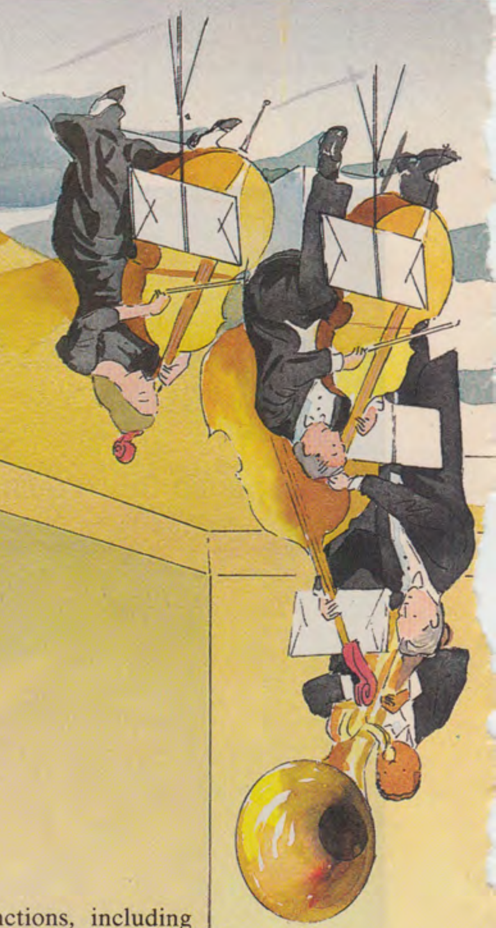
The MUSICAL BRAIN

Studies of pitch and melody reveal the inner workings of the mind, from basic perception to appreciating beauty

