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Will my children be musical? Exploring current research on the role of genetics and the heritability of music ability

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Abstract

Research over the past decade has provided a strong, ongoing discourse and evidence of the heritability of genetic ability and, furthermore, its role in understanding complex issues, such as intelligence and musical ability. However, it is often difficult to keep up with current trends and make sense of new research. The aim of this article is to review the current literature, in the rapidly growing inter and multidisciplinary fields of music and psychology, on the role of genes and the heritability of musicality, musical ability, intelligence and musical development, from various sources in an effort to better comprehend the role of genetics in the inherited musical ability and expression of our children. The article concludes that evidence from the studies of genetics suggests that it is unlikely that there are single genes responsible for any complex behaviour, including musicality and musical ability. Behaviour depends on a complex interaction between skills and experience. Genetics may play a substantial role in the link between music training and IQ, although the role of personality and cognitive ability is substantial and is still being investigated. Musical development is a non-linear process in constant interaction with many factors.

Key words: Genetics, musical ability, IQ, musical development, musicality, heritability

Opsomming

Navorsing oor die afgelope dekade het ‘n sterk deurlopende diskoers en bewyse van die oorerflikheid van genetiese vermoë, en voorts, sy rol in die begrip van komplekse kwessies soos intelligensie en musikale vermoë. Dit is egter dikwels moeilik om tred te hou met die huidige tendense en gevoel van nuwe navorsing. Die doel van hierdie artikel is om die huidige literatuur te hersien in die vinnig groeiende inter-en multidissiplinêre velde van musiek en sielkunde oor die rol van gene en die oorerflikheid van musikaliteit, musikale vermoë, intelligensie, en musikale ontwikkeling vanuit verskeie bronne in ‘n poging om ‘n beter begrip te hê oor die rol van genetika in die oorerflike musikale vermoë en uitdrukking in ons kinders. Die artikel sluit af dat bewyse uit die studie van genetika daarop dui dat daar onwaarskynlik enkele gene verantwoordelik is vir enige komplekse gedrag, met inbegrip van musikaliteit en musikale vermoë. Gedrag is afhanklik van ‘n komplekse interaksie tussen vaardighede en ervarings. Genetika kan ‘n belangrike rol speel in die skakel tussen musiek opleiding en IK, maar die rol van die persoonlikheid en kognitiewe vermoë is aansienlik en word nog ondersoek. Musikale ontwikkeling is ‘n nie-lineêre proses in konstante interaksie met baie meedelende faktore.

Sleutelwoorde: Genetika, musikale vermoë, IK, musikale ontwikkeling, musikaliteit, oorerflikheid

Introduction

Our wedding, 22 years ago was attended by approximately 150 guests, of whom 26 were “new” Dutch family members, who had travelled to the Cape, especially for the occasion. Mid-way through the reception, the Dutch group stood up, huddled together and started singing traditional songs from Zeeus-Vlaanderen, Holland. They each had a few pages of lyrics. This performance was to be my surprise. It was an incoherent, embarrassing musical disaster, resembling a work of aleatory rather than folk songs. They could not sing in tune nor keep to a steady beat. In fact, between them they were not singing the same songs. This did not dampen their enthusiastic performance, which continued for 20 excruciating minutes, much to the bewilderment of the remainder of the guests. The thought that crossed my mind then was: Our children have a 50% chance of being musical. The extended family performance sealed the “genetic fate” of our offspring. Years later, I keenly looked for early signs of musicality in our two children. It seemed that I had won the genetic gamble, as both children enjoyed singing from a young age and responded positively to all types of music.

In hindsight, my understanding of musicality and genetic ability was naïve.

The aim of this article is to review the rapidly growing inter- and multidisciplinary research field of music and psychology, in an attempt to explore, evaluate and understand the most recent research evidence regarding environmental and genetic influences on musicality and

musical development. The implications of the research evidence might shed light on why individuals possess different kinds and levels of musical skills, as well as the role of genetics in what our children may inherit from their parents.

Genetics and ability

What can genetic research reveal about human abilities? Is there a genetic basis for musical ability? During the Human Genome Project (1990 – 2003), geneticists aimed to identify all the genes in DNA. The first results revealed that the human genome comprised approximately 25 000 genes – 75 000 fewer than was previously believed. This means that gene interactions are more complex than considered previously and that it is unlikely that a single gene could account for psychologically complex behaviour (Passer and Smith, 2011:69).

