# Neuroscience meets music education: Exploring the implications of neural processing models on music education practice

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# Neuroscience meets music education: Exploring the implications of neural processing models on music education practice

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### Abstract

Over the past two decades, neuroscientists have been fascinated by the way the brain processes music. Using new technologies, neuroscientists offer us a better understanding of the human brain's structures and functions. They have further proposed explanatory models for how the brain processes music. While these models shed light on how the brain functions, they have yet to make an impact on the field of music education where skills in music processing are a central concern. This article examines the implication of one music-processing model on music education practice. This conceptual study consisted of: 1) transforming the model to make it accessible to music educators, and 2) comparing the model with the experience of learning and teaching music. The study found that there were identifiable connections between Koelsch's model of music processing and the lived experience of music learning. These connections could inform future curriculum design and practice in music education.

### Keywords

music, music education, music processing, neuroscience

The process of music education often reminds me of trying to unravel a tangled extension cord, or if you prefer, a hopelessly tangled necklace. Either metaphor illustrates the point. It is a combination of logically and methodically unraveling knots as well as pulling instinctively on different sections until a serendipitous event causes a number of knots to unravel at once. When I am teaching music, whether it is in a classroom or music ensemble, to adults, teenagers or young children, I find myself combining these two approaches to untangling music understanding. Yet I am never quite certain when the methodological or serendipitous approaches might work, but somehow I continue to watch my students reach the state of an unraveled extension cord or ready to wear necklace. This state is where they exhibit a level of musical understanding indicative of an

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independent musician, able to continue their musical development unassisted by me because they possess all the tools to do so themselves. As Eisner (2002) put it, ‘education is a process of learning how to become the architect of your own experience and therefore learning how to create yourself’ (p. 24). My question is: *If I knew more about how music processing occurs, could I assist my students to reach that state of musical independence more effectively?*

This article will outline a conceptual study of the implications of a model of music processing on music education practice. This model was initially developed by neuroscientists Koelsch and Siebel (2005) and later revised by Koelsch (2011). The study aimed to explore if the Koelsch model could contribute new or notable knowledge to the field of music education and music pedagogy. The study was preliminary in nature and as such was closely linked to my personal pedagogical practices. Ethnographic techniques were utilized to create exemplars to translate neuroscientific concepts into the music education field. The study aimed to identify future directions for conceptual and practical research between the fields of neuroscience and music education.

## Context

*Neuroscience meets music.* During the past two decades, neuroscientists have been using music in a multitude of ways to understand how the brain’s structures and functions operate and develop. As Zatorre (2005) explained,

> … listening to and producing music involves a tantalizing mix of practically every human cognitive function. Even a seemingly simple activity, such as humming a familiar tune, necessitates complex auditory pattern-processing mechanisms, attention, memory storage and retrieval, motor programming, sensory–motor integration, and so forth. (p. 312)

Music literally ‘lights up’ the brain like no other human activity and neuroscience has shown that while some activities such as reading or solving mathematic problems used discrete areas of the brain, listening and creating music engaged multiple areas of the brain, either simultaneously or in intricate, interrelated and astonishingly fast sequences (Hyde et al., 2009). There are significant differences between listening to music and producing music, and consequently these two activities diverged into different areas of enquiry. In this article, I will focus on brain activity that occurs when listening to music.

Initially, researchers examined how the brain processed single elements of music such as pitch, rhythm, and tone color (Fujioka, Trainor, Ross, Kakigi, & Pantev, 2004; Pantev, Roberts, Schulz, Engelien, & Ross, 2001; Peretz, 2006; Tervaniemi, 2009). With this as a research base, neuroscientists then moved onto researching how multiple musical elements were processed (Peretz & Zatorre, 2005; Strait & Kraus, 2011; Tervaniemi et al., 2009). Finally, complete models of music processing were proposed (Koelsch, 2011; Koelsch & Siebel, 2005; Peretz & Zatorre, 2005; Peretz et al., 2009).

Closely connected to the field of music processing research is the field of language-processing research. This connection comes from the discovery that music processing is closely intertwined with language acquisition and processing. Although this premise was heavily debated at the beginning of the period of research in the 1990s, current research (Patel, 2003, 2008, 2009, 2012; Schon, Magne, & Besson, 2004, Wong, Skoe, Russo, Dees, & Kraus, 2007) strongly indicates that music processing and language processing are more than just complimentary cognitive functions. As Koelsch (2011) put it, ‘the human brain, particularly at an early age, does not treat language and music as strictly separate domains, but rather treats language as a special case of music’ (p. 16). Consequently models in music processing display significant integration of music and language processing.