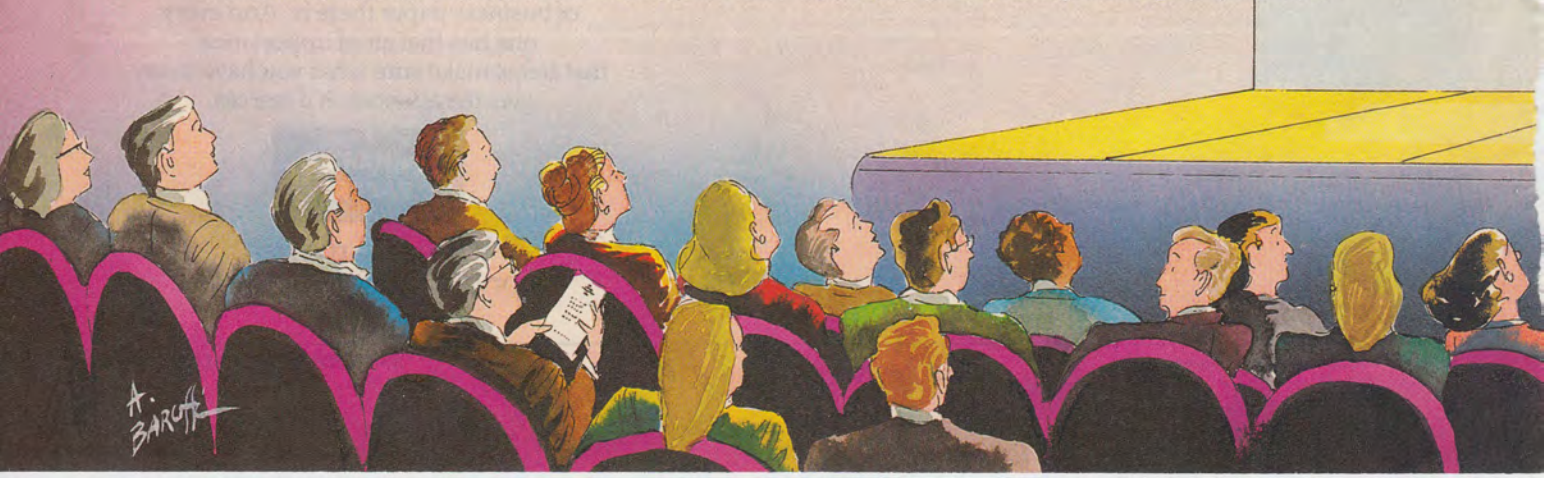


Its glories have been with us from the start. On the wall of a cave called Trois Frères in the south of France, a 40,000-year-old painting depicts a masked figure playing a one-stringed instrument. From Bronze Age Sumeria, a harpist graces a clay seal, while in China, a set of bells from 500 B.C. rings notes still in tune with modern instruments. Since humans first staked a claim to this earth, music has shown its power to lull infants to slumber, send soldiers to war and sometimes even cause audiences to riot —as was the case in Paris when Igor Stravinsky's "The Rite of Spring" premièred in 1913.

Today, scientists are beginning to find that music, beyond its power to stir the soul, can also be a potent tool for probing the mysteries of the brain. Long the province of music theorists studying the intricacies of composition or physicists examining the mechanics of sound, music is now fueling a flurry of new research by psychologists who see it as a unique window into the mind, even one that is musically naïve and tone-deaf. Aided by a recent revolution in computer technology that allows researchers to generate almost any sound imaginable, scientists are using music as an experimental probe to see how the brain works, from its filtering of incoming information to its abilities to generalize and remember to the biological roots of our notions of grace and beauty.

One of the broad findings from this new area of research is that the mental mechanisms that process music are deeply entwined with the brain's other basic functions, including perception, memory and even language. In a study to be published this summer, Diana Deutsch of the University of California at San Diego reveals, for instance, that the perception of music is influenced by the sounds people use while speaking. Presenting subjects with pairs of complex tones that were electronically engineered so as not to rise or fall, Deutsch found that some tone pairs were nevertheless heard as rising in pitch and others as descending. (Examples of these tones as well as other "musical illusions" can be heard in a *U.S. News* telephone demonstration; see box on page 62.) Deutsch suggests that even though most people can't consciously name a particular note as an F or a B-flat, for instance—an ability known as true perfect pitch—

Since most people hear high-pitched sounds better in their right ear, orchestras ideally should play upside down



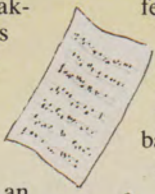
the brain nevertheless categorizes the tones according to a musical scale fixed deep within the mind. In other words, most people possess a subconscious form of "perfect pitch."

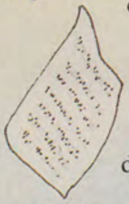
Community choir

Even more surprising is Deutsch's discovery that this mental musical template depends on the range of sounds people use for language—and is different for people in different communities. Those who heard the experimental tones as changing the same way also spoke with the same range of sounds in their voices. Furthermore, students at U.C. San Diego perceived the tones as changing in a manner different from the perceptions of groups of people in Sweden and Austria.

Deutsch suggests that the brain may use its subconscious sense of perfect pitch not only in music but as a key component of an overall survival strategy: Being able to judge whether a person's voice is pitched higher than usual may serve as a type of lie detector or warning signal, for instance, indicating that the speaker is under stress. This subconscious mental pitch scale may also provide subtle cues indicating whether a stranger is part of the local community.

Studies of the mind's affinity for music have also shed light on an even more basic—and important—mental function: The brain's ability to pay attention to only a tiny fraction of the barrage of information coming into it from the outside world. Though little understood by psychologists, this fundamental perceptual ability is vital to everyday miracles such as picking out the shape of a single rose from a St. Valentine's Day bouquet or distinguishing the aroma of bacon frying from the scent of freshly brewed coffee. It is also vital to music, because the ears admit any and all sounds coming their way, leaving the brain to sort them into a friend's chatter, a distant dog bark, the hum of the refrigerator and the plaintive notes of a string quartet.