Technological advances enabled geneticists to describe the biological structure and functions of genes, as well as providing them with the ability to change the genes themselves (epigenetics). Gene activity, however, lies behind every structure and process in the body and "behaviour reflects a continuous interplay between a biological being and the environment in which it operates" (Passer and Smith, 2011:70). In other words, the heredity of genes cannot be studied in isolation, because environmental factors influence human existence from conception. Behaviour genetics examines these influences, which may account for individual differences in behaviour. Passer and Smith (2011:71) claim that the probability of sharing any particular gene with one's parents is 50%.

Twin studies, family studies and adoption studies are used to study genetic influences in families. Results of twin studies revealed that many psychological characteristics, including intelligence, personality traits and some psychological disorders had a notable genetic trace (Bouchard, 2004). Adoption and twin studies made it possible, via statistical techniques, such as heritability estimates, to calculate the extent to which genetic differences occur. For example, the heritability of height is high. However, behaviour geneticists realise that genes and environment are not separate determinants of behaviour because they operate as a "single integrated system". Passer and Smith (2011:73) write that gene expression is influenced daily by the environment. Plomin and Spinath (2004) found that two children of equal intellectual potential might have major differences in IQs, depending on the environment in which they were raised.

Shared and unshared environment

According to Passer and Smith (2011:76), the environment is a broad term that includes everything from the prenatal stage to the complex social system we interact with. Behavioural psychologists distinguish between the terms, "shared" (our family, household, school classroom, siblings and friends) and "unshared environments" (experiences that are unique to each of us, such as distinct relationships).

The genetic factors relating to intelligence and personality have been studied and debated in great detail and, more in particular, differences in intelligence (as defined by IQ scores). Although there is strong evidence that genes play a significant role in intelligence (Plomin and Spinath, 2004), the analysis of the human genome has not conclusively proven that there is a single intelligence gene (Plomin and Craig, 2002). Genetics research, therefore, provides a convincing argument that the environment contributes significantly to intelligence (Plomin and Spinath, 2004).

The reality is that genetic factors and the environment interact with one another. Genetics may influence the way in which people experience the same environment and, the environment in turn, could influence the way in which genes express themselves. According to Passer and Smith (2011:93), genetic factors can influence the environment in three ways. Firstly, genes shared by parents and children may be expressed in the way in which the parents behave and in the environment they create. Secondly, genes may produce traits that influence others' responses. Thirdly, people may create or seek out environments that are consistent with their genetic traits.

Genetic factors in musicality

The Human Genome Project may have raised expectations that a musical gene could be identified, which could, as Sloboda (2005:312) states, help dispel a few deeply ingrained cultural myths – for instance that musical achievement depends on the pre-existence of a rare, inherited quality, called "talent", and that musical excellence grows from within. The term, "talent", in music refers to many different things, including technical instrumental expertise and creativity (Davidson & Faulkner, in press, in McPherson et al, 2012:96).

There is a growing consensus that acknowledges the term, "gifts", as innate abilities, and the term, "talent", as an observable skill (McPherson et al, 2012:94). Gagné (1985:103), however, from his research into giftedness and talent, believes that "talent" refers to superior performance, while "giftedness" corresponds to above-average potential. Gagné (2009, in McPherson et al, 2012:95) differentiates between early emerging forms of giftedness that have biological roots, and talent. "Gifts include a cluster of natural abilities, aptitudes, or potentials in various domains: four related to mental processes (intellectual, creative, social and perceptual), and two related to physical abilities (muscular and motor control)."

According to Gagné (2009), physical characteristics are indisputably inheritable, and it is known that general cognitive ability, also referred to as "g", is an inheritable behavioural trait. All kinds of variables shape the growth of individual talent, such as the impact of physical traits or states, personality and temperament.

Various cultures have a vastly different understanding of musical ability and creativity, which is deeply reflected in

ingrained societal beliefs. Hill (in Hargreaves et al, 2012: 94) writes that, in Venda society, every person is believed to have musical ability, although some are acknowledged to have more exceptional skills than others. Everyone is expected to participate in communal ceremonies, which include singing, improvising and dancing. Blacking's (1978) field-work among the Venda led him to conclude that musicality and music ability are the products of societal beliefs. The same belief system applies to notions of talent and giftedness which, in Western culture, are understood as a rare, innate musical ability (Hill, in Hargreaves et al, 2012:94).