Two of the pioneering music processing models are the *Musical Lexicon* (Peretz, Gosselin, Belin, Zartorre, Plailly, & Tillmann, 2009) and the *Neurocognitive Model for Music Perception* (Koelsch, 2011; Koelsch & Siebel, 2005). Both models share a close connection between music and language processing, Peretz et al. (2009) placing this as a connecting function of music processing, while Koelsch (2011) connects language processing to every step of his model. Both models detail how the brain dissects the musical elements from the complete piece of music, examines them, categorizes them and examines them again as part of the whole. Both models also highlight the physical reactions, both physiological and behavioral, that music processing creates.

These two models are based on two decades of research findings that are now being replicated and verified through a number of different research studies. These models are neither preliminary nor definitive, but they may be based on a sufficient research base to warrant attention from music educators.

*Neuroscience meets music education.* In 2000, Donald Hodges, Director of the Music Research Institute at the University of North Carolina, assembled a panel of four neuroscience experts to discuss the current findings about music and the brain. Late in the discussion he asked the panel what they thought music educators should know about the neuroscientific research. They discussed the implicit musical knowledge we are born with and the possibility of building on that knowledge, the value of music training on healthy aging and the possibility that musicality is genetically determined. These comments, while interesting, would probably not have had any measurable impact on the practice or pedagogy of a music educator. In the year 2000, it was too soon to begin examining the implication of neuroscience on music education.

Four years later, at the XXVIth ISME International Conference in Spain, Gruhn (2004) put forward a compelling position that we do not know enough within the field of neuromusical research to start making pedagogical decisions and that at that time it was too much of a leap to begin trialing pedagogical changes. Only four years later, Gruhn and fellow researcher Rauscher's (2008) thoughts on the connections between neuromusical research and music pedagogy had advanced considerably. In the preface to their book of collected essays on the topic of the neurosciences and music pedagogy, they highlighted that brain research has 'attracted growing interest [from music educators] because it can explain, support and ground pedagogical common sense on empirical data' (p. vii). While this statement indicates a refining of the reasoning behind why music educators should examine the possible impact of neuromusical research on music pedagogy, the question remains, how can music educators access and use brain research, including the emerging models of music processing?

A number of barriers exist to both the access and use of brain research by music educators to support and advance their music pedagogy. The first is the ability to understand the research findings and models, as neuroscience is generally outside the typical expertise of a music educator. This lack of access creates further barriers to the application of these findings and models to music pedagogy. This conceptual study aimed to address both of these barriers by first translating a model of music processing proposed by Koelsch (2011) using terminology and examples that a typical music educator could access, and then to comparing the model to the lived experience of music learning.

## Purpose

The purpose of this conceptual study was to explore if and how Koelsch's (2011) model could contribute new or notable knowledge to the field of music education and music pedagogy. As part of a larger doctoral study, the music processing models by Peretz et al. (2009), Koelsch

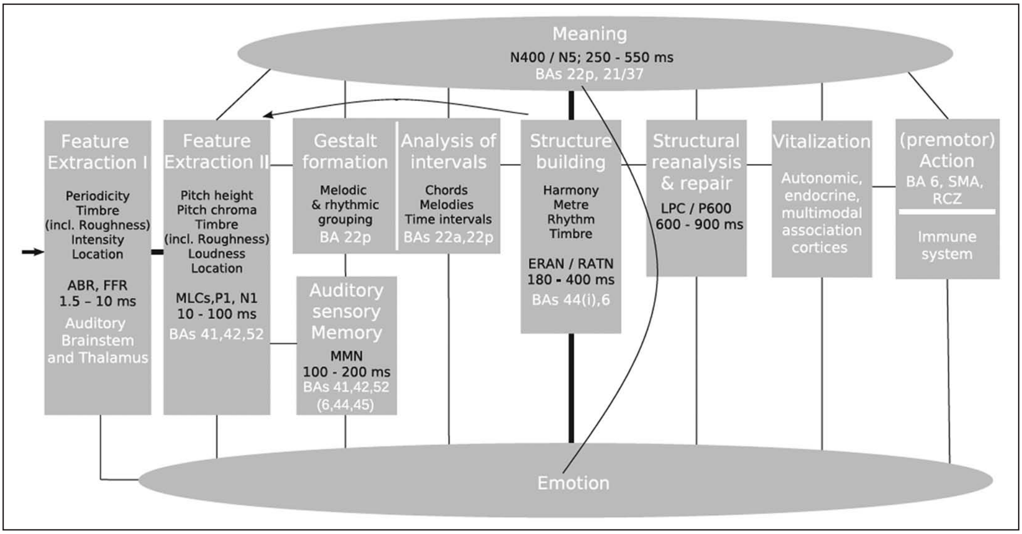


**Figure 1.** Neurocognitive model for music perception (Koelsch, 2011).

(2005) and Koelsch & Siebel (2011) were examined for their possible impact on music education practice. The latter model was chosen for further conceptual study due to its lineal structure, currency and the level of detail available concerning the various elements of the model. The conceptual study consisted of translating the model from the neuroscientific language into music education language, using appropriate examples and nomenclature. The translated model was then compared against established music education pedagogy and methodologies to reveal any commonalities. Finally, implications of the findings were explored in light of future research and development directions.

