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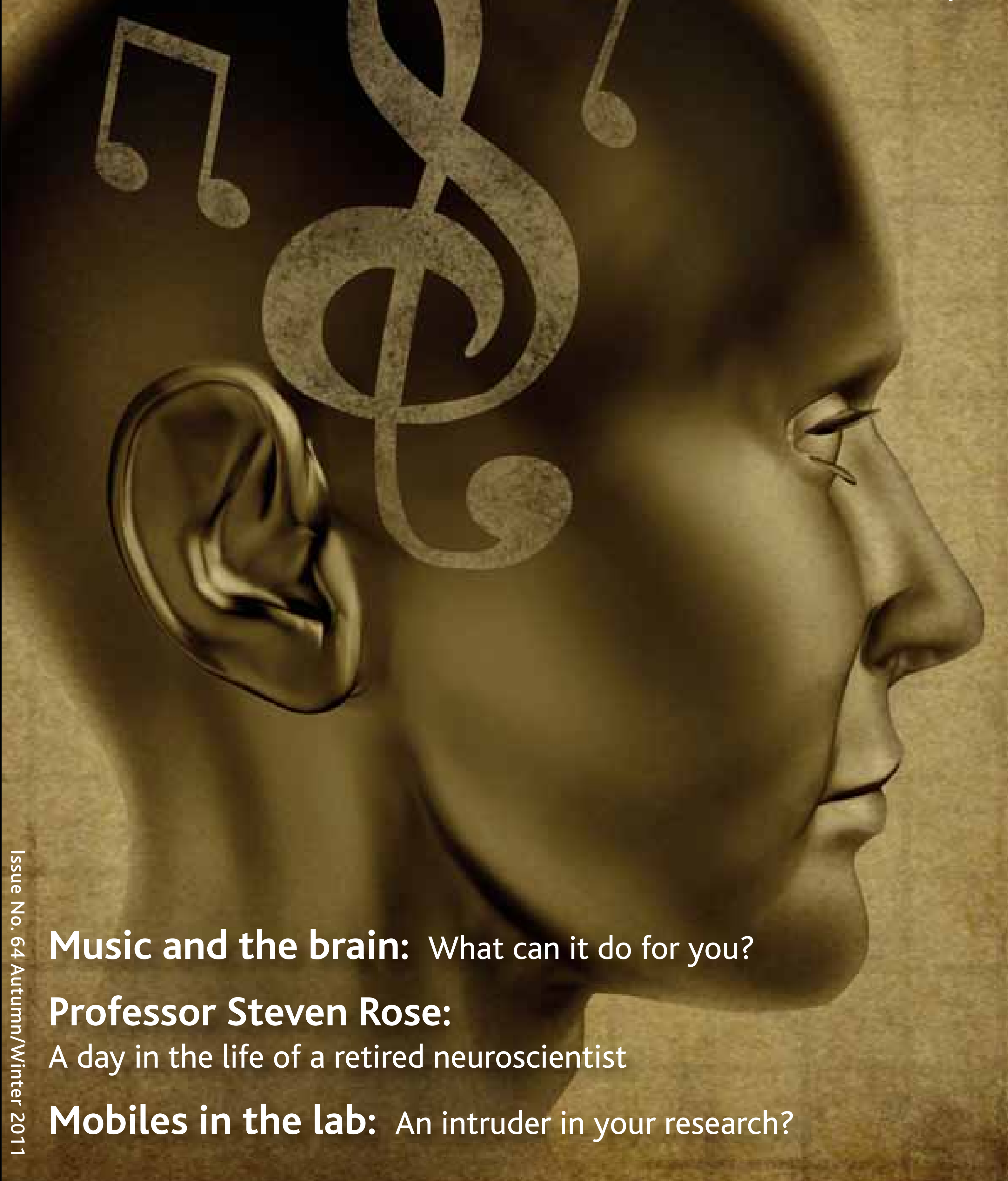

Music and the brain: What can it do for you?

Professor Steven Rose:
A day in the life of a retired neuroscientist

Mobiles in the lab: An intruder in your research?

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WHAT MUSIC CAN DO

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The identity of our species is inextricably linked with music. Every known culture and tribe of humans uses music for social interaction, from the grandest ritual to the softest lullaby. A great many parallels exist between music and language, not least for their universality among and specificity to humans. As with language, certain aspects of music are found in the innate neural architecture, while other components need to be learned from others. Study into music and musicians is not a new phenomenon. Post-mortem examinations of the brains of musicians date back to the 19th century [1], as investigators pursued a neural substrate for musicians' talents. Prodigious advances in the field in recent years have resulted from the revolutionary advances in neuroscience brought about by in vivo functional imaging technologies; it is now possible to begin to unravel the neural activity that allows an individual to produce, interpret, enjoy, loathe, perform and dance to music.

