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From Neuromyth Towards Neuroscience

- Prevalence and Predictors of Music-related Neuromyth embedded in Pre-service Music Teachers -

신경계 신화에서 신경과학으로

– 예비음악교사들의 음악 관련 신경계 신화 수준과 예측요인을 중심으로 –

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Abstract

From Neuromyth Towards Neuroscience

- Prevalence and Predictors of Music-related Neuromyth Embedded in Pre-service Music Teachers -

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For several decades, the development of neuroscience has changed the paradigm in various disciplines. In the field of education, a new academic discipline named educational neuroscience has emerged and attempts have been made to integrate two different categories, education and neuroscience. In musicology, an interdisciplinary approach entitled neuroscience of music has amplified the role of the psychology of music in terms of understanding the human brain, which generates and appreciates music. With this background, music teachers need to acquire proper knowledge about the brain and its mechanisms. However, false beliefs based on inaccurate knowledge of the brain, namely neuromyths, were made in the process to integrate neuroscience and other fields of study. More seriously, these misconceptions among teachers are being applied to teaching methods with adverse results.

In order to avoid this undesirable situation from an early stage of training teachers, this study investigated the degree of neuromyth among pre-service music teachers, based on three topics: general knowledge of the brain, educational neuroscience, and neuroscience of music. A total of 132 pre-service music teachers participated in the survey and their degree of neuromyth was compared with the survey result of additional 210 general college students.

As a result, only half of statements (23 out of 46) were correctly answered by more than 50% of the participants. Both pre-service music teachers and general college students showed lower scores in 'educational neuroscience' and 'neuroscience of music' compared to 'general knowledge of the brain'. Based on the signal detection theory, sensitivity analysis showed a neuromyth / neuroscience discrimination ability of sensitivity index $d' = 0.41$ ($SD = 0.81$) for pre-service music teachers and $d' = 0.07$ ($SD = 0.68$) for general college students, respectively. Though both groups were not able to distinguish neuromyth statements from neuroscience statements, pre-service music teachers seemed more able than general college students. Discrimination ability was found to be markedly poor in music-related statements. In addition, both groups showed a tendency to evaluate the statements as scientifically proven (pre-service music teachers: response bias $c = -0.56$; general college students: $c = -0.41$). A lower degree of neuromyth among the participants was predicted by higher level of awareness about the importance of knowledge of the brain in music education and the educational experience related to the brain ($R^2 = 0.10$).

The results of this study indicate that educational programs for pre-service music teachers can be the best way to raise the awareness of the importance of understanding the workings of the brain in music education and to promote their neuroscience-literacy. Pre-service music teachers should be warned that their misunderstandings of the brain can lead to invalid teaching methods. Also, they should be trained to discriminate the myths from scientific facts by acquiring neuroscientific knowledge. In addition, brain-related education should be provided to pre-service music teachers and the gap between music education and neuroscience needs to be lessened through communication among scholars of neuroscience, education, and music.

Keyword: neuromyth, pre-service teacher, neuroscience of music, educational neuroscience, brain
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Table of Contents

List of Tables

List of Figures

CHAPTER 1. INTRODUCTION

With growing interest in human brain, there have existed many attempts to apply the brain-related knowledge to the field of education; these attempts led to the emergence of educational neuroscience, which is a new interdisciplinary study of neuroscience and education, and also a new educational paradigm, known as brain-based education (Carew & Magsamen, 2010; Jensen, 2008). Both of these fields aim to make a more effective educational environment through the application of studies of the brain to education (Carew & Magsamen, 2010).

The attempt to apply the brain / neuroscience knowledge in education can also be found in the field of music education. In fact, the question of how the human brain and music are related is not a recent issue; since the 19th century, phrenologists believed that the extraordinary musical abilities of great musicians such as Franz Joseph Haydn (1732-1809) may have originated from special areas in their brains. With the development of neuroimaging techniques such as functional magnetic resonance imaging (fMRI) in the early 1990s, neuroscientists began to actively study the way the brain appreciates and makes music, along with the effect of music on the brain. Consequently, neuro-musical research has emerged and become a popular area of research among neuroscientists.

In recent years, the neuro-musical research results have been incorporated into the field of music education research and educational practice by music educators. These attempts assume that neuro-musical research can support the work and goals of music teachers and their students (Curtis & Fallin, 2014). Additionally, the neuroscience paradigm based on scientific evidence can suggest a new perspective on the value of the music education that has been only considered within the philosophical or aesthetic frame.

Even though many studies on the brain have been done in the education field, there are practical difficulties in infusing neuroscience into education. Generally, in neuroscientific research on humans, a small number of people had participated and the experiments are carried out in a strictly controlled environment. Therefore, there exists a gap between the experimental conclusions of experimental studies and its practical adoption in the real classroom (S. W. Park, 2016). The difficulty also stands in the field of music education; the aesthetic or artistic value of music that has been emphasized in musicology may serve as a barrier to the scientific approach rather than emotional approach to music education. In addition, most neuro-musical research focused on a small number of professional musicians and intensive instrumental training, it is therefore difficult in generalizing the results to the regular school classes.

Most of all, the greatest obstacle to the application of brain-related knowledge in an educational setting is concerned with the misunderstandings and misconceptions of the brain. The integral approaches towards the relationship between education and neuroscience often lead to mistaken beliefs related to the brain. The inaccurate knowledge about the brain was named neuromyth by the Brain and Learning project of the Organization for Economic Co-operation and Development (OECD) in 2002. Since then, neuromyth has been receiving great attention from around the world (Geake, 2008; Willingham, 2006). Misinterpretation or rash generalization of neuroscientific research injures the original purpose of educational neuroscience and brain-based education, which is to improve students' educational environment by understanding the brain.

Music-related neuromyths spreading in the field of music education also make it difficult to apply the results of neuro-musical research to music education. For example, the Mozart effect (Chabris, 1999; Jakob Pietschnig, Martin Voracek, & Anton K. Formann, 2010; Rauscher, Shaw, & Ky, 1993) is one of the most typical neuromyth related to music; in 1993, Rauscher and colleagues investigated the effects of listening to Mozart's music on spatial reasoning (Rauscher et al., 1993). The spatial reasoning scores (as measured by spatial reasoning sub-tasks of the Standford-Binet IQ test) of participants were improved after listening to Mozart’s sonata for two pianos in D major, K. 488. Even though it was proved that only Mozart’s sonata K. 488 affected the improvement of the spatial reasoning in a short period, its misinterpretation and over-generalization gave rise to this neuromyth. After that, prenatal and child education using Mozart's music became prevalent all over the world (Bangerter & Heath, 2004). The music-related neuromyth, the *Mozart effect*, is still believed in many educational settings.

Likewise, neuromyths are widespread in music educational settings. Also, music education is thought to be sensitive to these neuromyths because misunderstanding of the brain among music teachers can result in the wrong musical experience of students. Thus, neuromyth is an important issue within the field of music education; it is essential for music teachers to have a clear and correct knowledge of music and the brain to supply a more effective environment of music education through applying neuroscientific research. Despite the importance of this application, there are few studies dealing with neuromyths related to music. Additionally, there are limited studies on the paradigm of neuroscientific research in the field of music education, especially in South Korea.

Being conscious of this problem, the present study made two new attempts. First, the empirical identification of neuromyths embedded among pre-service music teachers was conducted. The research that identifies the pre-service music teachers' level of knowledge of the brain can be used as significant basic data to prevent the misconception about the brain from being applied indiscriminately to the music educational settings. Second, the results of neuro-musical research were considered in the frame of music education. This promotes a clear understanding of the results of neuro-musical research as well as suggests new possibilities for combining the two disciplines of music education and neuroscience.

1.1. Purpose of Study

The purpose of the present study was to correct mistaken knowledge about music and the brain which is prevalent in the field of music education, based on an original integral approach towards the relationship between music education and neuroscience.

