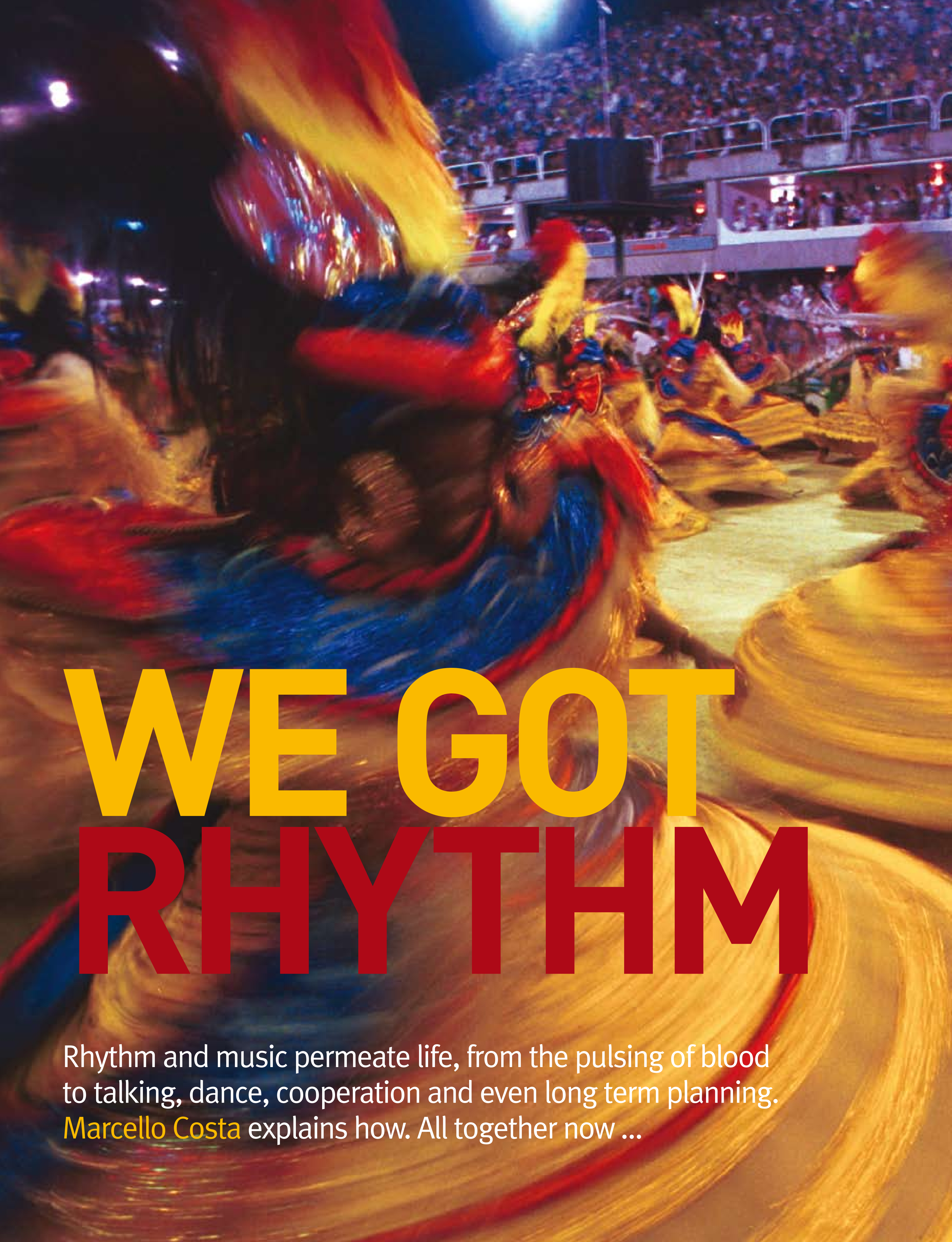

WE GOT RHYTHM

Rhythm and music permeate life, from the pulsing of blood to talking, dance, cooperation and even long term planning. Marcello Costa explains how. All together now ...

FROM THE INFECTIOUS CARNIVAL dancing in the streets of Rio de Janeiro, to the deep experience of classical music, from a rock concert to opera productions or during more intimate improvised jazz sessions, we humans appear to reach the highest level of collective happiness in such musical events.