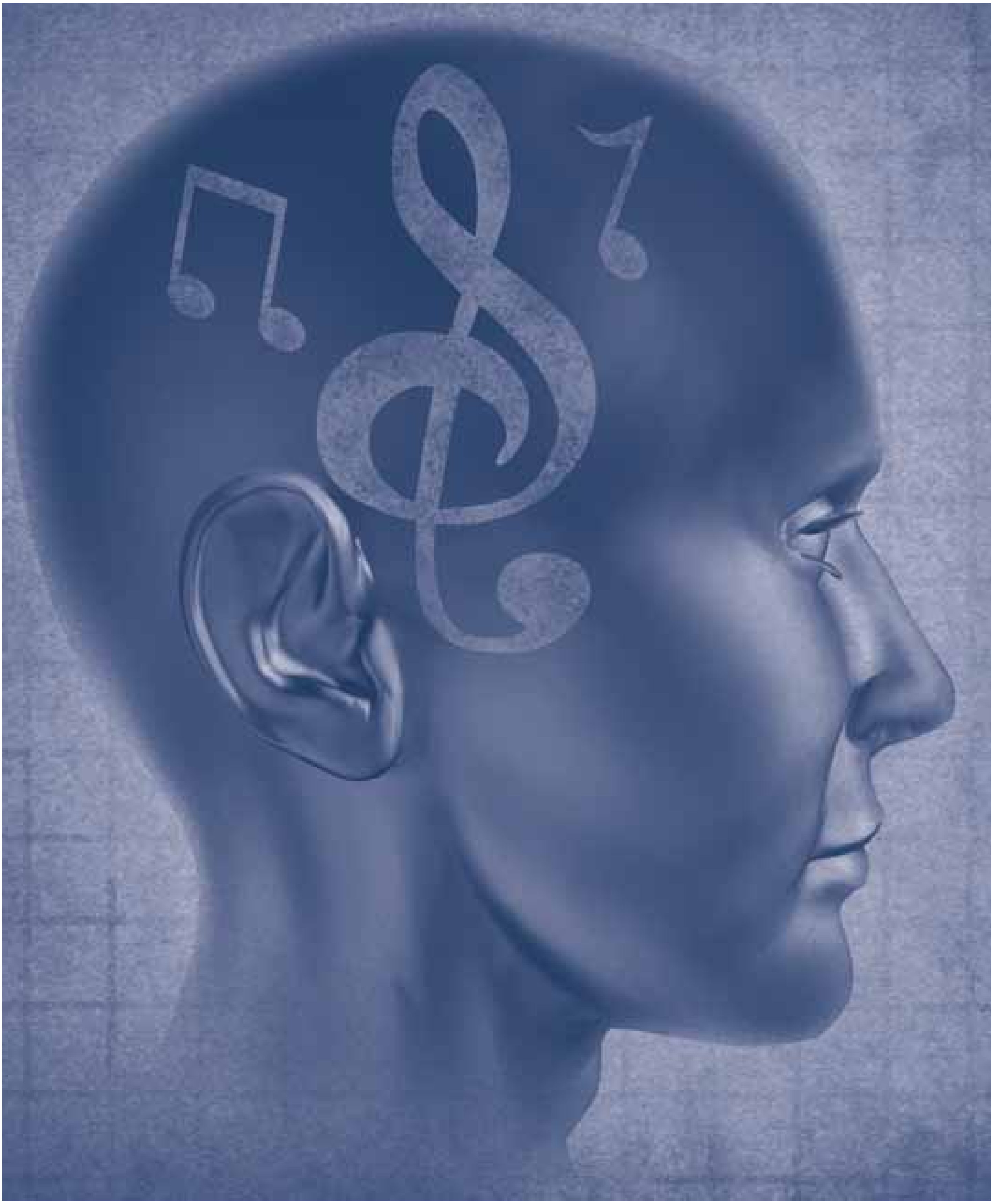
The origins of music itself are largely unclear. Early evidence of music dates back over 30,000 years ago with a paleolithic bone flute, showing that when humans colonised Europe, musical traditions were already advanced [2]. Although hard evidence does not exist from before this time, the fact that music is present ubiquitously in human culture suggests that music existed at a very early point in human history; its absence in chimpanzees and other primates is evidence that music is younger than the most recent common ancestor. Like all primates, humans find faster tempos more invigorating and less relaxing than slower ones, and prefer note combinations that are consonant, i.e. where the ratios between wavelengths form simple ratios (for example, two notes an octave apart have wavelengths in the ratio 1:2; notes a perfect fifth apart have wavelengths in the ratio 2:3), to dissonant notes, which sound harsh and unpleasant [3]. Very young infants display this preference for consonance at such an early age that it is not thought to result from the infant learning common intervals from listening to music, and is therefore thought to be an innate preference [4], although it is unclear whether this preference is derived from the signals sent from the inner ear or the neurological processing. Unlike human infants, however, other primates prefer silence to consonant notes and melodies [5]. This suggests an innate response to music in infants that is not learned.