## *Approach*

Koelsch and Siebel first proposed the Neurocognitive Model for Music Perception in their 2005 paper for *Trends in Cognitive Sciences Journal*. The model was based on research on the neural functions and brain structures that are associated with the different aspects of music processing. Essentially, Koelsch and Siebel integrated multiple results from brain research regarding the structural components of music processing into a coherent model of music perception based on the neural brain conditions. In 2011, Koelsch revisited the model in light of the research findings that had emerged in the intervening 6 years. While the basic model remained largely unchanged, the level of detail and supporting research had increased significantly. One of the most significant developments was the deeper understanding of the close relationship between music processing and language processing (see Figure 1).

The key features of the Koelsch model are the largely sequential left to right progression of the stages of music processing with the consistent reference to the meaning and emotional content of the information being processed. In broad terms, these are the areas of the brain that are involved in the perception of music from the first contact to the higher levels of perception (see Table 1).

Throughout these steps, the brain is constantly referring to and creating meaning and emotion from the information it is processing. Research into memory encoding and retrieval has shown that

**Table 1.** Broad stages of the Koelsch (2011) model.

| | | |
|---|---|---|
| Stage 1 | Feature extractions I & II | Extract the different features of the music that are basically perceived (e.g. periodicity, timbre and localization of sound) |
| Stage 2 | Gestalt formation, auditory sensory memory, analysis of intervals, structure building, and structural reanalysis and repair | Structural grouping and conceptualizing according to already remembered patterns |
| Stage 3 | Vitalization and premotor actions | Physical reaction, bodily movements, for example tapping one's foot and feeling good when listening to the music |

the emotion related to an experience can significantly affect the meaning that is created (Hamann, 2001; Otani et al., 2011). The memories are used as a reference for the next time we hear and process a piece of music. Peretz et al. (2009) coined the term *Musical Lexicon*, or our brain's dictionary for musical knowledge, to describe this part of the process.

Upon initial examination, Koelsch's model would mean little to a music educator as it is largely in the language of neuroscience. In order for a music educator to gain an understanding of the model, the language would need to be altered. The process of translating the model into language that a music educator could relate to involved two steps. The first was to understand each area of Koelsch's model from a neuroscientific perspective and then devise a musical example that would encapsulate the area in question. It is important to acknowledge that this translation only highlights the broad strokes of Koelsch's model. The purpose of the translated model was to enable music educators to access and understand this model through their own nomenclature. In the translated model every effort was made to provide a clear and concise example of an extremely detailed neuroscientific concept (see Figure 2).

The translated model was designed to visually resemble Koelsch's (2011) model as closely as possible. However, the model in its current state does lack an element of aesthetic appeal, which would have an impact on the intended audience of musicians, both performers and educators. For the purposes of this paper, the model has remained faithful to the aesthetic qualities of the scientific model. However, important for future development of the model would be the modification of the aesthetic qualities in order to create the greatest impact on the intended audience.

## *Findings & discussion*

Once the translation was completed, there was a moment of pause. In fact, I paused for several weeks to contemplate the translation. The steps of music processing seemed obvious, when I thought about my own process of understanding music; I could see how I followed one step with the next. In my training as a performance musician and ensemble conductor, I processed music using these steps, and in my teaching of upper secondary school students, I used these steps to teach musical analysis. Where was the new understanding that I thought neuroscience might bring to my teaching practice?

Another issue to contend with was the transference of the neuronal structure of music perception outlined in Koelsch's model, which is a sequence of events within the brain (left to right), to the process of music education, which is a series of scaffolded learning experiences across years of educational development (bottom to top). Any comparison between the two models seemed impossible, and any attempt to create connections could be problematic and inaccurate. Again, it did not