Experiments by Deutsch demonstrate that the brain sorts out the noises it hears by grouping together sounds that appear to come from the same direction, and that it accom-

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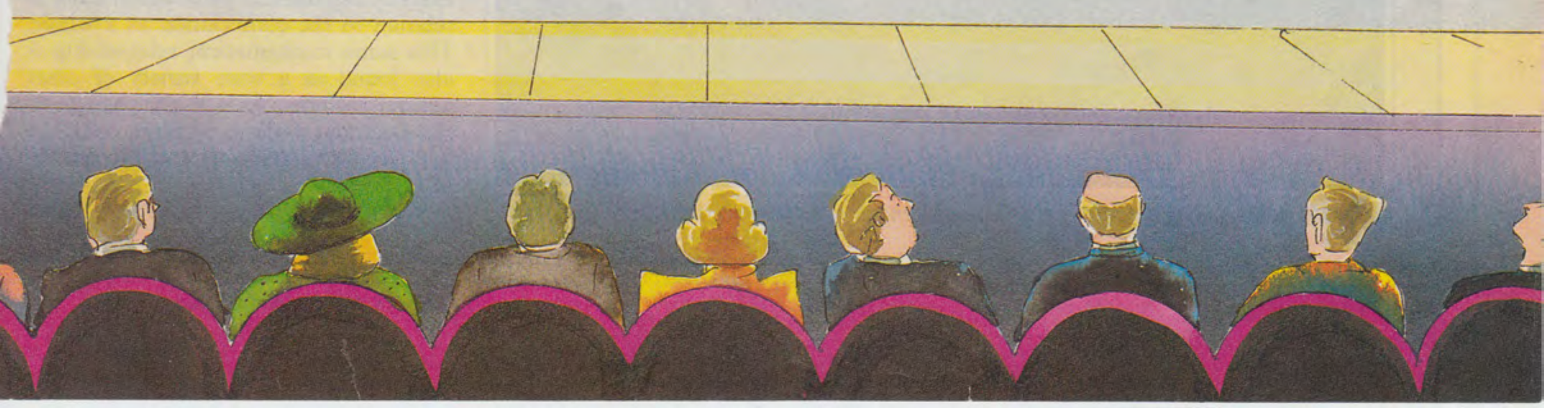


plishes this by listening for high-pitched notes. Because high notes don't travel as far as low ones—which is why the bass drum of an oncoming marching band can be heard long before the piccolos—the brain assumes that the ear hearing the highest notes is closest to the musical source.

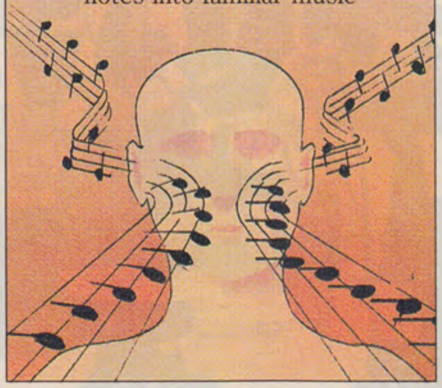
While this ability was certainly helpful for early humans dodging predators, it may pose a problem for concertgoers today. Because one side of the brain generally is dominant over the other, most people hear high-pitched sounds coming through the right ear best. But the typical seating arrangement for an orchestra places higher-pitched instruments to the musicians' right, resulting in the high notes coming from the left of the stage. The only way to accommodate the brains of both audience and musicians is to stand one group on its head.

Missing notes

Proof that this direction-finding mechanism is but one of many mental "modules" operating simultaneously to shape the mind's perceptions came when Deutsch made one module override another. Playing alternating high and low tones into a person's left ear and the reverse pattern into the right, Deutsch found that listeners heard all the high notes as if they were coming into the right ear and all the low notes as though they were coming into the left. The rapidly alternating directional cues apparently confused the mental mechanism responsible for detecting direction, causing it to override the module responsible for perceiving the sound itself and to create the musical "illusion" of each ear's hearing notes that weren't there.