First, the current study was intended to investigate how pre-service music teachers perceived the importance of understanding the brain in music education, and to evaluate the prevalence and predictors of the neuromyths among them. Furthermore, their degree of neuromyth was compared to those of other ordinary college students.

Second, based on the literature of the neuro-musical research, this study aimed to provide a clear understanding of the relationship between music and the brain, based on a literature review of the neuro-musical research. For this purpose, existing studies in neuroscience, cognitive psychology, educational psychology, and music psychology were collected and the effects of learning music on the human brain were examined. Additionally, the current study drew implications of these results for music education.

The current study finally suggests the possibility of applying brain research to the field of music education, both in research areas and real educational practices, and by presenting a new perspective, based on the scientific basis of neuroscientific research, on the necessity of music education.

1.2. Theoretical Framework

The current study is an attempt to consider music education through a paradigm of neuro-musical research. With increasing interest in music and the brain, many music educators have attempted to derive implications for neuroscience research in the field of music education (Bott, 2014; Collins, 2012, 2013, 2014a, 2014b; Curtis & Fallin, 2014; Edwards, 2008; Edwards & Hodges, 2007; Flohr, 2010; Habib & Besson, 2009; Hodges, 2000, 2010; Iusca, 2011; Peterson, 2011; Pike, 2011; Stewart & Williamon, 2008). However, in research of music education in Korea, it is difficult to find such new attempts.

Studies on the neuromyth are also very rare. In recent years, studies that confirmed the belief of teachers and pre-service teachers in neuromyths have been actively conducted (Dekker, Lee, Howard-Jones, & Jolles, 2012; Deligiannidi &

Howard-Jones, 2015; Gleichgerrcht, Lira Luttges, Salvarezza, & Campos, 2015; Herculano-Houzel, 2002; Karakus, Howard-Jones, & Jay, 2015; Kelly, Laura, Alida, Joanna, & Lauren, 2017; Marietta, Eleni, & Filippos, 2017; Pei, Howard-Jones, Zhang, X., & Jin, 2015; Rato, Abreu, & Castro-Caldas, 2013). A study of music-related neuromyth was first carried out by Düvel and colleagues (2017), examining neuromyths related music for music teachers and music students.

In South Korea, discussions about neuromyth have been taking place in general education (Howard-Jones, 2013; Kim, 2006). However, these are a very limited number of studies, identifying neuromyths in the field of education by using an empirical method, is quite small; Park and colleagues (2016) attempted to identify neuromyths embedded in pre-service teachers, but such empirical studies to evaluate the prevalence of neuromyths among teachers and students are especially rare. Furthermore, there are no studies that verify music-related neuromyths in Korea. Therefore, based on neuroscience studies on music and the brain, and neuroeducational studies on neuromyth, the present study aims to empirically evaluate the prevalence and predictors of music-related neuromyth embedded in pre-service music teachers and general college students.

1.3. Research Questions

The present study has addressed the following research questions to verify neuromyths in music education and as well as to provide clear knowledge about music and the brain. Furthermore, the current study has attempted to derive the implications of neuro-musical research in music education. The specific research questions are as follows:

1. Can neuro-musical research contribute to music education?
    1-1. Do pre-service music teachers and general college students think that knowledge of the brain helps to learn or to teach music?
    1-2. What are the neuro-musical research implications in the field of music education?
2. How much knowledge about the brain do pre-service music teachers and general college students have?
3. How much knowledge about the neuroscience of music do pre-service music teachers and general college students have?
    3-1. What kind of statements are neuromyths related to music?
    3-2. What could be the predictors of music-related neuromyths among pre-service music teachers and general college students?

The principal hypothesis for the present study is that misconceptions about music and the brain are embedded in pre-service music teachers as well as general college students. So far, the question of the value and significance of music has been addressed in the philosophical or aesthetic point of view. This leads to the assumption that pre-service music teachers do not have many opportunities to gain an accurate knowledge of music and the brain. Additionally, neuroscience is a very specific field, and it is difficult for non-experts to understand the terminology, methods, and results of research. However, the topic of the human brain always fascinates people and makes them have a strong mistaken belief about the brain.

For this reason, it seems that the pre-service music teachers believe neuromyths about music, started from ignorance or blind faith.

1.4. Definition of Terminology

1.4.1. Neuro-musical Research

Neuro-musical research is a new interdisciplinary study of neuroscience and music. It is also called cognitive neuroscience of music, music neuroscience, and so on. This study refers to the study of the complex relationship between music and the brain as *neuro-musical research*.

In *neuro-musical research*, musical stimulus involves listening, performing, composing, and reading music. The researchers observe what happens in the brain during these musical activities. It is also studied how musical training affects the development of the human brain.

The present study attempts to collect previous *neuro-musical research* and clarify the effects of music on the human brain. To this end, the results of *neuro-musical research* are classified according to eight subjects: (1) musical aptitude, (2) music processing, (3) intelligence, (4) transfer effect, (5) music and language, (6) music, body, and brain, and (7) brain plasticity.

1.4.2. Neuromyth

The term *neuromyth* was first used by neurosurgeon Alan Crockard to refer to non-scientific beliefs related to the brain in the medical field in the 1980s (Crockard, 1996; Howard-Jones, 2014). Later, in 2002, the Brain and Learning project, which was promoted by the Organization of Economic Co-operation and Development (OECD) in the UK, sparked international attention for *neuromyth*. OECD redefined the term *neuromyth* as 'misconception generated by a misunderstanding, a misreading or a misquoting of facts scientifically established (by brain research) to make a case for use of brain research in education and other contexts' (OECD, 2002). In previous studies on *neuromyth* (Dekker et al., 2012; Deligiannidi & Howard-Jones, 2015; Gleichgerrcht et al., 2015; Herculano-Houzel, 2002; Karakus et al., 2015; Kelly et al., 2017; Marietta et al., 2017; Pei et al., 2015; Rato et al., 2013), the term *neuromyth* was used only in a restricted range of education.

In the present study, however, *neuromyth* is used to describe the broader concept that contrasts with neuroscience, beyond the field of education, and defined as 'non-scientific belief in the brain'. Moreover, it is distinguished from ignorance of the brain. And by extension, music-related *neuromyth* is defined as 'mistaken belief in the relationship between music and the brain that has not been scientifically substantiated by the neuro-musical research'.

1.4.3. Pre-service Music Teachers

Previous studies on neuromyth have focused on teachers, while some studies have been carried out on pre-service teachers. Pre-service teachers refer to people in preparation for qualification to teach at public or private schools.

In the present study, *pre-service music teachers* who participated in the survey consisted of both students majoring in elementary education and students majoring in secondary education. Students in the college of music who are taking a course in teaching also participated in the survey.

CHAPTER 2. PREVIOUS SCHOLARSHIP ON NEUROMYTH, NEUROSCIENCE, AND BRAIN PLASTICITY

This study aims to contribute to the transition from neuromyth towards neuroscience by investigating the prevalence of music-related neuromyth among pre-service music teachers and general college student and providing accurate knowledge of music and the brain. Therefore, previous studies were reviewed for a clear distinction between neuromyth and neuroscience related to music. The statements of the questionnaire used in this study were selected based on this literature review. Neuromyths in general education and music education will be reviewed and a review of research findings in the neuroscience of music, or neuro-musical research will follow. And then, a review of brain plasticity induced by music will be addressed in detail to discuss effects of music education with scientific evidence.

2.1. Recent Studies on Neuromyth

2.1.1. Educational Neuromyths: Definition and Instances

In the education field, issues of the brain are easy to mislead not only for students but also teachers. This often leads to the spreading of false beliefs about the brain, called neuromyth. Many teachers and educational specialists want to improve and enrich educational practice by applying neuroscientific research findings what they have read in the popular press (OECD, 2002). Furthermore, these neuroscience studies are commercialized as brain-based learning tools (OECD, 2002). However, in fact, it is very difficult for educators who do not have specialized knowledge of the brain to fully understand the results of neuroscientific research. Therefore, the expectations of the application of brain research to educational practice and misconceptions about the brain rapidly spread neuromyths.