Musical behaviour during these human communal activities evokes in us the richest emotional experiences, gives us a sense of participation, and stimulates our cognitive dimension giving us a deep sense of feeling free. Music appears to be one of the very few non-threatening human activities in which collective and individual physical, emotional and intellectual pleasures can be freely expressed and, with few exceptions of extreme groups, are welcomed and accepted in all cultures.

An important ongoing question is whether music is a generic skill of the evolved brain, as maintained by Harvard University cognitive scientist Steven Pinker, who regards music as just 'auditory cheesecake' with no adaptive function or, as anthropologist Steven Mithen suggests, music is a newly evolved feature of the human brain with adaptive advantages. Whatever the answer, everybody agrees that the ability to perform music, listen and dance to it is universal to individuals of all human cultures. The happiness that humans experience with music has probably existed since the dawn of humans. As such, music probably went hand in hand with all other aspects of human biological and cultural evolution.

What happens in the brain in music?

An exercise that may help to clarify the role of music in human biological and cultural evolution is to look at what happens in the brain and the body while performing, listening and dancing to music.

Music since its beginnings is rhythm, composed of a mixture of internal pacing and external paced movements which involves complex motor skills, exquisite detection of sensory cues such as tempo, pitch, melodies and rhythms, often accompanied by singing with words. It consists in repeated movements that generate sounds from instruments or voices. The movements and the resulting sounds elicit auditory, tactile and visual experiences shared by active and passive participants. Music involves a unique integrated sequence of actions (playing or singing) locked into a self-sustaining loop of motor actions accompanied by stimulation of the visual, tactile and auditory senses glued together by emotional processes.

It is an activity initiated and maintained by humans with no other inputs from nature needed. Few human activities include so many brain functions integrated together in individual and communal moments.

I will argue that music is the natural result of the uniquely human ability of the different parts of the brain to work in synchrony, from locomotion to the highest cognitive functions, ability that coincides with the appearance of a self aware, conscious mind.

Moving around

The best example of the simplest rhythmic behaviour is walking or running. We share this rhythmic activity with animals. Locomotion is initiated within the most primordial neural circuits in the spinal cord and is modulated by sensory experiences.

How does this coordinated rhythmic motor activity come about? All nervous system functions are the result of interactions between a myriad of little cells called neurons that send signals at high speed to each other. These fast electrical signals (in neuroscientific jargon: action potentials, nerve impulses or spikes that last a few thousandths of a second) are often superimposed onto slower electrical oscillations in neurons (lasting more than a tenth of a second). In fact, all living cells show similar slow chemical oscillations resulting from the complex feedback loops of their biochemical reactions. Neurons are unique in that they transform these slow biochemical oscillations into slow electrical oscillations.

In the spinal cord of vertebrates, since their appearance on earth around 450 million years ago, such oscillating neurons generate the remarkable collective behaviour that becomes locomotion, whether swimming, slithering, walking or flying. The rhythmic oscillations of some of the 'pacing' neurons drive neural circuits to produce appropriate alternating right-left, head to tail or hip-leg to foot movements.

Rhythms resulting from oscillating neural circuits are thus embedded into all levels of the nervous system from its early evolution. The realisation that the brain and spinal cord generate their own oscillatory activities (everybody has heard of 'brain waves') has resolved the

old philosophical question as to whether the brain is a blank slate (tabula rasa), simply responding to external demands or has some internal predispositions to action. The brain grows with predisposed neural ‘programs’ for action (behaviour) as well as the capacity to be continuously shaped by sensory experience.

The evolution of freedom

The interaction between the oscillating neural circuits that generates locomotion and the sensory feedback from the motion itself in the physical medium (water or air) represents the very first step for the animal in acquiring the ‘freedom’ of moving around.

The evolution from the first primitive vertebrates (such as lampreys, eel-like animals found seasonally in rivers) to humans, involves cumulative additions of superimposed loops of oscillating neural circuits. These enable greater integration of sensory information, making vertebrates increasingly independent from the environment. According to the philosopher Daniel Dennett this is part of the ‘evolution’ of freedom.