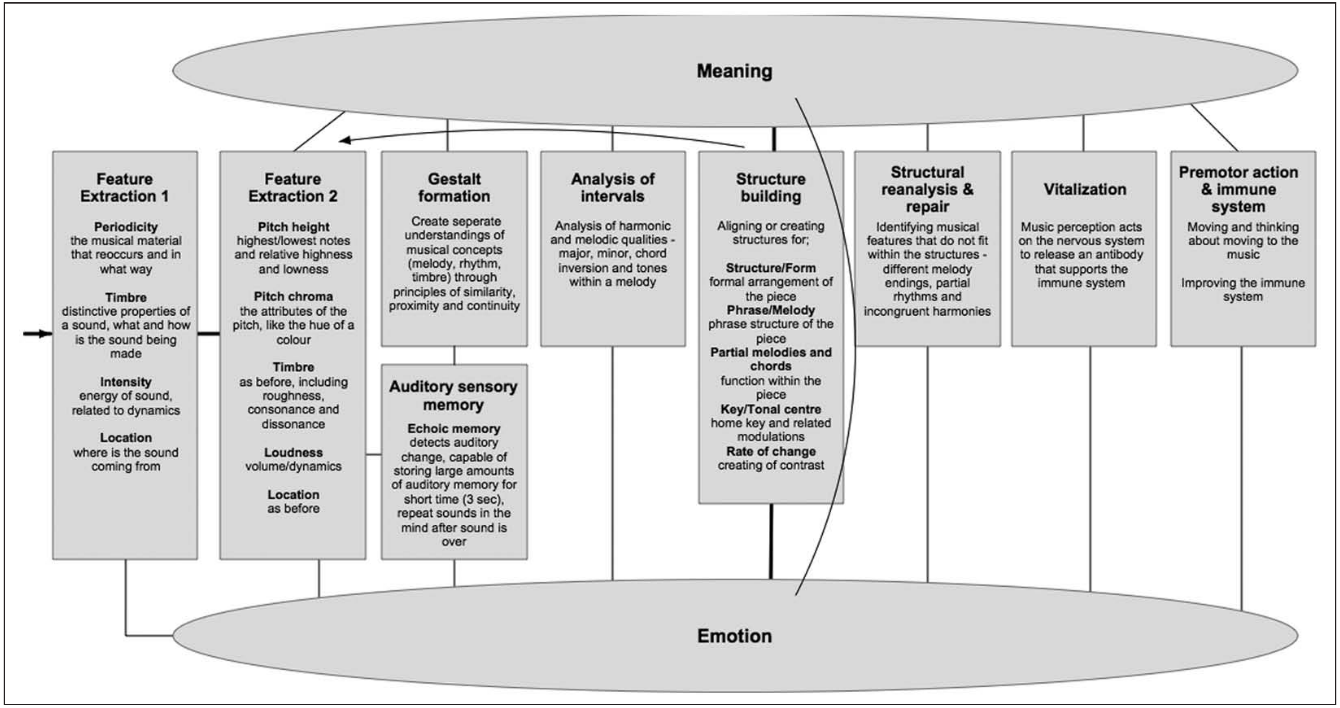


**Figure 2.** Author translation of the neurocognitive model of music perception (Koelsch, 2011).

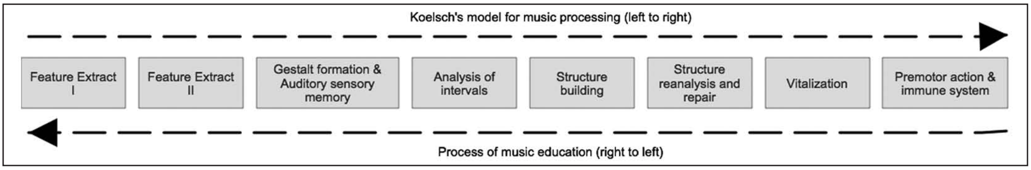


**Figure 3.** Music processing and music education.

seem that this model of music processing might not be able to shed any light on my practice as a music educator.

After some frustration I approached the translated model using the Ockham's razor principle: all things being equal the simplest answer is often the right one. At this point I also began to think of music teaching experiences other than musically advanced secondary school students and professional performers. I began to look of the learning experiences and associated methodologies and pedagogies of young children and pre-service generalist teachers learning about music education. Both groups shared a limited knowledge of music and music was not as significant a part of their lives as it was for the advanced or professional musicians.

Finally, it dawned on me. Koelsch's model worked from left to right, starting with the extraction of features and ending with bodily movement. Advanced musicians can articulate those steps explicitly using musical language. But when we begin music education with young children, or with pre-service teachers who are not highly musically-trained, we work with the model from right to left. *We work backwards*. We begin with bodily movement and embrace the positive physiological effects of music first and from this point we build musical understanding and language. This model shows us how our brain, common to every human being, processes music. We do not need musical training to complete the music processing procedure; every brain has the capacity to do it subconsciously. Through music education, we endeavor to make music processing a conscious experience and develop the student's understanding and vocabulary to express musical concepts. I spend my entire professional life working to make the subconscious become conscious, the metacognition of music processing (see Figure 3).