As the risk of this phenomenon increased in the field of education, OECD (Organization of Economic Co-operation and Development), in 2002, drove the Brain and Learning project to promote understanding of the brain in the educational community. OECD (2002) defined the term neuromyth as 'misconception generated by a misunderstanding, a misreading or a misquoting of facts scientifically established (by brain research) to make a case for use of brain research in education and other contexts'. Typical examples of neuromyth in the education field include: (1) VAK learning style, (2) hemisphere dominance, (3) enriched learning environments, (4) critical periods, and (5) transfer effect.

VAK Learning Style. This neuromyth is based on the premise that learning could be improved if children were classified and taught according to their preferred learning style (Dekker et al., 2012). The VAK learning style model is a learning method that provides information in one of the visual, auditory, and kinesthetic forms. It claims that students have a particular preference for the sensory modalities (visual, auditory, or kinesthetic) and they learn better when receiving information in that sensory forms.

This misconception originated in research finding that visual, auditory, and kinesthetic information is processed in different parts of the brain (Dekker et al., 2012). Gilmore and colleagues (2007), however, denied the classification according to a VAK learning style, indicating that since these different parts of the brain are strongly interconnected and cause cross-modal activation, it is incorrect to assume that only one sensory modality is involved with information processing (Dekker et al., 2012). In addition, some studies have shown that children do not process information more effectively when learning according to their preferred learning style (Coffield, Moseley, Hall, & Ecclestone, 2004; Geake, 2008; Kratzig & Arbuthnott, 2006). Students may have preferences for the sensory modality, but there is no scientific basis to support the statement that they learn better when they receive information in that sensory forms. Although the validity and effectiveness of the visual-auditory-kinesthetic learning style have not been scientifically proven, students are still classified and educated according to the VAK learning style in educational practice.

Hemisphere Dominance. Besides the VAK learning style, there is another neuromyth that oversimplifies the learning style in the education field. It is a false belief that there are left- and right-brained learners. This is the most prevalent misconception among the public and can be traced back to a clinical study by Sperry (1968). To reduce seizures in epileptic, Sperry (1968) severed their corpus callosum, the bundle of nerves that connect the left hemisphere and the right hemisphere. He investigated the lateralized functions of the left and right hemispheres through the patients' 'split-brains' and found that the linguistic functions are dominant in the left hemisphere and spatial functions are dominant in the right hemisphere. Later, it was found that Broca's area which plays a significant role in speech production and Wernicke's area which is involved in the comprehension or understanding of language are located in the (most commonly) left cerebral hemisphere. Such the theory of brain lateralization, the tendency for some neural functions to be more dominant in one hemisphere than the other, has been widely accepted by public as a false dichotomy that the left hemisphere is thought to be involved in logical, analytical thinking, language and number, while right hemisphere plays a key role in intuitive insight, creativity, and artistic sense. And this led to a false belief that there are more logical people using the left brain more dominantly and more artistic people using the right brain more dominantly.

However, humans do not use one side of the brain more dominantly over the other. Nielsen and colleagues (2013) measured the functional lateralization of the brains of 1,011 people and found no evidence that people used one brain hemisphere dominantly. The participants, in fact, used their entire brain equally, thus the researchers demonstrated the lateralization is a local rather than a whole-brain (Nielsen et al., 2013). There is considerable evidence to refute this neuromyth. Many studies showed that two halves of the brain are not exactly alike and work together (Singh & Boyle, 2004; Walsh & Pascual-Leone, 2003). Therefore, the dichotomous idea of classifying people into 'left-brained' or 'right brained' is wrong and applying it to education is particularly dangerous.

Enriched Learning Environments. Another example of a neuromyth is a fallacy that an enriched environment promotes a child's brain development. This neuromyth seems to have come from the laboratory experiments with rodents. Several studies have shown that the synaptic density of rats increases with the addition of a complex environment (Barbro & Pavel, 2002; Diamond et al., 1987; Jess & Anthony, 2006). In this case, a complex environment was defined as a cage with other rats and toys to play – crowded enriched condition. Rats in enriched environments showed increased synaptic density and performed the learning tasks better than control group lived in poor or isolated environments. However, there is a leap in interpreting these results as promoting brain development in a complex environment. Considering the natural environment rats live in, they live in stimulating environments with drainage pipes, water-fronts, and so on (OECD, 2002). Therefore, it would be more appropriate for the rat studies to show that restricted environments can inhibit their brain development.

Furthermore, it is the result of the laboratory experiment with rats, so cannot be directly related to the development of the human brain. Although few parallel neuroscientific studies showed the effect of enriched or isolated environment on the development of human brain, there are researches which showed the effects of stimuli-deprived environments on the inhibition of human brain rather than the effects of enriched environments on the development of human brain (Rutter et al., 2007). O' Connor and colleagues (1999), who studied Romanian orphans, found that there could be ill effects of severely restricted environments, but even in these cases, rehabilitation is possible. Moreover, the determination of a term 'enriched environment' in learning is subjective and there are too many factors to take into account when defining what an enriched environment.

Critical Periods. The public tends to believe that there is a critical period in which something cannot be learned after a certain age in childhood (S. W. Park et al., 2016). For a long time, the issue of critical periods in biological development has drawn lots of educators as well as neuroscientists. This is a misconception that began with studies of the visual system of animals. Wiesel and Hubel (1963) found that if visual stimulation was denied in kittens within the first 3 months of life, they were not able to restore their sight. Later, in 1977, Hubel and colleagues (1963) confirmed that enucleation shortly after birth can inflict permanent eye damage in monkeys. However, the research results of sensitive periods for cat vision are not always consistent and it is far too risky to generalize for humans from the animal studies. Also, the studies of kittens and monkeys are about a particular biological event – the development of primary sensory – so they cannot be applied to learning in humans.

Of course, in humans, some particular abilities can be better acquired in the early years of life. For example, grammar learning and second language acquisition are thought to occur best during early stages of life (DeKeyser, 2000; Jia, 2008; J. S. Johnson & Newport, 1989; OECD, 2002). Thus, some scholars suggested the use of the term 'sensitive period' (Knudsen, 2004) or 'optimal period' (Werker & Tees, 2005) rather than 'critical period'. The term 'critical period' implies that if the time frame for a biological milestone is missed, the opportunity is lost (OECD, 2002). 'Sensitive period', on the other hand, implies that the time frame for a particular biological marker is important but necessary in the achievement of a particular skill (OECD, 2002). Education at an early age is highly important for human. However, the plasticity in the human brain, which refers to the characteristics of lasting change in the brain depending on experience or training, occurs throughout an individual's life course. So, it is not necessary that learning must be concentrated into the early childhood years.

Transfer Effect. The neuromyth for transfer effect was considered what caused commercial brain-based programs such as Brain Gym to be prevalent. Brain

Gym, also known as educational kinesiology, claims that repeating certain simple physical movements such as crawling, yawning, making symbols in the air, and drinking water integrate and repattern the brain, and it can lead to improving educational outcomes for children (Goldacre, 2010; Hyatt, 2007). The neuromyths related to transfer effect include such ideas as “exercises that rehearse co-ordination of motor-perception skills can improve literacy skills” and “short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function”. However, many studies have emphasized that the ideas like this, which form the basis of Brain Gym are not supported by evidence and are pseudoscience (Denton, 2011; Goldacre, 2010; Howard-Jones, 2007, 2014; Hyatt, 2007; McCall, 2012).

According to Adrian and colleagues (2010), it is possible to increase specific cognitive abilities through training, but this does not lead to an improvement in other cognitive abilities not being trained. In other words, far-transfer does not happen easily. Perkins and Salomon (1988) also said that unlike low road transfer, which occurs with automated techniques – without special awareness, high road transfer requires a conscious process of applying abstract knowledge or principle, that was learned before, to new situations and tasks.