A MASTERFUL MENTAL MAESTRO

The brain excels in organizing sounds into regular patterns. When strange melodies are played in each ear, the mind automatically rearranges the notes into familiar music



The interaction of these various modules of the mind may be responsible for the brain's ability to be precise and to generalize at the same time. The ears can perceive sounds as low as a rumbling subway car and as high as a bird's chirp and distinguish the minuscule differences in notes produced by twisting the tuning knob of a violin ever so slightly. Yet studies of music from around the world suggest that despite the ear's ability to make minute discriminations of sounds, most cultures divide the vast range of audible sounds into musical scales of only about five to seven notes. That the brain is willing to sacrifice some precision and allow a single note to represent a broad range of sounds is evident in opera, for instance, where a singer's vibrato moves the sound of the note up and down quickly but never stays long on the exact pitch. Yet the singer is perceived as being on key. As with many mental processes involved in music, the brain's willingness to trade precision for generalization may help people adapt in other arenas: It explains, for example, why people can understand a person's speech even though it is heavily accented or recognize the aged face of a long-lost acquaintance.

The brain's willingness to choose generalizations over precision is largely responsible for its uncanny ability to remember melodies. While few can rival Mozart, who is said to have been able to

R. F. VOSS—IBM RESEARCH

Mountain sounds. *The equations that underlie music also create naturalistic images*

NATURE'S SCORE

Landscapes and lullabies

Unlike sculpture or painting, music doesn't resemble anything else in the world. So what is it about music that people like? One intriguing clue has come from a physicist who suggests that music resembles not the sounds heard in nature but the essence of nature itself.

Analyzing music from many different cultures and historical periods, Richard Voss of IBM's Thomas J. Watson Research Center found that a simple mathematical relationship describes how the notes of any musical piece rise and fall in relation to the composition as a whole. This same mathematical relationship is also found in a wide variety of other natural patterns, such as the changes in the electrical patterns of brain cells, the fluctuations in sunspots and the growth of tree rings.

What distinguishes music from other

remember an entire symphony after hearing it only once, most everyone carries around dozens of tunes that have been learned effortlessly. Studies by Jay Dowling of the University of Texas at Dallas show that the key to remembering a melody is that instead of learning the exact sounds that make up a tune, the brain remembers only the *relationship* between the notes. "Almost everybody can sing 'Happy Birthday' starting from any note on the piano," says psychologist Jamshed Bharucha of Dartmouth College. "You don't have to be Mozart to do it."

Hidden knowledge

The brain's quest to find overall patterns in the seemingly random world is evident in experiments by Deutsch that show that the mind will rearrange a jumble of notes it hears into familiar patterns. Playing a complex array of notes in one ear and a different complex musical pattern in the other, Deutsch discovered that her subjects in fact heard two simple musical passages. Faced with a barrage of confusing sounds, the brains of Deutsch's subjects simply combined the notes that were closest to each other into familiar tunes. This same effect occurs as the brain weaves together the myriad notes played simultaneously by an orchestra in a performance: In Tchaikovsky's Sixth Symphony, for example, the violins, viola and cello each play musical passages that actually are never heard by most people in the audience because the brain automatically rearranges the combined notes of these instruments into different—and more familiar—musical patterns.

HOW THE MIND KEEPS MUSICAL SCORES

The brain remembers melodies not as specific notes but as patterns of rising and falling sounds. That's why people can sing "Happy Birthday" starting with any note on a piano

The brain's effort to tease out general patterns often takes place without a person even being aware of it. Psychologists have long known that as children develop they gradually construct a "great chain of being" by which they divide objects in the world into such categories as inanimate and alive, mythic and real. Similarly, people learn their native tongue without explicitly learning the rules that govern that language—a point obvious to students who struggle to learn the "pluperfect subjunctive" in a foreign language while using that verb form effortlessly and often without knowing it in their everyday speech.