But what is musicality? Hargreaves (2001:24) warns against formulating precise definitions around concepts like musical ability, musical aptitude and musicality, because it points to problems experienced in measuring these traits accurately. On the heritability of musical ability, Sloboda (2005:276) writes that there is not (to date) a "generally accepted psychometric measure of musical ability that has the validity and reliability of standard measures of intelligence", and that twin studies concluded that differences in musical ability correlated more strongly with IQ than with inherited factors. This view is strongly supported by Schellenberg (2011), who conclusively found a correlation between IQ, musical training and cognitive ability.

McPherson (2009:60) states that musicality comprises "physical, physiological, cognitive and dispositional traits in a complex series of interactions." Parncutt and McPherson (2002 4, 14) state that all children have musical potential, but it is a composite phenomenon involving a number of factors, including ability. They also emphasise that musical potential takes many forms and occurs at different levels and, importantly, conclude that the quality of a nurturing environment is crucial.

According to Hallam (in McPherson, 2009:104), much of the controversy surrounding musicality relates to its origins and the heritability of musicality. One debate claims that all humans have the capacity to make music and that musicality is a universal ability (Wallin et al in McPherson, 2009 104).

The other debate focuses on whether there are "genetically determined individual differences in musical ability" (McPherson, 2009:110). Pulli et al (2008:451) aimed to study the biological background of music perception, using molecular and statistical genetic approaches. Fifteen Finnish families were recruited. The results indicated that there was indeed a genetic contribution to musical aptitude. A notable limitation to the study, however, was the small sample size.

Suppose we accept that all humans have the capacity to make music as a universal ability, why then do some have superior skills, progress faster and succeed in achieving better musical skills than others?

Musical development

Researchers are yet to find consensus on what constitutes musical development and, indeed, what develops in musical development. Musical development is discussed from varying angles and theories, such as the bio-ecological systems theoretical models; theories of creativity; the generative theory; the cognitive theory; and sociological perspectives.

Sloboda (1985) claims there are two types of musical development, namely enculturation (this happens generally and without effort) and training (specialised, deliberate and focused). Deliège and Sloboda (1996) consider musical development as the development of competencies, such as singing, performance and composition. Hargreaves (1996:145) distinguishes between activities of competence, such as "singing, graphic presentation of music, melodic perception and composition".

Jeanne Bamberger (in McPherson, 2009:71) lucidly argues that musical development is a "spiraling, endlessly recursive process in which multiple organizing constraints are concurrently present, creating an essential, generative tension as they play a transformational dance with one another". She rightly points out that the learning of, and knowledge about music, could take different forms. This view acknowledges differences in human musical experiences and hearing which, in turn, influence development progress or a lack thereof, "depending on the theories to which you ascribe and the culture to which you belong" (Bamberger in McPherson, 2009:88). Furthermore, Bamberger is of the view that learning and development constitute the same thing – a "single system".

Theoretical models of musical development mostly focus on the individual and milestones reached, like Swanwick and Tillman's model of musical development (1986), involving a longitudinal study of 3 to 11 year olds. Tan et al (2011:169) explain that the findings of Swanwick and Tillman suggest an orderly sequence of musical development. The model is based on Piaget's ideas of assimilation (relating to internal meaning) and accommodation (ability to modify these systems). At specific stages in development, musical "schemes" change and adjust, which affects the child's understanding of music (McPherson, 2009:358).

Hargreaves and Galton (1992, in McPherson, 2009:359) propose a similar developmental model, based on listening and generative skills. This model differs from others in that it does not explain progress but rather describes it. Feldman (in McPherson, 2009:358) points out that all these models are based on Piaget's learning theory and none relates to the development of extreme talent in prodigies.

How musical development proceeds is still not clear. What role then does intelligence play in musicality and musical development?

The nature of intelligence

Gardner's (1982) theory of multiple intelligence (1983/1993) is the only theory to date that recognises music as an independent intelligence. Gardner believes it is possible to

learn intelligences because he acknowledges the interaction between biological and environmental factors. The theory suggests that we have a unique blend of intelligences that explain our differences and individual preferences.