However, this revelation did not account for the fundamental differences between the two models. Koelsch's model worked from left to right as a sequence of brain structures involved in music processing. My practice as a music educator worked from bottom to top by scaffolding a series of learning experiences throughout a student's educational development. I would consider a student who was able to articulate all the processes outlined in Koelsch's model a highly developed and independent musician. If they were able to listen to, perform or create a piece of music and identify all of the individual features, how the features interacted and furthermore contributed to the piece as a whole, then that student would possess all of the skills and conceptual understandings to be an independent musician. A student with these abilities could continue their own musical development beyond the music classroom, recognizing where and how to seek assistance from experts.

I realized that this was the level of musicianship I aimed to equip my students with by the time they completed their secondary school music education. Indeed, on occasion I had seen it emerge well before they completed secondary school. So Koelsch's model had revealed possible connections between the sequence of structures that the brain uses to process music and the series of scaffolds that I used in music education to assist students to become independent musicians. Therefore to relate Koelsch's model to music education and music practice, it not only worked backwards but also from bottom to top (see Figure 4).

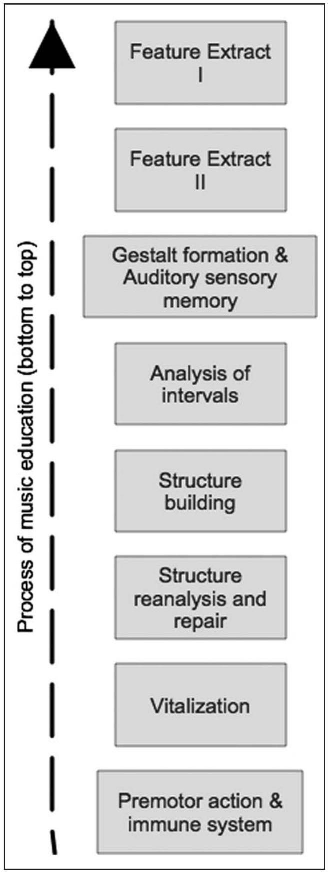


**Figure 4.** Development of musical independence.

At this point I had to marvel at the human brain. I was struck at how quickly music processing occurs in the brain. When listening to music with both children and adults, it only takes one to two bars for feet to start tapping or hands to start clapping. This means that subconsciously they have dissected, identified patterns, compared it to what they already know and reassembled the music in a matter of seconds. This process of metacognition is both complex and extremely rapid.

In order to explore these connections further, I set about comparing the music processing sequence from Koelsch's model with established music education pedagogies and methodologies as well as my own teaching experience. As I worked from right to left on the translated model, I compared the types of conscious music processing abilities with two areas: the age groups and educational levels I had observed these cognitive developments in children and the teaching methodologies that are commonly used. These comparisons were made with the Australian education context of mind, which is similar in many respects to the educational contexts in other Western education traditions found in the UK, US and Canada. These can be seen in Figure 5.

In my experience in music teaching, I had observed the **Premotor action**, **Immune system**, and **Vitalization** steps occurring in early childhood and lower primary classroom. These steps appeared to encompass many of the foci and practices that existed in the established methodologies of Orff, Kodaly and Dalcroze. Moving to music, whether it is prescribed or freeform, is a foundation of these methodologies. It is also the most natural and easy way to express an understanding of music