Recent experiments that tested nonmusicians' musical skills dramatically illustrate that most people have an exquisitely crafted musical sense that has developed subconsciously over their lifetimes, even if they don't know Mozart from Madonna. Music theorist David Butler of Ohio State University's School of Music found that listeners with no musical training can nevertheless indicate by whistling or choosing from a set of tones which of the 12 possible pitch keys a piece of music is in, sometimes after hearing only a few sample notes. Butler suggests that people subconsciously know through experience that particular combinations of notes occur only in certain keys and gradually narrow the possibilities as more combinations of notes are heard.

This "hidden" knowledge in the mind

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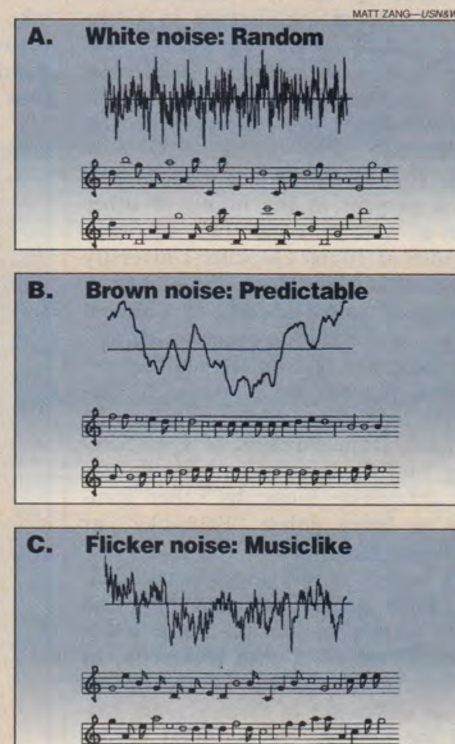
sounds, says Voss, is that music varies in a manner that is midway between random and predictable. A waterfall, for instance, produces random sounds, generating the nonmusical rumble physicists call "white noise." Similarly, if notes are assigned randomly on a musical staff, the resulting "white music" (see A at right) sounds nothing like the real thing. At the other extreme is highly regular natural variation, such as the motion of a floating particle of dust being jostled by air molecules. A melody based on this pattern (see B), which Voss calls "brown music," is so predictable that it, too, sounds very unlike music.

Universal rhythm. In between these two types of sound is a natural variation known as "flicker" noise. The most common kind of noise found in nature, it typically is not heard as sound but rather reflects how a particular physical system—that of a clock, for instance—varies over time. In fact, all timepieces, from a modern atomic clock to an hourglass, deviate in accuracy in a pattern that is described by the formula for flicker noise.

Analyzing all kinds of music, from Russian folk songs and Hindu ragas to Beethoven and the Beatles, Voss found that nearly every kind of music—the exception being some modern, dissonant compositions—can be described mathematically as a type of flicker noise. Music based on flicker noise (see C)—in one instance Voss used the varying water levels of the Nile to compose a piece—can't hold a candle to Mozart, but most listeners nevertheless judge the tunes distinctly musiclike.

Clearly, music is much more than a simple mathematical equation, but Voss's research suggests that the essence of music may be its subtle reflection of nature. Using similar equations—part of a new science known as "fractal geometry"—Voss and other researchers have created realistic-looking artificial landscapes, planets and clouds. Composers, too, appear to be taking an interest in flicker noise. In April, the Guggenheim Museum featured a multimedia presentation of flicker music written by Pulitzer Prize-winning composer Charles Wuorinen and accompanied by slides of fractal landscapes.

MATT ZANG—*USN&WR*



in a listener's enjoyment of music, it should be no surprise that music also has a profound influence on mood and behavior. In one experiment, Vladimir Konecni of the University of California at San Diego hired actors to antagonize other people taking part in a series of phony experiments. He found that the angered people invariably chose the slowest and quietest music from a selection of tapes while they sat in a waiting room between sessions, suggesting that people will often unconsciously select music that will alter or enhance their mood and behavior. Other research has shown that playing music in a store increases the amount of time—and money—shoppers spend there, and music is increasingly being used by psychotherapists as part of relaxation programs and as therapy for autistic children. Contrariwise, the appeal of so-called "new age" music, which is composed using formless melodies and lulling rhythms, is that the brain can relax or concentrate on something else while listening to it.