2.1.2. Prevalence and Predictors of Neuromyths among Teachers

Since the neuromyth was first put on the table in the OECD (2002), studies have more recently been done on the prevalence of neuromyths among teachers in some countries. In 2012, beginning with the study conducted by Dekker and colleagues (2012) on teachers from the United Kingdom and the Netherlands, several studies on neuromyth embedded in teachers took place in Portugal (Rato et al., 2013), Turkey (Karakus et al., 2015), China (Pei et al., 2015), Greece (Deligiannidi & Howard-Jones, 2015; Marietta et al., 2017), Latin America (Gleichgerrcht et al., 2015), Korea (S. W. Park et al., 2016), and the United States (Kelly et al., 2017) – in the U.S. research, not only teachers but also the public participated in the neuromyth survey and the survey was conducted amongst people from all over the world. The participants of each study were presented in Table II-1.

Table II-1

A summary of the neuromyth literature: Participants

#	Paper	Nation	Group	N	
1	Dekker et al. (2012)	United Kingdom	primary school teachers Secondary school teachers	137	242
		Netherlands	Other teachers	105	
2	Rato et al. (2013)	Portugal	Preschool – High school teachers	583	
3	Karakus et al. (2015)	Turkey	Primary school teachers	124	278
			Secondary school teachers	154	
4	Pei et al. (2015)	China	Primary school teachers	238	
			Secondary / high school teachers		
5	Deligiannidi & Howard-Jones (2015)	Greece	Primary school teachers	102	217
			Secondary school teachers	109	
			Both type of school	6	
6	Gleichgerrcht et al. (2015)	Latin America	Teachers from Argentina	551	3,451
			Teachers from Chile	598	
			Teachers from Peru	2,222	
			Teachers from other Latin American countries (Mexico, Nicaragua, Colombia, Uruguay)	80	
7	Park et al. (2016)	Korea	Pre-service teachers of elementary school	269	521
			Pre-service teachers of middle school	252	
8	Marietta et al. (2017)	Greece	Pre-service teachers	573	
9	Kelly et al. (2017)	countries across the globe, including the U.S.	General public	3,045	3,877
			Educators	598	
			High neuroscience exposure	234	

The survey was conducted online or offline and the researchers presented a questionnaire about general knowledge of the brain and educational neuromyth to the participants. The participants were asked to evaluate the statements by selecting one of three options: ‘correct (agree)’, ‘incorrect (disagree)’, and ‘do not know’.

The most prevalent of neuromyths identified by nine studies were (1) “Individuals learn better when they receive information in their preferred learning style (e.g., visual, auditory, kinesthetic)”, (2) “Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners”, (3) “Short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function”, (4) “Exercises that rehearse co-ordination of motor-perception skills can improve literacy skills”, (5) “Environments that are rich in stimulus improve the brains of pre-school children”. Especially, the statements related to VAK learning style and hemisphere dominance were being misunderstood by so many teachers in all research. Table II-2 showed the statements in which almost or more than 50% of the participants in each study had misconceptions.

Table II-2

A summary of the neuromyth literature: Prevalence of neuromyths among teachers in nine different international contexts

	Percentage of teachers who believe in neuromyth (% / Rank)									
Literature #	1		2	3	4	5	6	7	8	9
Nations	UK	NL	PT	TR	CN	GR	LA	KR	GR	US, etc.
Individuals learn better when they receive information in their preferred learning style (e.g., visual, auditory, kinesthetic).	93 (2)	96 (1)	50 (2)	97 (1)	97 (1)	97 (1)	90 (2)	97 (1)	94 (1)	82 (2)
Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners.	91 (3)	86 (2)	-	78 (4)	71 (6)	71 (4)	73 (5)	81 (3)	55 (6)	48 (9)
Short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function.	88 (4)	82 (3)	-	72 (5)	84 (4)	56 (6)	77 (4)	-	37 (15)	86 (1)
Exercises that rehearse co-ordination of motor-perception skills can improve literacy skills.	78 (5)	63 (4)	-	56 (8)	79 (5)	72 (3)	86 (3)	77 (4)	78 (3)	77 (3)
Environments that are rich in stimulus improve the brains of pre-school children.	95 (1)	56 (5)	-	86 (2)	89 (3)	97 (1)	92 (1)	86 (2)	90 (2)	37 (10)
Children are less attentive after consuming sugary drinks, and/or snacks.	57 (7)	55 (6)	-	43 (11)	62 (7)	48 (8)	51 (9)	-		49 (8)
It has been scientifically proven that fatty acid supplements (omega-3 and omega-6) or other medications have a positive effect on academic achievement.	69 (6)	54 (7)	10 (7)	79 (3)	14 (19)	50 (7)	71 (6)	-	54 (7)	-
There are critical periods in childhood after which certain things can no longer be learned.	33 (9)	52 (8)	-	67 (6)	14 (19)	24 (15)	68 (7)	52 (6)	48 (9)	20 (16)
We only use 10% of our brain.	48 (8)	46 (9)	30 (4)	50 (9)	59 (8)	45 (9)	61 (8)	48 (8)	47 (10)	27 (12)

Note. The wording of neuromyth statements used above was taken from the study by Dekker et al. (2012). Higher values indicate strong beliefs in each myth. The shaded cells represent the response as more than 50% of incorrect answers.

These studies also investigated that what factors predicted discrimination performance for neuromyth / neuroscience statements in the participants. The researchers analyzed the variables predicting neuromyths. For example, the following predictor variables were entered: age, gender, type of school, general knowledge about the brain, reading scientific journals, in-service training, and so on. Predictors of neuromyths varied from study to study. However, general knowledge of the brain predicted neuromyths in three studies (Dekker et al., 2012; Gleichgerrcht et al., 2015; Marietta et al., 2017). The predictors of neuromyths in each study were presented in Table II-3.

Table II-3

A summary of the neuromyth literature: Predictors of neuromyths

#	Predictor variables	Predictors of neuromyths	***B*** **(SE)**	***β***	***p***	**Adjusted** R^2
1	Country (UK / NL), Age, Gender, School type, Reading popular science magazines, Reading scientific journals, In-service training, General knowledge about the brain	General knowledge about the brain	0.240 (0.071)	0.24	$p < 0.001$	0.089
2	Area of expertise, Educational stage, Years of experience as teacher, Geographical region of teaching	None of the factors predicted neuromyths				
3	-	-	-	-	-	-
4	-	-	-	-	-	-
5	-	-	-	-	-	-
6	Age, Years of experience as teacher, General knowledge about the brain	General knowledge about the brain	$r = 0.21$		$p < 0.001$	0.45
7	Age, Gender, School type, Helpfulness of brain knowledge, Brain education, General knowledge about the brain, Knowledge about brain plasticity, Media, Newspaper, Internet, Scholarly article, Book	Gender	-0.184 (0.075)	-0.108	$p < 0.05$	0.178
		School type	-0.174 (0.070)	-0.108	$p < 0.05$	
		Helpfulness of brain knowledge	0.128 (0.050)	0.110	$p < 0.01$	
		Knowledge about brain plasticity	0.218 (0.031)	0.306	$p < 0.001$	
		Media	0.179 (0.071)	0.108	$p < 0.05$	
		Scholarly article	0.324 (0.127)	0.108	$p < 0.05$	
8	Graduate status, University, Number of books, Reading of popular science, Error score on general knowledge of the brain	Error score on general knowledge of the brain	-	0.34	$p < 0.001$	0.07
9	Neuroscience exposure, Science career-related media exposure, age, gender, education level	A few neuroscience courses	-	-0.153	$p < 0.001$	0.148
		Many neuroscience courses	-	-0.187	$p < 0.001$	
		Reading peer-reviewed scientific journals	-	-0.175	$p < 0.001$	