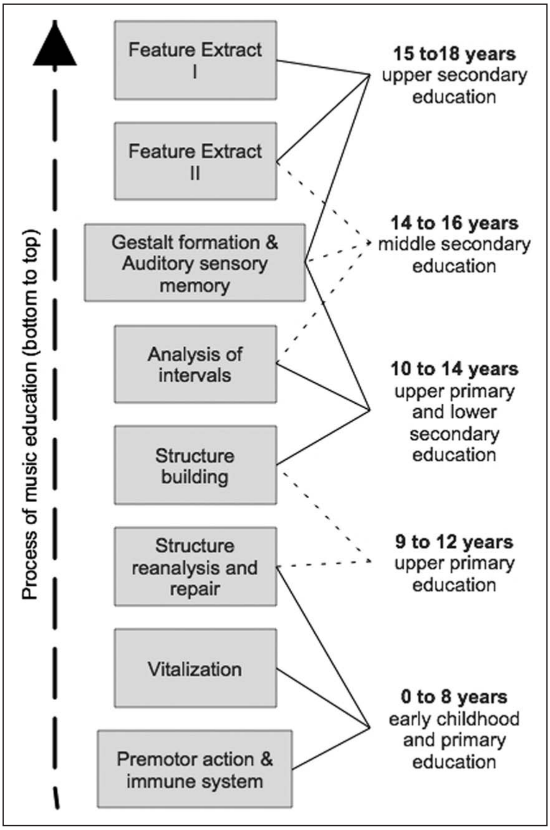


**Figure 5.** Mapping development in stages in music education.

explicitly. Orff believed that students should physically experience beat, meter and rhythmic patterns from the very beginning, and express that understanding through dancing and playing musical instruments (Anderson & Lawrence, 2007). Dalcroze used body movement to develop rhythmic concepts associated with pulse, meter, and rhythm (Constanza & Russell, 1992) and believed that 'the entire physical system is almost unconsciously controlled by the brain in response to the dictates of musical rhythm' (Walter, 1959). Callen (1985) proposes that movement is encourage as the first expression of music in the Orff and Kodaly methods because it is 'a mode of developing psychological dispositions to recognize and respond to patterns of tension, suspense, and relaxation which characterize the rhythms, harmonies, melodies, and cadences in the music' (p. 47). The use of movement has proved successful through these methodologies as a way of opening a child's mind to understanding music in a conscious manner.

**Structural reanalysis and repair** is essentially the ability to identify *same* and *different*. In my experience with programming for middle and upper primary school classes, many of my activities focused on increasing the student's sensibility to, and recognition of, this very aspect of music. This focus also exists in the methodologies of Kodaly, Orff and Dalcroze, and increases in complexity as students develop their musical skills and vocabulary. Countless method books outline music activities such as 'the students use simple body signs, for example, touch shoulders for high sounds and waist for low sounds' (Houlahan & Tacka, 2007, p. 147). This elementary activity allows students to physically express when they hear differences in pitch and naturally leads onto more complex and refined understandings.

The natural progression from the reanalysis and repair step in my programs was towards **Structure building.** This is the very essence of a middle school (or upper primary/lower secondary) music education program. To build on the skills of identifying *same* and *different* elements of music, students begin to flesh out the structures of music. The following script could be some typical responses from a student at this level of music processing.

Teacher: *What can you tell me about the structure of this song?*
Student: *I can hear it has an introduction, this sort of introduced all the instruments and the beat, then when the singer comes in it is the start of the verse. The song is about travelling. Then there is a chorus, you can tell because it repeats the name of the song a lot…*
Teacher: *And how about the melody in the verse?*
Student: *It kind of goes in two sentences, the first one goes up and then the second goes down. I think it ends on the same note it starts on.*
Teacher: *Does the song keep going the same way until the end?*
Student: *No, it gets a bit boring so they all start singing and playing higher. It is like it goes up a step.*

There is a basic level of musical vocabulary and the student is able to identify the type and location of changes in the music. This marks the ability to separate the different musical concepts from the whole and distinguish changes in these separated parts. In addition to the logical analysis of music, the affective and personal interpretation is equally important. The conversation may continue like this.

Teacher: *Do you like this song?*
Student: *Yeah I liked it. I can hear where the next phrase is going to start and that means I know where the music is going.*

Music education has given the student the ability to not only make a personal judgment about the music, but to understand some of the music elements that contribute to that judgment. The response was not just 'yes, I like it' or 'no, I don't' but rather a qualified statement. In my experience, this marks a significant shift in a students' music-processing ability.

Many of the pre-service generalist teachers I work with, the majority of whom have elementary levels of music education, struggle to identify the difference between a subjective and objective analysis of music. It is only when they gain a grasp of the structures of music that they can exhibit the same type of analytical thinking as the student in the script.

The ability to build musical structures, and vocabularies for each, then allows deeper and more specific music processing to occur. Typically in my experience, lower secondary music education contains exercises in melodic dictation, rhythmic transcription and simple harmonic analysis. These are all elements of the **Analysis of intervals** process. I might explain this to my students using a metaphor; the ability to see the whole bowl of noodles and pick out just one or to see a bunch of clean clothes and expertly retrieve the particular top you want to wear (Collins, 2009). It is at this stage of music processing that the philosophical discussion concerning the central purpose of music comes to the fore. Within a curriculum, learning activities concerning the dissection of music into its smallest parts run the risk of losing the understanding of music as a whole. Consequently the concept of music as 'aesthetic education' (Swanwick, 1979) can be lost. Put another way, it is the reverse approach suggested by Peters & Miller (1982) for creating music-meaning which is the 'result of perceiving and reacting aesthetically to the formal and technical qualities of musical objects' (Swanwick, 1979, p. 28). In Koelsch's model, this would be a focus on the process of 'Analysis of intervals' with a disregard for the close and consistent reference to meaning and emotion of the music. This holistic approach is reiterated by Swanwick (1996) who contends that the principles for music educators should be to 'care for music as conversation, care for the autonomy of students, teaching for expressiveness and promoting fluency before literacy' (p. 16). Mirroring Koelsch's model some 15 years later, Swanwick compares this final point, the ability to make music before reading it, with language development and the ability to speak before we can read.