Ceci et al (1990) acknowledge the importance of information processing, experience and context, and their impact on intelligence. It is interesting to me that he highlights the importance of context and motivational forces. Hallam (in McPherson, 2009:97) concludes that, according to Ceci's bio-ecological theory, ability and knowledge are fundamentally inseparable and that it is not possible to isolate cognitive potential, context and knowledge, because environmental and biological contributions and intellectual functioning are intricately interwoven and in a constant state of change.

Perkins (1995) emphasises the importance of "learning how to learn" and views intelligence from three perspectives, namely neural (intelligence with IQ), experiential (experience and knowledge) and reflective (good mental management). Perkins suggests that intelligence is based on effective learning because it leads to deep understanding, high levels of retention and the ability to apply knowledge in a range of contexts (Hallam in McPherson, 2009:98).

Sternberg (1999:359) argues that intelligence can be understood as developing expertise, which is an ongoing and fluid process of acquisition and consolidation of a set of skills. An example of this is the "Flynn Effect" (1987, cited in Sternberg 1999:366), which found an overall increase in IQ around the world throughout the 20th century. This effect must be due to environment, because major genetic changes world-wide, in such a short time span, would be impossible. The contribution of genes to one's intelligence cannot be measured directly, because human ability reflects the interaction of genetic and environmental factors. Sternberg suggests that we rather view intelligence in terms of "successful intelligence" or the ability to adapt and shape to society. Successful intelligence involves an understanding of our strengths and weaknesses and then finding ways to exploit patterns of strengths. Three broad abilities are important for successful intelligence, namely analytical, creative and practical ability (Sternberg & Kaufman, 1998:494).

In spite of various theories focusing on ability and learning, there is yet to be a fully integrated theory that takes into account the myriad of factors that contribute to expert music-making. However, musical expertise has been shown to leave imprints on the function and structure of the brain.

The musical brain

Hodges (in McPherson, 2009:53) believes that all human beings are biologically equipped to be musical and that genes and experience work together in a process called "neural pruning". Neural pruning is evidence of the interplay between nature and nurture. Genetic instruction is present in each of us, with varying possibilities, but actual experiences sculpt the brain towards its adult state.

Children are born with the capacity to learn any music genre, but the specific style depends on the culture in which they are raised. The brain regions develop at different rates and experience growth spurts. There are critical periods and optimal periods during which stimulation is necessary for normal development. Penhune (2011) reviews behavioural studies in the context of what is known about sensitive periods for musical training.

Research into musicians and brain plasticity further supports the nurture debate, in that there is overwhelming evidence that musical training changes the brain in function and structure. For this reason, neuroscientists are particularly interested in musicians, because of their potential to demonstrate neural plasticity, as well as the capacity of our nervous systems for change. According to Schlaug (in Hallam et al, 2009:198), musicians are an ideal model for studying the long-term brain effects of sensori-motor, auditory, auditory-spatial, visual motor and auditory-motor skills.

Results of fMRI (functional imaging) studies reported that musicians' brains not only had enlarged grey matter and anatomical differences that were related to the instruments they played, but also showed greater inter-hemispheric activity.

Schlaug et al (2005) examined a group of children before the onset of musical training to investigate whether there would be structural and functional differences. A large group of five to seven year old children was tested prior to music lessons. After approximately 15 months, significantly greater changes were found in the group involved in instrumental lessons, compared to the control group who received none. Not only was there an increase in grey matter (particularly the corpus callosum) in those in the instrumental group, but they also showed improved fine motor skills and auditory discrimination skills (both rhythmic and melodic).

An additional cross-sectional study of 9 to 11 year olds, with an average of four to five years of music training, compared to a group of non-musicians, indicated that instrumentalists performed significantly better in skills directly related to music training, such as fine motor skills and auditory discrimination skills. Furthermore, instrumentalists showed better verbal skills and visual pattern matching skills, as well as a significantly increased grey matter volume – particularly in the sensori-motor cortex, bilaterally. These differences were more pronounced in those with a longer duration of musical training and higher practice intensity.

Schlaug (in Hallam et al, 2009:204) concludes that music-making engages the primary auditory and motor regions in the brain, as well as regions that integrate and connect areas that are involved in both auditory and motor operations, together with integrating other multisensory information. Musicians learn through repeated practise and associate finger orhand movement with musical sound and visual patterns (notation), while receiving continuous multisensory feedback. This learning leads to structural and functional changes in the brain.