A mirror of nature?

Ultimately, one's appreciation of music may have its roots in nature itself. Richard Voss at IBM's Thomas J. Watson Research Center has found that nearly all kinds of music, old and new, share a fundamental mathematical formulation that expresses how the notes change in pitch over the course of a musical work. According to this mathematical formulation, the notes in music vary in a manner that lies halfway between the total randomness of static noise and the dull predictability of simple physical systems such as a buoy bobbing in the sea (see box, page 58).

Surprisingly, the same mathematical formula that characterizes the ebb and flow of music has been discovered to exist widely in nature, from the flow of the Nile to the beating of the human heart to the wobbling of the earth's axis. Remarkably, this equation is closely related to other mathematical formulas used by computer experts to generate amazingly realistic pictures of coastlines, clouds and mountain ranges and other natural scenery.

Could it be that the ancient Greeks, who believed that the planets made music as they traversed their heavenly orbits, almost got it right? Voss's research raises the intriguing possibility that we enjoy music because it reflects not only the workings of the mind but, as the Greeks believed, the harmony of the cosmos as well. The brain, with its insatiable love of teasing out patterns in the world around it, may create, produce and enjoy music as a demonstration—and celebration—of its being tuned into the ultimate rhythms of nature. ■

by William F. Allman

CONDUCT YOUR OWN EXPERIMENT

1-900-654-NEWS

To reveal some of the musical magic performed by the mind, *U.S. News* has created a brief audio demonstration of "musical illusions" that you can experiment with over the telephone. Dial 1-900-654-NEWS. This presentation was prepared with the assistance of psychologist Diana Deutsch of the University of California at San Diego, a leading researcher on the brain's musical powers and editor of the scientific journal *Music Perception*.

The demonstration begins with two examples designed to illustrate how the brain perceives the sounds it hears and turns them into music in the mind. The first example shows how the seemingly simple act of hearing a note is a multifaceted task involving many different mental mechanisms. A listener not only hears the pitch of a particular note, for example, but also perceives another property that music researchers refer to as the pitch's "height"—that is, whether the note is a *high* C or a *low* C. The example demonstrates how by mixing up these two properties in the notes that make up a musical passage the brain can be confused and fail to recognize a familiar melody. See if you can "name that tune." Next there is a musical illusion that demonstrates how the brain automatically rearranges complex information—in this case two different melodies containing a scrambled jumble of notes—into familiar musical patterns.

Following these examples are two demonstrations of how the brain's musical abilities are related to more-sophisticated mental functions such as language and memory. First are pairs of bizarre tones that are electronically engineered so that they go neither up nor down, but are nevertheless heard by most listeners as rising or descending. These tones demonstrate that most people have a subconscious ability to judge the exact pitch of a note. Recent studies have discovered that this mental template is related to the pitch people use when they speak and is different for different people. Compare the way you hear the tones with how someone else hears them—or listen with a group on a speaker phone. It is likely that not everyone will perceive the tones in the same way.

Finally, there is a quiz of your musical memory. The first quiz shows that it's easy to judge whether two notes are the same or different if they are separated by three seconds of silence. Recent psychological studies by Deutsch demonstrate that it is also easy to match the notes even if they are separated by spoken words. But the next two examples illustrate how difficult the task becomes when the silence between the two test notes is filled with eight other notes. This test shows that part of the brain's memory for music is performed by a distinct "module" in the mind that sometimes can be overloaded.

TOLL CALL

The audio demonstration lasts about 2 minutes and 50 seconds and costs 95 cents a minute. Proceeds will be used to promote literacy in the United States