Newborn babies feel the beat

When you tap your foot in time to your favorite song, you're engaging in a process called beat induction: You pick out a periodic pulse from a nonrepetitive sequence of sounds, and you anticipate the next pulse in time to lift your foot and lower it again. The downbeat, or beginning of a rhythmic unit, might be louder or longer than the surrounding notes, but it doesn't have to be—a regular downbeat can be induced even if it's not marked by any special stress. Now, researchers in Hungary and the Netherlands, led by István Winkler of the Hungarian Academy of Sciences in Budapest and Henkjan Honing of the University of Amsterdam, have found that three-day-old infants are also capable of beat induction—a potentially important step toward understanding how older infants and children learn to process the sounds they hear.

The researchers had 14 babies listen to a repeating synthesized drum rhythm from which notes were sporadically omitted. Because newborns can't be asked to tap their feet, their reactions were monitored using electroencephalography: the measurement of electrical activity in the brain via electrodes affixed to the head, as shown in the photo. When the omitted sound was a downbeat, the electrodes picked up a strong discriminative response, but when a note in any other position was left out, the infants showed no measurable response.[1]

The result suggests that beat induction is either innate or learned in the womb—but those two possibilities are not as distinct as they might seem. "Normal development of the brain requires some stimulation," Winkler explains. "Rather than clarifying the issue of which capabilities are innate and which are learned, experiments that isolated animals from certain types of stimulation—within the womb or right after birth—produced animals with severe brain dysfunctions." The human fetus can hear and process sounds for some months prior to birth, and Winkler suspects that exposure during that time to rhythmic sounds such as the mother's heartbeat is probably necessary for the development of beat-induction ability. But it may not be the whole story: The rhythm used in the experiment is more complex than a heartbeat, and the distinction between important and unimportant beats in the drum sequence is not something that could obviously be learned by listening to a simple repeating sound pattern. Winkler concludes, "In any reasonable meaning of the expression, human babies are born with the ability to detect the beat in rhythms."

The researchers did not attempt to determine whether some of the infants were better at beat induction than others. But they are embarking on an investigation with the related goal of testing whether there is a relationship between the perception of musical rhythm at birth and the ability to properly time vocal communication later in infancy—for example, how to take turns making sounds in a "proto-conversation" with a parent. Ultimately, they hope to develop a way to screen for communication problems at an early age. As Winkler explains, "Communication skills affect attachment to the parents, and that has a strong effect on development in many important areas." (Photo courtesy of Gábor Stefanics, Hungarian Academy of Sciences.)

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Reference

1. I. Winkler et al., *Proc. Natl. Acad. Sci. USA* (in press), doi:10.1073/pnas.0809035106.

functions are consistent with the ΛCDM paradigm. The curves in figure 2 correspond to a model in which all the parameters except σ_8, which serves to normalize both mass functions, were fixed at previously established values.

Perhaps the parameter of most interest is w. If the equations of general relativity require a cosmological constant, then empty space will act as if permeated by fluid that exerts negative pressure and speeds up the universe's expansion. In 1968 Yakov Zel'dovich showed that the vacuum energy of quantum field theory is mathematically equivalent to Einstein's cosmological constant. In either case $w = -1$.

Using the cluster data alone, Vikhlinin and his colleagues find that $w = -1.14 \pm 0.21$. Combining cluster data with other, independent methods of determining w, they obtained a value of 0.991 with a statistical error of ± 0.045 and a systematic error of ± 0.039. The combined result represents an increase in accuracy of a factor of 2.

Vikhlinin's model presumes w varies with neither time nor space. Both possibilities feature in various alternatives to vacuum energy. And if general relativity fails on large scales, the discrepancy would show up as a variable w.

Current observations, including Vikhlinin's, don't place strong constraints on the variation of w, but there are clues from the early universe. The density fluctuations that left their stamp on the cosmic microwave background and the nucleosynthesis of light elements both occurred in the universe's first billion years. Neither phenomenon requires dark energy to account for its observable effects. That's no problem for constant w. If, at that early epoch, dark energy had the same strength as it has now, matter and radiation predominated.

More accurate probes will determine whether w does vary. One promising tack is to look for the influence of dark energy on scales far larger than galaxy clusters. Those structures can be tied more directly to the primordial density fluctuations than clusters can. However, observing them will require a three-dimensional map of the universe similar to, but more accurate than, those derived by the Sloan Digital Sky Survey and 2dF (Two Degree Field system). So far, dark energy remains mysterious and general relativity remains safe.

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References

1. S. W. Allen et al., *Mon. Not. R. Astron. Soc.* **383**, 879 (2008).
2. A. Vikhlinin et al., *Astrophys. J.* (in press).