With upright walking the forelimbs become free to develop new tasks, and manual dexterity quickly emerged in early hominids. Accurate timing is so important in motor control that big chunks of subcortical brain, eg cerebellum and basal ganglia, are dedicated to ensure appropriate timely muscle coordination. Not surprisingly these areas are active during music behaviour, even simple rhythmic tapping.

Humans seem to be predisposed or hardwired to extract regularity from temporal sequences. This is probably because any signal arriving in rhythmic fashion will resonate better with intrinsic neural rhythms. In infants of all cultures their sense of binary rhythm is linked to their body in stereotypical movements of head, arm, chest or early bipedal kicking, all part of a self-generating loop of sensory and motor activity involving oscillating neural circuits. Such metric regularities are universal building blocks on which more complex rhythmic patterns, such as a waltz or more complex syncopated rhythms, are later superimposed.

Although other non-human species can discriminate between rhythmic and non-rhythmic sequences, the ability to keep a steady intrinsic beat or to entrain to an external timekeeper is probably uniquely human. This ability to keep and follow beats is critical also for the syntactic constructions of music and language. Indeed infants are sensitive to the rhythmic properties of speech. For example, French newborns differentiate English utterances from Japanese utterances. The link between primordial language and music has been well recognised. The very language of babies, from the initial babbling with interactions with the mother, is highly musical.

The importance of sensing noises and sounds from the environment, enabling animals to localise the source of either predator or prey, dates way back in evolution. Periodic sounds are important in the natural environment because other animals almost exclusively produce them, and so pitch is a good cue to segregate these sounds from background noise. Marmosets monkeys, with whom we share a common ancestor several tens of millions years ago, are highly vocal creatures. The development of pitch-sensitive neurons, located in a specific region of the human brain cortex, could be seen as precursors to human pitch perception, which has led to our unique development of language and music.

Music and language

Both music and language share common features involving perceptually discrete elements organised in hierarchically structured sequences (syntax). Speech rhythms are dependent on a specific region in the left frontal cortex while the melodic aspect of speech is dependent on a corresponding region of the right cortex. Similarly the metric features of music are dependent on a very specific region in the left frontal cortex close, but are separate from the speech area, while the melodic features of music (humming, ‘in tune speaking’) are dependent on the corresponding right cortex. Listening to melodies and harmonies, recognising pitch, tones and beat, all activate specialised areas of the cortex that are also dedicated to listening and understanding words, rhymes and intonations.

However, distinct regions mediate recognition of lyrics, text and tune in songs. For example, tone deaf individuals have less white matter in the right frontal inferior gyrus, an area just behind the right side of the forehead, compared to musically normal controls, suggesting the right frontal cortex is implicated in perceiving pitch and remembering music. In contrast, language is most often localized on the left side of the brain. Poetry even more clearly preserves musical aspects of prosody and euphony (rhyme).

The power of music to enhance language abilities is also demonstrated in the improvement of stuttering by singing the words. ‘Choral’ speech or speaking in unison is an undeniable phenomenon that immediately induces fluent and natural sounding speech in almost all people who stutter.

Singing is the most widespread mode of musical expression. Infants spontaneously sing around the age of one. By the age of five, children have a large repertoire of songs of their own culture. During development, the cortex becomes segregated in areas dedicated to different high functions depending on life experiences. Bilingual people develop closely associated, but different, areas of the cortex dedicated to each language. Similarly, singing areas of the cortex can be dissociated from speech areas. Separate cortical areas perform reading of musical notation and words.

Neuroscience of music

Increasingly neuroscientists are exploring the uniqueness of music. A new Institute – the Brain Music & Sound Research Center – has opened in Canada devoted to the study of the neuroscience of music using psychological tests, brain imaging and clinical studies of patients with lesions (Balter, 2007). Neuroscientists from this Institute and from many laboratories around the world are mapping brain regions that are activated and involved in some aspects of music.