Determining which aspects of music are transferrable between all cultures, and those which are specific to certain traditions, allows us to unravel further the innate, neurological processes that allow music production in humans. All forms of music share a definite beat at regular temporal intervals, which even newborn infants can detect, and when a downbeat in a regular pattern is omitted, brain activity associated with deviation from sensory expectations can be noted [6]. As with simple ratio harmonies, regular beat is present in all music cultures and has a 'hard wired' neurological correlate. At the point of a beat within music, listeners will often feel an urge to move with the music, often with a definite beginning beat at the start of a short, repeated pattern of stressed and unstressed notes. The point at which a listener would naturally move with the music, for example by tapping their foot, is known as the tactus, and indicates an underlying pulse to music. Neuroimaging studies indicate basal ganglia activity when listening to music, and that when listening to a piece of music with a regular beat, areas including the putamen, pallidum and caudate are activated more robustly than in pieces of music with an irregular beat, indicating that the basal ganglia are of utmost importance to perceiving and generating a beat [7]. The involvement of these regions in voluntary motor activity may explain why there is such a pronounced motor aspect to music; even when listening passively, one may feel an urge to move with the music. Additionally, conserved in musical traditions is the idea of transposing a piece, where the relation of a note to others, rather than their absolute wavelength, is important in remembering and recognising musical passages. Infants as young as six months have been shown to recognise musical phrases by virtue of relative, rather than absolute pitch, which is more common in younger infants and in nonhumans [8]. Some adults do retain absolute pitch, especially if they have received musical training from a young age. The ability to detect changes in pitch, rather than decoding their wavelengths may be important from an evolutionary standpoint in the development of language and the ability to recognise voices.

Musical skill, often possessed in greatest abundance by those who have received formal training, is lacking completely in those suffering from a condition known as amusia, with amusics making up an estimated 4% of the population [9]. The condition is characterised by the sufferer finding it impossible to identify differences in pitch between notes or to remember musical phrases, although changes in rhythm and volume can be detected. Amusics suffer no defect to the ear, or the primary auditory cortex, which responds normally to changes in pitch; defects in frontotemporal pathways, and grey matter cortical differences in the frontal lobe are thought to cause the disorder.

Congenital aphasia, a disorder in language, sheds more light regarding the neurological processes important for music. As aphasia can exist without amusia (and vice versa), the processes that govern language and music cannot be exactly the same, although there is a degree of overlap between the neurological systems governing both, owing to their large degree of similarity [10]. Syntax is integral to the composition and interpretation of both music and language, where basic elements combine to form words and sentences, or chords and melodies. One hypothesis based on neuroimaging and neuropsychological studies states that frontal regions common to both music and language perform syntactic processing of information, based on representations of syntactic information found in posterior regions of the brain [10]. By definition, there can be no animal models for experiments involving uniquely human attributes; by using music and language to serve as experimental models for one another, as when studying how aphasia affects amusia, more conclusions can be drawn than when studying either in isolation.