The only two processes that happen simultaneously in Koelsch's model are **Gestalt formation** and **Auditory sensory memory**. Gestalt is most commonly defined as *a whole that is larger than the sum of its parts*. In musical terms this is the understanding of how the interaction and intersection of the musical parts creates a large artistic entity. This step in the music processing sequence embodies the concept of aesthetic education as well as the intrinsic value of music education described by Reimer: 'the value of the experience comes from its own, intrinsic, self-sufficient nature' (1989, p. 103). Interestingly, it is my experience that Gestalt formation occurs in the middle- to upper-secondary years of music education. In Australia, this is generally when Music becomes an elective subject in the curriculum, meaning that compulsory music education ends when students are in the **Structure building** or **Analysis of intervals** stages of music processing. How might this impact on the levels of aesthetic education within general society? How might the levels of aesthetic education influence other social and economic areas of society? These questions may benefit from closer examination in light of other neuroscientific discoveries around the intellectual, social and health benefits of music training.

**Auditory sensory memory** is the mechanism that allows us to replay sounds in our mind. From an evolutionary perspective, it is also called echoic memory, namely the ability for the brain, while we are sleeping, to identify sounds in case they are of danger to us. Put another way, when a tree branch breaks a window on a windy night, our echoic memory wakes us to alert us to possible danger. When we wake, we replay the sound in our minds to help us identify what has happened.

In explaining this concept to my students, I refer to it as *audiation* or *inner hearing*. Kodály believed strongly in cultivating this skill through his method, 'we should read music in the same way that an educated adult will read a book: in silence, but imagining the sound' (Kodály, 1954, p. 204). He believed the development of inner hearing led to musical independence as well as the ability to compose. The development of this skill is vital throughout music education, and leads to, among other things, the ability for students to compose their own music. It is this step in the music processing sequence that interests neuroscientists as advanced musicians have been found to have significantly better memory skills (Dunbar, 2008; Jonides, 2008; Tillmann, 2009), through the development of their auditory sensory memory.

**Feature Extraction I & II** are the final two steps in the music processing sequence. These require a high level of music vocabulary and skill in order to complete, such as the knowledge of how a bassoon sounds different from a clarinet or why accents change the meter of a bar. It is both the end and the beginning of music processing, and when it is a conscious process, it marks a base of musical skills that enables for independent lifelong learning in music. In my experience this occurs during the final years of secondary school and sometimes into tertiary music education. As a music educator it is the 'ah-ha' moment when I step back and feel confident that the student can process the music, with all of its parts and meanings, on their own. In our current educational system and pedagogical paradigms, this can take some 18 years to reach.

By comparing the translated model to my own understanding of music pedagogy and experience with young, adolescent, and adult learners, I was able to find a number of connections.

Primarily, this conceptual study made the process of musical understanding, as I had understood and experienced it, more explicit for a music educator. Secondly, it challenged and clarified my thinking about the possibilities and limitations of taking a model based on neuronal structures created without music education in mind with established music education practices and pedagogies. Connections are possible and new understandings could be gained from such comparisons, but the fundamental differences between the experiment methods and research intentions of the two fields must remain at the forefront of any investigation.

## Conclusions

This study has revealed what was both implicit and explicit. Music processing is a natural and automatic function of the brain and acts in both a sequential and holistic manner. It provides a new layer of understanding for music educators and supports many of the tenants of current music education methodologies. It also prompts questions about how we sequence and structure music-learning experiences for students and how the cognitive development of music-education progresses. As a music educator, the model shows how I facilitate the process of metacognition and where the pitfalls between processing and practice can exist. It will also lead to a greater focus on ways I can create greater integration and connections between the music-processing steps. The extension cord is still tangled, and will always be so, but this study has given me a Gestalt view of my practice as a music educator; I can see both the parts and whole more clearly.

This conceptual study showed that the findings in the neuroscientific field may have progressed far enough to inform music education practice. This new view of the music-processing sequence has influenced my concepts of curriculum design and strengthened the need to reference meaning and emotion at every point of the process. It is important when translating research findings and models from neuroscience language into music educators' language to maintain the authenticity, currency, and whenever possible the complexity of the findings. It is also vital to recognize, and where possible, reconcile, the differences between such models. Koelsch's model is not a model of or for music education; it is an integration of multiple research studies on the structural brain components that have been observed to contribute to music processing. However, it is a model that contributes a new view of the way human beings process music, and that makes it part of the field of music education as well as neuroscience. Gruhn and Rauscher's (2008) concluding comments highlight the need for research communities to 'do a better job of making its [neuroscience] methods and results comprehensible and accessible to music teachers, school administrators, and parents' (p. 277). This conceptual study contributes to that need and could provide the basis for practically-based research connecting neuroscience and music pedagogy. The future relationship between these two fields needs to be continually mapped and refined. Neuroscience may not fundamentally alter music pedagogy but 'the information coming from the neurosciences certainly can provide a more informed basis for the decisions we make in our schools and classroom' (p. 278).