2.1.3. Neuromyth in Music Education

The studies on neuromyth in general education have been conducted in several countries (Dekker et al., 2012; Deligiannidi & Howard-Jones, 2015; Gleichgerrcht et al., 2015; Karakus et al., 2015; Kelly et al., 2017; Marietta et al., 2017; S. W. Park et al., 2016; Pei et al., 2015; Rato et al., 2013). Based on an extensive literature research, researchers selected neuroscientific music-related theses. And then, through the evaluation by experts, 7 neuromyths and 7 scientifically substantiated theses were used in the survey. In an online survey, music teachers (*n* = 91) and music students (*n* = 125) evaluate the theses in a 2-AFC paradigm: ‘scientifically substantiated’ or ‘scientifically unsubstantiated’. The most prevalent misconception about neuroscientific music-related theses among music teachers and music students were (1) “Cognitive abilities, e.g., intelligence in children can be effectively enhanced by music education”, (2) The ability to improvise on the piano is controlled by the right hemisphere. Special exercises can enhance the performance of this hemisphere”, and (3) “Right-handers process speech in the left hemisphere of their brains and music in the right”. Table II-4 showed the percentage of correct answers among teachers and students for each of the theses.

Table II-4

Prevalence of music-related neuromyths among music teachers and music students in the study by Düvel et al. (2017)

Thesis ID	#	Thesis	Correct answers (%)	
			Teachers	Students
Neuromyths	1	Certain music genres require special ways of listening attitude. For classical music, only an intellectual listening style is appropriate.	96.7	90.4
	2	Excellent classical musicians are on average more intelligent than non-musical graduates of a university program.	75.8	80.8
	3	Those who listen passively to classical music during certain learning phases have advantages over those who do not listen passively to music.	68.1	64.8
	4	Music education improves one's performance in calculus significantly.	62.6	51.2
	5	Right-handers process speech in the left hemisphere of their brains and music in the right.	39.6	62.4
	6	The ability to improvise on the piano is controlled by the right hemisphere. Special exercises can enhance the performance of this hemisphere.	44.0	40.8
	7	Cognitive abilities, e.g., intelligence in children, can be effectively enhanced by music education.	29.7	24.8
Scientifically substantiated theses	1	Musicians show a strong neurophysiological "coupling" between hearing and motor movement. This link was developed by intensive training.	79.1	87.2
	2	The anatomic structure of the brain changes through intensive practice of an instrument.	81.3	79.2
	3	Music education can enhance language skills.	82.4	76.0
	4	Musicians can process music faster, more precisely and more efficiently than non-musicians.	81.3	74.4
	5	Although not hearing-impaired, some people cannot understand tones, melodies and rhythms.	72.5	80.8
	6	The processing of auditory information is trained by music listening.	73.6	78.4
	7	The influence of passive listening to music during nonmusical activities depends, for example, on a person's degree of musical sophistication, the emotional effect and the character of the music.	62.6	68.0

Note. Neuromyths and scientifically substantiated theses are presented from highest to lowest accuracy rates.

Furthermore, the evaluation of the 14 theses was analyzed according to Signal Detection Theory (Macmillan & Creelman, 2005). Discrimination performance was revealed as sensitivity index $d' = 1.25$ (SD = 1.12) for the music teachers and d' = 1.48 (SD = 1.22) for the music students. This indicates the participants of this study showed a medium to a large ability of discrimination. And the participants showed an overall tendency to generally evaluate the theses as scientifically substantiated (music teachers: response bias $c = -0.35$, students: $c = -0.41$).

The researchers also determined possible predictors for the discrimination performance. For the teachers, a large number of media about educational neuroscience and related topics predicted discrimination performance ($R^2 = 0.06$). For the students, the best predictors of neuromyths were a high number of reading media and the hitherto completed number of semesters ($R^2 = 0.14$). The detailed results of multiple regression analysis were presented in Table II-5.

Table II-5
Predictors of neuromyths in the study by Düvel et al. (2017)

Group	Predictor variables	Predictors of neuromyths	B (SE)	β	p	Adjusted R^2
Music teachers	Age, Gender, Type of school, Studied to become a teacher, PhD degree, Relevance of genetic endowment and environmental factors on learning success, Knowledge about neuroscience, Knowledge about educational neuroscience, Number of read media	Number of read media	0.121 (0.050)	0.249	0.017	0.062
Music students	Age, Gender, Type of school, Relevance of genetic endowment and environmental factors on learning success, Knowledge about neuroscience, Knowledge about educational, Number of read media, Duration of studies, Duration until completion, Total duration of academic studies, Entering the teaching profession.	Number of read media	0.189 (0.069)	0.237	0.007	0.141
		Duration of studies (semesters)	0.081 (0.029)	0.240	0.006	

2.2. Findings in Neuroscience of Music

Observing how the brain appreciates and produces music and how music affects the brain has drawn lots of scientists' attention for a long time. Also, this topic fascinated ordinary people because it deals with music, which is often called human nature and desire, and the brain, which is considered to be the most mysterious part of human body. The huge popularity of *Musicophilia: Tales of Music and brain* (Sacks, 2007) and *This is Your Brain on Music* (Levitin, 2006) among the public showed the charm of this topic well. Ironically, however, such popularity generated the spreading of myths about music and the brain like Chinese whispers.

The important issues that have been covered in the field of neuro-musical research will be reviewed in order to provide accurate knowledge of music and the brain and to consider the effects of music education on the human brain. The results of the neuroscientific research were divided into seven categories: (1) musical aptitude, (2) music processing, (3) intelligence, (4) transfer effect, (5) music and language, (6) music, body, and brain, and (7) brain plasticity.

2.2.1. Musical Aptitude

The question of whether musical aptitude is inherent or acquired through education or training is an important issue and used to controversy for music educators. Quite a number of studies using behavioral genetic or molecular genetic methods investigated the genetic bases of various aspects of music ability, such as absolute pitch (Baharloo, Johnston, Service, Gitschier, & Freimer, 1998; Baharloo, Service, Risch, Gitschier, & Freimer, 2000; Gregersen, Kowalsky, Kohn, & Marvin, 1999; Gregersen, Kowalsky, & Marvin, 2001; Gregersen et al., 2013; Gregersen & Kumar, 1996; Profita & Bidder, 1988; Theusch, Basu, & Gitschier, 2009; Theusch & Gitschier, 2011), music perception (Drayna, Manichaikul, de Lange, Snieder, & Spector, 2001; Oikkonen et al., 2014; Pulli et al., 2008; Ukkola, Onkamo, Raijas, Karma, & Järvelä, 2009; Ukkola-Vuoti et al., 2013), melodic memory (Granot et al., 2007), singing accuracy (H. S. Park et al., 2012), and music creativity (Ukkola et al., 2009; Ukkola-Vuoti et al., 2013). Trainor (2008) reported that such genes control the characteristics of neural circuits, developmental waves of neuronal and synaptic proliferation, and the later pruning of neural connections to form efficient circuits for processing sound.

However, experience also profoundly affects the neural connections formed (Trainor, 2008), so musical aptitude also could be affected by the musical experience. In other words, even if whoever was born with genetic factors influencing musical development and aptitude, but if not used through the experience, musical aptitude cannot be obtained.

Also, musical aptitude is not depended on the dominance of one of the hemispheres. People often differentiate between the role of two hemisphere – the left brain is responsible for the process of rational thinking, while the right brain is responsible for emotional experience. This dichotomous thinking categorizes logical and analytical people as left-brains and creative and artistic people as right-brains. Thus, the major center for music is considered to be on the right side of the brain. Further, right-brained people are believed to be more talented in music. However, left and right hemispheres do not function independently of each other

(Walsh & Pascual-Leone, 2003), and human does not use one half of their brain more dominantly (Nielsen et al., 2013). In addition, musical activities involve not only the right brain but use the entire brain (Alluri et al., 2013; Sammler, Kotz, Eckstein, Ott, & Friederici, 2010; Tervaniemi, Sannemann, Noyranen, Salonen, & Pihko, 2011). Therefore, it is not true that the people, who have developed right brain are gifted in music.