Music and intelligence

Does music contribute to intelligence and, if so, how? Schellenberg (2011 284) states that the available literature confirms that there are clear associations between music training and cognitive abilities. He holds the view that there is an association between specific cognitive performance and musical training.

In 2006, Schellenberg showed that music training was positively associated with performance in school and, furthermore, the duration of playing an instrument during childhood predicted a higher IQ in adulthood. According to Schellenberg (2011:286), his data represents the only convincing evidence that music training causes an increase in cognitive ability. The link between music lessons and cognitive ability is indirect though and, according to Hannon and Trainor (2007), possibly mediated by executive function. They point out that perhaps music lessons train attentional and executive functioning (conscious, goal-directed problem-solving), which benefits most cognitive tasks.

Schellenberg aimed to understand the association between music lessons, intelligence, cognitive abilities and executive function. In a study with musically trained and untrained 9 to 12 year olds, he compared measures of IQ and five measures of executive function. Those in the musically trained group showed higher IQs than their counterparts. However, the association between music training and executive function was negligible. These findings suggest that children with higher IQs are more likely to take music lessons and, in turn, perform better in a range of cognitive ability tests – except those measuring for executive function.

Schellenberg (2011:287) later writes that the link between music lessons and general cognitive ability is indirect and mediated by executive function which, when not working correctly, results in poor planning, unwise judgements and cognitive inflexibility. He concludes that the association between music training and executive function is not substantial, although genetics must play a substantial role in the link between music training and IQ, while genetic differences that cause differences in cognitive ability must be instantiated in the brain. Children with higher IQs are therefore more likely to take music lessons and to perform well in a variety of tests.

Environmental influences in musical development

Gembris and Davidson (in Parcutt and McPherson, 2002:20) write that environmental influence starts before birth in the conditions under which the foetus develops in the womb. Major factors in this are stress hormones, growth hormones and nutrients. Richard Parncutt (in McPherson, 2009:1) considers the possibility that musical skills are partially learnt before birth. According to Plomin and Bergeman (1991), musical ability emerges from an interaction between genes and the environment, that this process starts as soon as the foetus begins to hear, and there is substantial observational evidence that the foetus responds to musical sounds during the last three months of pregnancy. In early childhood, parents and family constitute the most important influences with regard to musical development.

According to Trehub (in McPherson, 2009:43), there is no evidence that formal music exposure or training during the early years is necessary for the highest levels of musical achievement. A supportive home environment that encourages spontaneous expression of music is important (Manturzewska, 1990; Moore et al, 2003).

Although family environment may be crucial to musical development, there are many cases of successful musicians who excelled without a nurturing family environment or formal training.

The differences in the kinds and levels of musical skills

In a study exploring the conception of musical ability from the perspective of musicians, amateur musicians, non-musicians and children, Hallam (2010 308) found that musical ability was most strongly perceived as relating to a sense of rhythm; then the ability to understand and interpret the music; expressing emotions through sound; communicating through sound; motivation to make with music; **(?)** commitment; and making music with others.

Least important were possessing technical skills; being able to compose or improvise; being able to read music; and understanding musical concepts and musical structures. This study was interesting in that most of the participants were musicians. I have often experienced people mentioning their inability to sing as a predictor of their own musical ability, and most likely followed by a story involving a music teacher at school who turned them away from the choir with a comment about being tone-deaf.

It is notable that a large body of research into musical development; musical intelligence; and music and neuropsychology, is founded in data based on the classical music field of expertise, relying on years of musical training. Even though most theoretical models of musical development can be applied to differing kinds and levels of musical skills, such as folk music, pop music, jazz and improvisation, a more convincing body of evidence needs to be developed before conclusions can be drawn about why there are differing kinds and levels of musical skills.

Research nevertheless proved that the characteristic of the environment and the frequency and duration with which a person is exposed to (listening, watching, playing), or engaged with music, determine a framework in which musical socialisation and expertise take place. Collier (1983) describes Louis Armstrong's musical development and finds five critically important factors in the latter's development, namely early and frequent exposure to musical stimuli; opportunities to explore the jazz medium over time;

intense and positive early emotional responses to music; a large number of hours of practice; and a large number of motivating role models (Parncutt and McPherson, 2002: 22).