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### Author biography

Anita Collins is an Assistant Professor in Music and Arts Education at the University of Canberra. Anita teaches and researches both within the fields of music and arts education as well as the application of arts pedagogy, teaching and learning strategies and concepts across disciplines including nursing education, neuroscience, leadership and boys' education. Anita has been a Visiting Fellow at the Australian National University and completed her PhD study through the University of Melbourne in 2013.

## Abstracts

### *Une rencontre entre les neurosciences et l'éducation musicale: explorer les implications des modèles de traitement neuronal dans la pratique de l'enseignement de la musique*

Au cours des deux dernières décennies, les chercheurs en neurosciences ont été fascinés par la façon dont le cerveau traite la musique. En utilisant de nouvelles technologies, les chercheurs en neurosciences nous offrent une meilleure compréhension des structures et des fonctions du cerveau humain. Ils ont également proposé des modèles explicatifs de la façon dont le cerveau traite la musique. Bien que ces modèles mettent en lumière la façon dont le cerveau fonctionne, l'impact sur le domaine de l'éducation musicale où les compétences dans le traitement de la musique sont encore une préoccupation centrale. Cet article examine les implications d'un modèle de traitement de la musique (Koelsch & Siebel, 2005; Koelsch, 2011) sur la pratique de l'enseignement de la musique. Cette étude conceptuelle propose 1) une adaptation du modèle pour le rendre plus accessible aux enseignants de musique et 2) une comparaison du modèle avec l'expérience d'apprentissage

et d'enseignement de la musique. L'étude montre qu'il y a des liens identifiables entre le modèle de Koelsch de traitement de la musique et de l'expérience vécue de l'apprentissage de la musique. Ces liens pourraient éclairer la conception des curriculums futurs et les pratiques en éducation musicale.

## *Neurowissenschaft trifft Musikpädagogik: Eine Untersuchung der Auswirkungen neuronaler Prozesse auf die musikpädagogische Praxis*

Im Laufe der vergangenen zwei Jahrzehnte waren die Neurowissenschaftler fasziniert von der Art und Weise, wie das Gehirn die Musik verarbeitet. Mit Hilfe neuer Technologien vermitteln uns die Neurowissenschaftler ein besseres Verständnis der Strukturen und Funktionen des menschlichen Gehirns. Sie haben darüber hinaus Erklärungsmuster dafür vorgelegt, wie das Gehirn Musik verarbeitet. Während diese Modelle die Funktionsweisen des Gehirns erhellen, geht von ihnen bereits eine Wirkung auf den Bereich der Musikerziehung aus, wo Fähigkeiten in der Verarbeitung von Musik von zentralem Interesse sind. Dieser Artikel behandelt die Auswirkungen eines bestimmten Modells der Verarbeitung von Musik (Koelsch& Siebel, 2005; Koelsch, 2011) auf die Praxis der Musikerziehung. In dieser Untersuchung geht es 1) um die Umformulierung des Modells, um es für Musikpädagogen zugänglich zu machen und 2) um die Betrachtung des Modells im Vergleich mit der Erfahrung des Lernens und Lehrens von Musik. Die Studie ergab, dass es deutlich erkennbare Zusammenhänge zwischen Koelschs Modell der Verarbeitung von Musik und der lebendigen Erfahrung des Musiklernens gibt. Diese Zusammenhänge könnten künftigen Lehrplänen und der Praxis der Musikpädagogik als Grundlage dienen.

## *Encuentros de la Neurociencia con la Educación Musical: Una exploración de los modelos de procesamiento neuronal en la práctica de la educación musical*

En las dos décadas pasadas nos neurocientíficos han estado fascinados por la manera en que el cerebro procesa la música. Gracias al uso de nuevas tecnologías, los neurocientíficos nos ofrecen una mejor comprensión de las estructuras y funciones del cerebro humano, y nos proponen modelos de cómo el cerebro procesa la música. Aunque estos modelos arrojan luz sobre cómo funciona el cerebro, aún tienen que influir en el campo de la educación musical, donde las habilidades para el procesamiento de la música son una preocupación central. Este trabajo examina las implicaciones de un modelo de procesamiento musical (Koelsch & Siebel, 2005; Koelsch, 2011) en la práctica de la educación musical. El estudio conceptual consistió en: 1) la transformación del modelo para hacerlo accesible a los educadores musicales, y 2) la comparación del modelo con la experiencia de aprendier y enseñar música. En el estudio se vio que había conexiones identificables entre el modelo del procesamiento musical de Koelsch y la experiencia vivida de aprender música. Estas conexiones pueden proporcionar información importante para futuros diseños curriculares y para la práctica en educación musical.