at times (inter-sample times) where there is none. The brain is a wonderful thing, both for its innate abilities and for what it allows us to understand when we apply it to any problem, including how the brain itself works.

In his *Incompleteness Theorem*, Gödel showed that no system, even mathematics, can prove itself from within.[13] Infantile nystagmus provides an example of how the brain circumvents this problem *by proving itself from without*, through its unique ability (or adaptability) to entrain its neural oscillations to the world's rhythms and thereby construct the illusion of perceptual stability that both underlies and defines human consciousness. According to the cognitive neuroscientist Alvin Noë, "Consciousness of the world around us is something that we do: we enact it, with the world's help, in our dynamic living activities. It is not something that happens in us."[14] Or, as presciently articulated by Charles Darwin, "The perception, if not the enjoyment, of musical cadences and of rhythm is probably common to all animals, and no doubt depends on the common physiological nature of their nervous systems."[15]

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REFERENCES

1. Nietzsche F. On Truth and Untruth. Selected Writings [abstracted from Nietzsche F. The Gay Science. 1882]. New York: Harper Collins; 2010:61–62.
2. Brodsky MC, Dell'Osso LF. A unifying mechanism for infantile nystagmus. *JAMA Ophthalmol* 2014;132(6):761–768.
3. James W. The Principles of Psychology. New York: Holt; 1890 [Reprint: Cambridge, MA: Harvard University Press; 1983:233–234].
4. Hickok G. It's not a stream of consciousness. *New York Times Sunday Review*. May 8, 2015.
5. Hickok G, Farahbod H, Saberi K. The rhythm of perception: entrainment to acoustic rhythms induces subsequent perceptual oscillation. *Psychol Sci* 2015;26(7):1006–1013.
6. Valera FJ, Toro A, John ER, Schwartz EL. Perceptual framing and cortical alpha rhythm. *Neuropsychologia* 1981;19: 675–686.
7. VanRullen R, Zoefel B, Ilhan B. On the cyclic nature of perception in vision versus audition. *Philos Trans R Soc Lond B Biol Sci* 2014;369(1641):20130214.
8. Schroeder CE, Lakatos P. Low-frequency neuronal oscillations as instruments of sensory selection. *Trends Neurosci* 2009;32(1):9–18.
9. Dell'Osso LF, van der Steen J, Steinman RM, Collewijn H. Foveation dynamics in congenital nystagmus: I: fixation. *Doc Ophthalmol* 1992;79(1):1–23.
10. Leigh RJ, Dell'Osso LF, Yaniglos SS, Thurston SE. Oscillopsia, retinal image stabilization and congenital nystagmus. *Invest Ophthalmol Vis Sci* 1988;29(2):279–282.
11. Wiggins D, Woodhouse JM, Margrain TH, et al. Infantile nystagmus adapts to visual demand. *Invest Ophthalmol Vis Sci* 2007;48(5):2089–2094.
12. Bedell HE. Perception of a clear and stable visual world with congenital nystagmus. *Optom Vis Sci* 2000;77(11):573–581.
13. Goldstein R. Incompleteness. The Proof and Paradox of Kürt Godel. Norton: Atlas Books; 2005.
14. Noë A. Out of Our Heads. Why You Are Not Your Brain and Other Lessons from the Biology of Consciousness. New York: Hill and Wang; 2005:64.
15. Darwin C. The Descent of Man and Selection in Relation to Sex. London, England: John Murray; 1871:333.

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