Perception of music has profound effects on the body, which cannot be bestowed by other, non-musical sounds. Dramatic changes of heart rate and other indicators of physiological changes within the body can be detected while a listener is passively listening to musical stimuli. Additionally, intense physical states such as raising of the hair on the back of a person's neck, part of a phenomenon described as "chills", can be exacted by specific pieces of music, often pieces with a perceived tension or release. Subjects report a much higher incidence of chills in pieces of music they know well, and that has previously resulted in the experience of chills [11]. This strong link between



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the physiological state, emotional state and music forms the basis of music therapy. As with the increased incidence of chills in music known to an individual, music therapy shows increased efficacy when well-liked pieces of music are used, when compared to novel pieces, further securing the link between music, emotion and memory within the brain. The therapeutic benefits of this music therapy are yet to be fully understood, however, if music therapy were able to reduce the pain and discomfort felt by patients, pharmacological pain relief could be reduced. In one study, surgical patients who listened to music before and during the procedure showed significantly lower stress levels to those who heard the normal sounds of the operating theatre with stress levels lowest in patients who were able to choose the music they listened to [12]. Both the enjoyable, calming aspect, and the feeling of control gained by listening to familiar music, appear to be beneficial for patients. Areas within the brain associated with music show connectivity with many disperse areas of the brain, and this expanse of pathways allows music to provide an important role in rehabilitation in patients with brain damage, for example those who have been affected by stroke. Those suffering with a non-congenital form of aphasia following stroke left unable to speak may be able to sing if the damage is localised to a small enough area; pathways involved in singing may be left undamaged, and by using their musical voice, patients may be able to re-access language centres of their brain previously beyond their reach [13], although the benefits provided by music may be limited to rhythmic, rather than melodic cues [14].

Strikingly, music has the ability to change the structure of the brain in drastic ways. In individuals who have practised tasks, and have become more proficient in them, are changing the landscape of their brain by virtue of neuroplasticity. Complex motor tasks such as juggling, in individuals who have practised for three months, are associated with an increase in grey matter volume in temporal regions and the left intraparietal sulcus. This expansion begins to reduce when juggling is stopped, although remains higher than before the skill was acquired [15]. Similarly, when learning a complex exercise on the piano over the course of a few days, the cortical representation of the muscles within the forearm increased [16]. The increased motor skills alone do not account for the changes the brain undergoes while practising music to a professional standard; increased motor dexterity on a keyboard may not be so different from the more common skill of typing, and may not, therefore, be evident in comparisons with controls. Indeed, more specific variations detected in Heschl's gyrus, correlated with an increased ability to detect subtle changes in repeated musical phrases, show a marked increase in activity in musicians [17]. Phrases which are musically incongruous, either by containing dissonant notes, or non-syntactic or unexpected rhythms, illicit a haemodynamic response in the brains of musicians that is both faster and of greater magnitude than in non-musicians [18]. Increases in frontal lobe activity while solving problems are correlated with an increase in divergent thinking, an important component of creative skills that musicians, especially composers, have in abundance [19]. While it would be obtuse to assume that genetics play no part in musicians' possession of their exceptional skills, it is the neuroplastic changes brought about by a change in behaviour, the countless hours spent practising, that are the most important determining factors in the remarkable characteristics of musicians' brains. This leads to a difficulty in defining the term 'musician' in experimental paradigms, as all individuals display musical talent on a continuum from amusia to that found in a professional musician. The distinction, usually based on professional status or formal training, will always be somewhat arbitrary.

Beyond the simple processing of acoustics, the differences in musical processing in musicians and non-musicians become more apparent, notably in the contrasting activity of hemispheric function. Individuals who do play an instrument, and are responding to a piece of music they are naïve to, show more activation within the right hemisphere, linked with an increase reliance on processing of timbre and melody of the piece while listening; Musicians, particularly those responding to a piece they know particularly well, show increased activation within the left hemisphere, indicative of an increased processing of the syntactic elements of the piece, formed of the individual pitches and rhythmic patterns present [20]. Thinking patterns are closely related with musicianship, with musicians often being intuitive, rather than logical thinkers. This has lead to musicians being found to perform better in verbal memory tasks than controls, thought to be a result of the cortical reorganisation found in musicians [21]. While performing music has no effect on normal age-related hearing loss, the complex processing of speech in a noisy environment, an ability that deteriorates with age, was found to be improved in musicians when compared to nonmusicians [22].

The possibilities for future research into music are near endless, and as the field grows it will prove to inform many disparate fields of study. The congruencies in the processing of music and language allow experimental models and comparisons to be drawn where there is no animal behavioural equivalent. Further understanding of the connections between purely musical functions and those of movement, memory, hearing and emotion will inform the research into these areas. The origins of music itself shed light into how our minds work. As we dissect and study music into infinitely smaller parts, we must remember how effortlessly music has become ingrained into our being, and the words of Elvis Presley -
"I don't know anything about music. In my line, you don't have to".

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