There is growing empirical evidence for the "10-year rule", which claims that a minimum number of 10 years of dedicated practice is required in order to become an expert in any field – from music to business – and in other cognitive fields (Ericsson et al, 1993). However, in music this path to expertise is usually much longer, requiring constant development and maintaining of skills. Furthermore, paradoxically, musical expertise is not necessarily determined by the quantity of practise hours, but also by the quality of practise. The development of musical expertise involves a great deal of focus, motivation and effort over many years (McPherson and Williamon, in McPherson, 2009: 244).

Conclusions

This article aimed to review literature in psychology and music in an effort to understand the role of genetics in the heritability of musicality. It also aimed to understand the impact of studies of related concepts, such as genetic factors in musicality; musical development; the musical brain; the nature of music and intelligence; as well as environmental influences on musical development and how these impact on the development of musical skills. No doubt each of these topics is complex and worthy of an individual article.

Mcpherson (2009:106) concludes that evidence from studies of genetics suggests that it is unlikely that there are single genes responsible for any complex behaviour, including musicality and musical ability. Behaviour rather depends on complex interactions between a range of skills and experiences. We may actually never know to what extent musical ability is inherited or learnt.

Therefore, I need not have worried about the family genes. Even if this were the case, I do not know exactly what the genetic constitution of either of our families is – there are no musicians in either. There are a variety of factors, which research has proven to be conducive to optimal musical development and which may have contributed to my children's "musicality". However, neither of them pursues music seriously and social and informal music drives their musical engagement.

At the recent International Conference for Music Perception and Cognition (ICMPC) held in Thessaloniki, Greece (July 2012), Schellenberg stated that new evidence on the role of personality in musical and cognitive ability needed to be more seriously considered. Perhaps Virginia Penhune (2011:1126) manages to summarise the nature-nurture saga most succinctly when she writes: "… [T]he striking individual differences in our skills and talents, along with the underlying structural and functional differences in our brains, are the outcome of a long-term interaction between pre-existing genetic make-up and experience".

It seems to me that genetics plays a marginal role in the heritability of musical ability, although exactly how much has not been discovered yet. Musical development is a non-linear dynamic process, in constant interaction with the shared and unshared (internal) environment, guided to a degree by our genetic make-up, and possibly more substantially by personality. Musical development is also fuelled by many constantly interacting factors, such as drive, motivation, family, parenting, teachers, teaching processes, peers, community, choice of instrument, musical style, lifestyle and health.

No doubt our understanding of musical development, ability and the role of genetics will grow as theories of genetics, intelligence, development and musical development evolve. Suffice to say that, as parents, we need to know that the links between music training and cognitive functioning are well documented (Schellenberg, 2011: 285). But, more importantly, that we must not limit our children's activities, musical or otherwise, based on erroneous beliefs about heritable characteristics and "talent".

Bibliography

Bamberger, J. 2009. What develops in musical development? In McPherson, G. *The child as musician: A handbook of musical development.* Oxford: Oxford University Press, 69-93.

Berk, L.A. 2003. *Child development*. Sixth edition. New York: Allyn and Bacon.

Bouchard, T.J. 2004. Genetic influence on human psychological traits. *Current Directions in Psychological Science*, 13, 148-151.

Ceci, S.J., Ramey, S.L. and Ramey, C.T. 1990. Framing intellectual assessment in terms of person-process-context model. *Educational Psychologist*, 25, 269-291.

Deliège, E. and Sloboda, J. (Eds). 1996. *Musical Beginnings: Origins and Development of Musical Competence*. Oxford: Oxford University Press.

Deary, I.J., Spinath, F.M. and Bates, T.C. 2006. Genetics of intelligence. *European Journal of Human Genetics*, 14, 690-700.

Ericsson, K.A. (Ed). 1996. *The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games.* Mahwah, NJ: Lawrence Erlbaum Associates.

Gagné, F. 1985. Giftedness and talent: Reexamining a reexamination of the definitions. *Gifted Child Quarterly*, 29, 103-113.

Gardner, H. 1982. *Art, mind and brain*. New York: Basic Books.

Gembris, H. and Davidson, J. Environmental Influences. 2002. In Parncutt, R, and McPherson, G. *The science and psychology of performance: Creative strategies for teaching and learning*. Oxford: Oxford University Press, 17-30.

Hallam, S., Cross, I. and Thaut, M. 2009. *The Oxford Handbook of Music Psychology*. London: Oxford University Press.

Hallam, S. 2010. 21st Century conceptions of musical ability. *Psychology of Music*, July, 38, 308-330.