2.2.2. Music Processing

Many neuroimaging studies of music have attempted to identify how does the brain process music. Researchers have focused on brain regions participating in processing of musical features, such as pitch (Patterson, Uppenkamp, Johnsrude, & Griffiths, 2002), loudness, rhythm (Chen, Penhune, & Zatorre, 2008; Grahn & Rowe, 2009), and timbre (Caclin et al., 2006; Halpern, Zatorre, Bouffard, & Johnson, 2004). Patterson and colleagues (2002) found that pitch activated Heschl's gyrus and planum temporale. And varying pitch in a melody was processed in the superior temporal gyrus and planum polare (Patterson et al., 2002). Grahn and Rowe (2009) investigated neural network involved in rhythm perception. They proposed that a cortico-subcortical network including the putamen, the supplementary motor area, and premotor cortex, and auditory cortex is engaged for the analysis of temporal sequences and prediction or generation of putative beats (Grahn & Rowe, 2009). According to Halpern and colleagues (2004), timbre is processed in primary and secondary auditory areas with some right-sided asymmetry. These studies suggested that the perception of individual musical features is processed in different parts of the brain. However, these were not about how the human brain processes the multitude of musical features.

The study by Alluri and colleagues (2012) started with recognition of this limitation. The researchers looked at changes in the participants' brain while they were listening to a modern tango. This study clearly shows that music is processed in the entire brain by investigating the neural mechanisms of timbral, tonal, and rhythmic features of a naturalistic musical stimulus. The study by Sammler and colleagues (2010) also proved music processing that occurs in the entire brain.

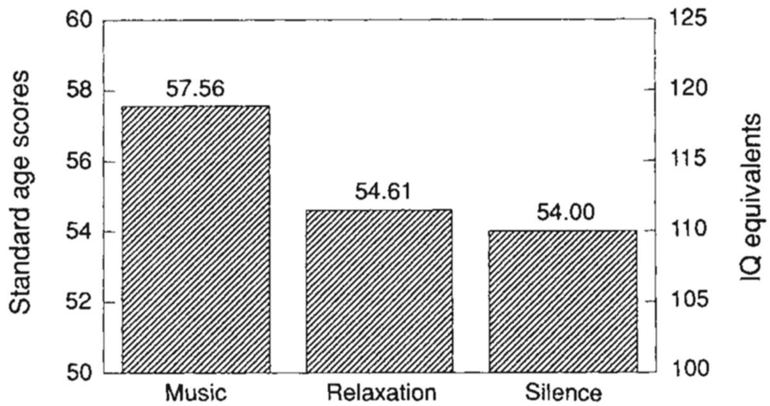
2.2.3. Intelligence

Learning music has an impact on intellectual development. The study by Hurwitz and colleagues (1975) is one of the first studies to investigate the role of music in children's intellectual development. In this study, children who received Kodaly music lessons for five days each week for seven months scored significantly higher than the control group on three of five sequencing tasks and four of five spatial tasks. Since then, many studies showed that learning musical activities, especially active engagement with making music, can have an impact on intellectual development (Bilhartz, Bruhn, & Olson, 1999; Costa-Giomi, 2004; Gromko & Poorman, 1998; Hetland, 2000; Orsmond & Miller, 1999; Rauscher, 2009; Rauscher & Zupan, 2000; Schellenberg, 2004; Schlaug, Norton, Overy, & Winner, 2005). Furthermore, several studies examined the relationship between learning music and academic achievement (Barr, Dittmar, Roberts, & Sheraden, 2002; Cardarelli, 2003; C. M. Johnson & Memmott, 2006; T. W. Schneider & Klotz, 2000; Trent, 1996; Yoon, 2000).

Rauscher and colleagues (1993) investigated the impact of music on students' spatial ability in three conditions: (1) listening to Mozart's sonata for two pianos in D major, K. 488, (2) listening to relaxation instruction tape, and (3) silence. The participants performed better on the spatial reasoning tests (as measured by spatial reasoning sub-tasks of the Standford-Binet IQ test) after listening to Mozart than after listening to either the relaxation tape or to nothing. The music condition differed significantly from both the relaxation and the silence conditions (Figure II-1).

Figure II-1

Standard age scores (SAS) for each of the three listening conditions in the study by Rauscher et al. (1993)



Note. Music: listening to Mozart's sonata for two pianos in D major, K. 488; Relaxation: listening to relaxation instruction tape; Silence: listening to nothing

This result misinterpreted to imply that only Mozart's music has influenced the improvement of spatial intelligence. However, the improved spatial ability of the participants is not because they listened to Mozart's piano sonata. The result of the study is not the effect of Mozart music, nor the effect of his piano sonata, K.

488. In music condition, music stimulus would have been possible not only for Mozart's music but also for music with a fast and rhythmic beat of any composers, such as Beethoven, Haydn, and so on. In other words, this study examined the effect of arousal by music on spatial ability compared to relaxation of silence.

After the study by Rauscher (Rauscher et al., 1993), the studies on the impact of music on spatial ability have increased. The researchers seek answers the question whether or not there exists Mozart effect (Chabris, 1999; Hetland, 2000; Jakob Pietschnig, Martin Voracek, & Anton K. Formann, 2010; Schellenberg, 2006). They concluded that this effect is not permanent, but also be caused by short-term arousal evoked by other auditory stimulation. Therefore, it is not true that listening to music of specific genres or composers especially improves children's intelligence.

2.2.4. Transfer Effect

Musical experience changes the human brain, and these changes lead to improvements in non-musical abilities as well as improvements in musical abilities. The effect of the execution of a task on the performance of another task is explained by the transfer effect. The transfer effect depends on the similarity of the processes involved in each task, so the higher the similarity between the processes of the tasks, the easier the transfer takes place. Perkins and Salomon (1988) classified the transfer effect into low road transfer and high road transfer. Low road transfers occur with automated techniques; techniques that are highly proficient and can be performed automatically, without special awareness. On the other hand, high road transfer requires a process of consciously applying previously learned abstract knowledge or principles to new situations and tasks. Many studies have investigated the effects of music education on non-musical abilities through behavioral tests.

Cognitive Aspects. According to many studies, musical activity improves the visual-spatial ability. Sluming and colleagues (2007) reported that musicians working in orchestral units are much better able to imagine three-dimensional objects than non-musicians and that this is related to Broca's area. Rauscher and Zupan (2000) found the relationship between such music training and spatiotemporal abilities through a longitudinal study of children. Children who took classroom keyboard lessons improved their ability to perform spatio-temporal tests such as puzzle-matching, block building, and picture retention after eight months compared to untrained children.

Working memory is also one of the cognitive abilities that can be improved through music education. The effects of musical training on working memory are largely divided into tonal working memory (Schulze, Zysset, Mueller, Friederici, & Koelsch, 2011) and verbal working memory (Brandler & Rammsayer, 2003; Chan, Ho, & Cheung, 1998; Ho, Cheung, & Chan, 2003). Schulze and colleagues (2011) experimented with both tonal working memory and verbal working memory for adult and non-musicians. As a result, musicians were better able to remember both musical stimuli (sine tone) and verbal stimuli (spoken syllable) compared to non-musicians, especially with respect to musical stimuli.

In addition, many studies have shown that music education positively affects linguistic abilities. Research on the relationship between music and language has been done in many different ways. The musical experience improves the ability to distinguish rapidly changing sounds (Gaab et al., 2005) and also improves the ability to perceive very small differences in phonemes (Anvari, Trainor, Woodside, & Levy, 2002; Gromko, 2005; Lamb & Gregory, 1993). Music-educated children were able to interpret the rhythm of emotional speech (Thompson, Schellenberg, & Husain, 2004), had excellent results in verbal tests (Magne, Schön, & Besson, 2006), and had excellent reading skills (Douglas & Willatts, 1994; Martin, Alan, Faith, & Donna, 1996). The positive effects of musical experience and music education on linguistic competence appeared in the second language as well as in the mother tongue (Anvari et al., 2002; Slevc & Miyake, 2006). The relationship between music and language will be discussed in more detail in the following part 'music and language'.