Not surprisingly these studies reveal that there are very few areas of the cortex and subcortical centres that are not activated by some aspects of music, be it playing, dancing, tapping, singing, music score reading, improvising or just listening. Thus each area of the brain also subserves specific aspects of musical behaviour. Rhythmic behaviours reveal the interacting network of brain and spinal cord areas active during spatially patterned, bipedal, rhythmic movements that are integrated in dance. Timing of movements of dance steps to music, compared to self-pacing movement, involves a specific part of the cerebellum. Voluntary movement to a regular beat involves not only the motor and premotor areas of the frontal lobes but also extensive deeper subcortical regions (the basal ganglia). Navigating safely in a ballroom while dancing a waltz activates a specific part of the parietal lobe. Playing instruments involves specialised regions of the brain. Visual experiences associated with all these activities activate broad and specialised areas of the cortex.

Music and emotion

Music activates those brain circuits involved in pleasure associated with physiological arousal. We readily distinguish happy from sad music and many people report a particularly pleasant or even euphoric musical experiences as one that give the 'chills' – the shiver down the spine effect.

Indeed music activates specific pathways in brain areas associated with emotional behaviour including responses to food and sex (eg insular and cingulate cortex, hypothalamus, hippocampus, amygdala, and prefrontal cortex). Dissonances and deviations of beats are readily detected and activate these very same areas involved in emotional experiences. Musical pulse is important in regulating emotions and motivational states by means of affecting states of readiness to action. Even the innermost working of the body is paced by oscillatory groups of cells, from the heart and pulse beating to breathing. Rhythm permeates life.

Social role of music

Music and dance are social activities par excellence. Synchronizing to a musical pulse or beat facilitates coordination of movements with others individuals for working tasks, or for social bonding and solidarity within social groups (Hauser and McDermott, 2003). Psychologists call this state of collective intentionality the 'We-mode'. The recent discovery that specific areas of the brain become active not only when a subject plays an instrument, but also when the subject observes somebody else playing, opens a new era in understanding how communal musical behaviors can generate a good sense of 'choral' activities. The neurons involved in this mutual understanding and empathy, discovered by neuroscientists from Parma (home of the well known cheese), are called 'mirror neurons'. Through these 'social brain' circuits music plays important roles in facilitating courtship and engenders a sense of well being as dancing, playing and listening together demonstrates.

Music also involves higher cognitive functions. Musical training enhances the ability to automatically note changes in the relative pitch (right cortex) and time structure (left cortex) of melodies. Such learning seems to extend to other cognitive functions (Peretz and Zatorre, 2005). For example, extensive musical training influences the perception of pitch contour in spoken language. The areas of the cortex dedicated to different aspects of music are larger in professional musicians, indicating the remarkable plasticity of the human brain.

Takako Fujioka from Canada last year provided evidence that musical training in children improves non-musical abilities such as literacy, verbal memory, mathematics, and intelligence quotient.

Music engages the brain over wide ranges of temporal scales. The frontal areas of the brain are most likely involved in longer musical structures beyond a few beats. These are areas also involved in long term planning of behaviour. Music thus reveals the very processes involved in every day small decision making in initiating movements and in long term planning.

From the gentle nursery rhyme to military marching, from the pervasive uninspiring 'musak' to the creative improvisation of a jazz musician, music can pace our lives.

Not all music is an expression of freedom. Individuals in some nightclub dancing can be heavily influenced by music and lose the sense of being in control. Similarly music in superstitious or sexual rites, religion, ideological mass rallies and military marches, clearly demonstrates the power of music in depersonalising individuals and in establishing behavioral coherency in masses. Conversely, the sense of freedom that music can give may be the reason why it is loathed and prohibited as sinful by some of the more conservative and repressive societies.

What is the significance of music for human evolution? The evolutionary emergence of the human subjective experience, of the sense of awareness of the self and others, is the result of synchronised activity of different parts of the brain.

The working together of different parts of the brain has broadened the horizon of experiencing the world both as observer and agent, consequently improving the ability to adapt to it. As observers we develop an increased awareness of our own moving body and of the surrounding world. This bottom up building of subjective experience goes hand in hand with top-down influences that occur at every brain level, reaching its peak with selective attention, which gives us the sense of being agents in control of our actions and with free intentionality, vital for guiding human behaviour. Music may tap these remarkable evolutionary resources and may represent the unavoidable result of the evolutionary ability of different parts of the brain of homo sapiens to work in synchrony, giving us the unique abilities to feel free and share complex experiences.

If the behaviour and experience of music epitomises the journey of becoming human, then its aesthetic value perhaps may allow us to remain so.

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