Hargreaves, D., Miell, D. and MacDonald, R. (Eds) 2012. *Musical imaginations: Multidisciplinary perspectives on creativity, performance and perception*. Oxford: Oxford University Press.

Hodges, D.A. The musical brain. In McPherson, G. 2009. *The child as musician: A handbook of musical development*. Oxford: Oxford University Press, 53-64.

Human Genome Project Information. http://www.ornl.gov/sci/techresources/Human_Genome/home.shtml. [Accessed 8 January 2012]

Lamont, A. 2009. Music in the school years. In Hallam, S., Cross, I. and Thaut, M. *The Oxford Handbook of Music Psychology*. London: Oxford University Press, 235-252.

Lehmann, A.C., Sloboda, J. and Woody, R.H. 2007. *Psychology for Musicians: Understanding and acquiring the skills*. Oxford: Oxford University Press.

McPherson, G. 2009. *The child as musician: A handbook of musical development*. Oxford: Oxford University Press.

McPherson, G., Davidson, J.W. and Faulkner, R. 2012. *Music in our lives: Rethinking musical ability, development and identity*. Oxford: Oxford University Press.

Milovanov, R. and Tervaniemi, M. 2011. The Interplay between musical and linguistic aptitudes: a review. *Frontiers in Psychology*, 2, 1-6.

Parncutt, R. Prenatal development. In McPherson, G. 2009. *The child as musician: A handbook of musical development*. Oxford: Oxford University Press, 1-27.

Parncutt, R, and McPherson, G. 2002. *The Science and Psychology of Performance: Creative strategies for teaching and learning*. Oxford: Oxford University Press.

Passer, M.W. and Smith, R.E. 2011. *Psychology: The science of mind and behaviour*. Fifth edition. New York: McGraw Hill.

Penhune, V.B. 2011. Sensitive periods in human development: Evidence from musical training. *Cortex*, 47, 1126-1137.

Plomin, R. 2003. Genetics, genes, genomics and g. Guest Editorial. *Molecular Psychiatry*, 8, 1-5.

Plomin, R. and Bergeman, C.S. 1991. The nature of nurture: Genetic influence on 'environmental' measures. *Behavioural and Brain Sciences*, 14, 373-427.

Plomin, R. and Petrill, S.A. 1997. Genetics and intelligence: What's new? *Intelligence*, 24 (1), 53-77.

Plomin, R. and Spinath, F.M. 2004. Intelligence: Genetics, genes and genomics. *Journal of Personality and Social Psychology*, 86, 112-129.

Pulli, K., Karma, K., Norio, R., Sistonen, P., Göring, H.H.H. and Järvelä, I. 2008. Genome-wide linkage scan for loci of musical aptitude in Finnish families: evidence for a major locus at 4q22. *Journal of Medical Genetics*, 45, 451-456.

Schellenberg, E.G. 2011. Examining the association between music lessons and intelligence. *British Journal of Psychology*, 102, 283-302.

Schellenberg, E.G. 2006. Long-term positive associations between music lessons and IQ. *Journal of Educational Psychology*, 98, 457-468.

Schlaug, G. Music, musicians and brain plasticity. 2009. In Hallam, S., Cross, I. and Thaut, M. *The Oxford Handbook of Music Psychology*. London: Oxford University Press, 197-207.

Sloboda, J. 2005. *Exploring the musical mind: Cognition, emotion, ability, function*. Oxford: Oxford University Press.

Sternberg, R.J. and Kaufman, J. C. 1998. Human abilities. *Annual Review Psychology*. 49:479-502.

Tan, S.L., Pfordresher, P. and Harré, R. 2010. *Psychology of Music*. New York: Psychology Press.

Trehub, S.E. 2009. Infants as musical connoisseurs. In McPherson, G. *The child as musician: A handbook of musical development*. Oxford: Oxford University Press, 34-49.

Wallin, N., Merker, B. and Brown, S. 2000. The origins of music. Cambridge, MA: The MIT Press. In McPherson, G. (2009). *The child as musician: A handbook of musical development*. Oxford: Oxford University Press.

Williamon, A. 2006. *Musical Excellence: Strategies and techniques to enhance performance*. Oxford: Oxford University Press.

Wolff, U. L. 2001. Choral unit standards and support material for primary schools in South Africa. DMus thesis, University of Pretoria.