The relationship between music and mathematics has been historically claimed for quite a long time (Vaughn, 2000). However, studies on the relationship between music and mathematics have partially conflicting conclusions. This is because the mathematical tasks and musical tasks do not share the fundamental process. However, among the mathematical abilities, there are some research results that music education can have a positive effect on the arithmetic side or the spatial perception side. Schmithorst and Holland (2004) asked adult musicians and non-musicians to solve simple mathematical problems and observe the brain regions activated by fMRI. As a result, musicians showed increased activation of prefrontal cortex and fusiform gyrus compared to non-musicians and decreased activation of visual association area and inferior parietal lobule. Schmithorst and Holland (2004) have concluded that musicians have better working memories than non-musicians and that they have a better ability to extract quantitative expressions. In addition, music-educated children or musicians have performed well in mathematical tests compared to children and adults without musical experience (Catterall, Chapleau, & Iwanga, 1999; Geoghegan & Mitchelmore, 1996; Haley, 2001; Martin et al., 1996; Rauscher, 2009; Rauscher et al., 1997; Rauscher & Zupan, 2000; Whitehead, 2001).

Kinesthetic Aspects. Without a doubt, musical training using musical instruments improves a fine motor skill (Schlaug et al., 2005). Fine motor skill is small movements that use hands and fingers. For this, coordination of eyes and hands, coordination of both hands, manipulation of objects, and agility and strength of fingers should all be in harmony. Musical instrument performance, which requires the delicate and aggressive use of the fingers, changes the area of the brain involved in movements, such as the primary motor cortex or cerebellum, leading to improved motor skills. This will be discussed in more detail in 'music, body, and brain' part.

It is very interesting that music education affects the ability to imitate any gesture. Spilka and colleagues (2010) experimented to see how adult musicians and non-musicians differed in imitating gestures. As a result, musicians imitated certain gestures more quickly and accurately than non-musicians. It suggests that the strong link between the development of the mirror neuron system and the perception and movement of the musicians contributed to the imitating gestures.

Finally, the musical experience improves visual attention and visuomotor ability. Humans tend to pay attention to visual stimuli that appear on the left side than that appear on the right side. Patston and colleagues (2007) observed differences in response to visual stimuli by musicians and non-musicians (Patston, Hogg, & Tippett, 2007; Patston, Kirk, Rolfe, Corballis, & Tippett, 2007). Both musicians and non-musicians responded more precisely and quickly to visual stimuli on the left side than to visual stimuli on the right side. It is interesting that musicians responded much more accurately and quickly to visual stimuli to the right of the vertical line than to non-musicians. This result shows that musicians have more bilateral attention and have an equilateral interhemispheric transfer for visual information.

2.2.5. Music and Language

Both music and language are means of communication with sound. Thus, music and language are processed in the auditory pathway from ear to brain. Some studies claim that music education improves the language processing efficiency of the brain because the music and language use some common auditory pathway (Kraus & Chandrasekaran, 2010; Patel, 2011).

Studies in the functional level measuring brainwave for speech sound stimuli and studies in the behavioral level giving tasks that distinguish speech sound have been investigated widely. These studies report that musical experience has a positive effect on discrimination of syllables (Kraus et al., 2014; Zuk et al., 2013) and pitch (Besson, Schön, Moreno, Santos, & Magne, 2007; Magne et al., 2006; Moreno et al., 2009) in language. Music production involves sensitive processing of the pitch, intensity, and timbre of the sound, so the auditory pathway develops through the musical experience. Such development leads to a sensitive processing of the acoustic characteristics of speech sound.

Musical experience affects not only acoustical processing of language but also higher-level language ability, such as reading, grammar, and meaning. Anvari and colleagues (2002) reported that music perception skills can improve reading abilities by discovering the correlation between the scores of the reading subtest of the standardized Wide Range Achievement Test-3 (WRAT-3) and the performance scores of music discrimination tasks. Tallal and Gaab (2006) found that children's language and literacy skills were improved after musical training. Some studies on the relationship between music and literacy skills suggest that musical training bolsters cognitive mechanisms which are important in language and literacy development (Collins, 2012; Strait & Kraus, 2011; Strait, Kraus, Parbery-Clark, & Ashley, 2010). Gordon and colleagues (2015) found an association between music education and reading skills, based on an extensive literature research. As a result, there was a statistically significant association between phonological awareness and rhythmic abilities. Norton and colleagues (2005) reported that phonemic awareness is related to music perceptual skills.

In addition, some brain areas are involved in both speech and music processing. These areas include Heschl's gyrus, the planum temporale, the supplementary motor area, Broca's area and Wernicke's area. Patel (2008) emphasized that music helps understand various brain mechanisms related to speech. It suggests that music and language use similar brain networks and thus linguistic abilities can be improved through musical experience.

2.2.6. Music, Body, and Brain

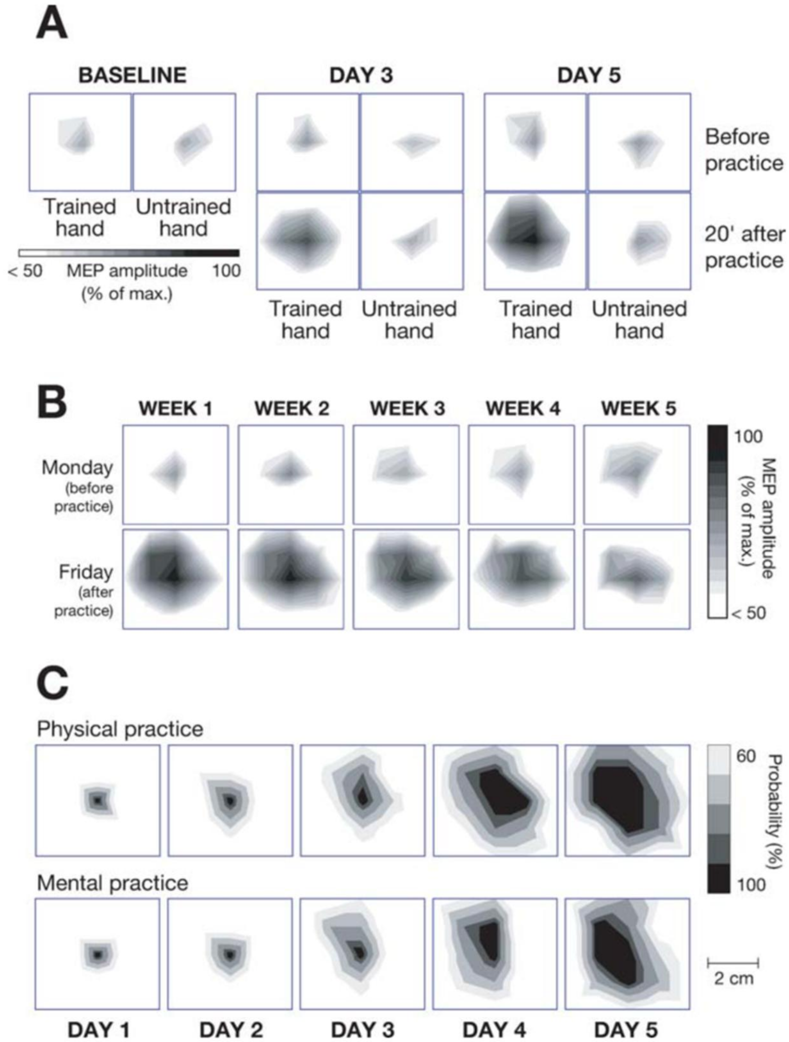
Musicians are said to be like athletes. Wilson (1982) said that there is very little to distinguish the serious musician from the serious athlete. According to him, musicians are athletes concentrating on perfecting control of the small muscles of the upper extremities, being relatively stationary while performing, and monitoring their output largely with their auditory system. Music playing requires finely-tuned motor movements, and musicians practice tremendous amounts of time each day to acquire and maintain excellent techniques. Paderewski, a famous Polish pianist, left a very famous saying, "If I miss one day of practice, I notice it. If I miss three days, the audience notices it.” It suggests that it is important for musicians to constantly train their finger muscles. Without a doubt, repetitive and intense musical training develops the finger muscles, leading to the technical movements of the fingers. However, musical training does not only develop the finger muscles, so enhanced kinesthetic skills do not just depend on muscle development.

According to Pascual-Leone and colleagues (2005), daily musical practice makes a cortical representation of the fingers bigger (Figure II-2). This result scientifically proves Paderewski’s famous saying. That is to say, musical training develops the brain area which is involved in the movements of the fingers, and it leads to enhanced finely-tuned motor movements.

Studies of musicians' brain and musical training have confirmed that musical performance activates many brain areas involved in planning and executing motor movements (Hodges, 2009). The primary motor cortex, the supplementary motor area, the premotor cortex, the cerebellum, and the somatosensory cortex are all brain areas that control motor behaviors, and for musicians, these areas are much bigger than non-musicians. Therefore, elaborate and fast movements of the fingers while playing the instruments are not only due to development of the finger muscles but also to the development of brain areas involved in the movements of the fingers.

Figure II-2

Changes in cortical representation of the fingers associated with learning a five-finger exercise on the piano



Note. A: Cortical output maps for the finger flexors of the trained and the untrained hands of a representative subject. Note the marked changes of the output maps for the trained hand following practice and the lack of changes for the untrained hand. Note further the significant difference in cortical output maps for the trained hand after the practice sessions on days 3–5. B: Serial cortical output maps to finger flexors in a representative subject during five weeks of daily (Monday to Friday) practice of the five-finger exercise on the piano. Note that there are two distinct processes in action, one accounting for the rapid modulation of the maps from Mondays to Fridays and the other responsible for the slow and more discrete changes in Monday maps over time. C: Average cortical output maps for the finger flexors of the trained hand in subjects undergoing daily physical versus mental practice. Note the similarity in output maps with either form of practice (Pascual-Leone et al., 2005).

2.2.7. Brain Plasticity

Brain plasticity is one of the most important findings of neuroscience and brain science so far. It refers to the characteristic that the structure or function of the brain is changed by the environment or experience. For a long time, music has provided a good model for neuroscientists to study brain plasticity. Musical activity is a complex task, requiring finely-tuned motor movements, highly developed sensory abilities (in auditory, visual, tactile, and kinesthetic modalities), the integration of motor and sensory information to monitor and correct performance, and higher-order executive and attentional functions (Herholz & Zatorre, 2012; Merrett & Wilson, 2011; Schlaug et al., 2005; Wan & Schlaug, 2010; Zatorre, Chen, & Penhune, 2007). Therefore, music could be a good framework for studies on plastic changes of the human brain. Changes in the brain induced by music education should be an interesting research topic for both neuroscientists and music educators. Its implications on the field of music education are of such importance that it will be addressed in greater detail in the following section.

2.3. Brain Plasticity: Does music education change the human brain?

The term brain plasticity is a concept that includes neural plasticity and synaptic plasticity and refers to the characteristics of the brain that change as a result of adaptation to experience, stimulus, or environmental needs. Changes in individual brain cells, the visible anatomical changes in the brain, and reorganization of the neural network helping a complex cognitive processing are all examples of brain plasticity. Brain plasticity can be divided into structural brain plasticity and functional brain plasticity. Structural brain plasticity refers to changes in the gross structural level of the brain, that is, changes in size, shape, density, and connectivity of the brain. For example, musicians have been found to have a larger corpus callosum, the connective bridge between the right and left hemisphere, enabling messages (synapses) to move more effectively and quickly between different hemispheres of the brain (Collins, 2012; Lee, Chen, & Schlaug, 2003; Öztürk, Tasçioglu, Aktekin, Kurtoglu, & Erden, 2002; Peretz & Zatorre, 2005; Schlaug et al., 2009; Schlaug et al., 2005; Schmithorst & Wilke, 2002). It can be said that musical training affects structural changes in human brain. Functional brain plasticity, meanwhile, refers to changes in brain processing, such as increasing or decreasing of activation, changes in the pattern of cortical activation, and changes in neural substrates or networks associated with given tasks. The gamma-band response associated with a high degree of cognitive information processing is much larger in musicians than in non-musicians (Trainor, Shahin, & Roberts, 2009). This is a typical example of functional brain plasticity. In the human brain, functional changes are accompanied by structural changes, so it is difficult to separate the notion of structural brain plasticity from that of functional brain plasticity.

In experience- and training-dependent brain plasticity studies, music has attracted great interest from neuroscientists (Boyke, Driemeyer, Gaser, Büchel, & May, 2008; Draganski et al., 2004; Draganski et al., 2006; Eleanor et al., 2000; Golestani & Zatorre, 2004; Herholz & Zatorre, 2012; T. Münte, Altenmüller, & Jäncke, 2002; Wan & Schlaug, 2010; Zatorre, 2005). In order to understand the reason for musicians and musical training have been a good model for demonstrating brain plasticity, conditions of experience- and training-dependent brain plasticity need to be reviewed. Several conditions of brain plasticity have been discussed in some reports of experience- and training-dependent brain plasticity (Green & Bavelier, 2008; Kleim & Jones, 2008). Kleim and Jones (2008) presented the ten principles of experience-dependent plasticity: (1) use it or lose it, (2) use it and improve it, (3) specificity, (4) repetition matters, (5) intensity matters, (6) time matters, (7) salience matters, (8) age matters, (9) transference, and (10) interference (Table II-6). To be short, repetition of, intensity of and specificity of training can induce experience-dependent plasticity.

Table II-6

Principles of experience-dependent plasticity (adapted from Kleim & Jones, 2008)

	Principle	**description**
1	Use It or Lose It	Failure to drive specific brain functions can lead to functional degradation.
2	Use It and Improve It	Training that drives a specific brain function can lead to an enhancement of that function.
3	Specificity	The nature of the training experience dictates the nature of the plasticity.
4	Repetition Matters	Induction of plasticity requires sufficient repetition.
5	Intensity Matters	Induction of plasticity requires sufficient training intensity.
6	Time Matters	Different forms of plasticity occur at different times during training.
7	Salience Matters	The training experience must be sufficiently salient to induce plasticity.
8	Age Matters	Training-induced plasticity occurs more readily in younger brains.
9	Transference	Plasticity in response to one training can enhance the acquisition of similar behaviors.
10	Interference	Plasticity in response to one experience can interfere with the acquisition of other behaviors.

Most professional musicians have intensive training from an early age, high level of expertise, immense about of accumulated, and great current engagement in music (Ericsson, Krampe, & Tesch-Römer, 1993; Merrett & Wilson, 2011). In addition, producing music is a complex task, requiring finely-tuned motor movements, highly developed sensory abilities (in auditory, visual, tactile, and kinesthetic modalities), the integration of motor and sensory information to monitor and correct performance, and higher-order executive and attentional functions (Herholz & Zatorre, 2012; Merrett & Wilson, 2011; Schlaug et al., 2005; Wan & Schlaug, 2010; Zatorre et al., 2007). Therefore, music and musicians provide an ideal framework for studying the plastic changes in the human brain. Sacks (2007) used the phrase “Anatomists today would be hard put to identify the brain of a visual artist, a writer or a mathematician - but they would recognize the brain of a professional musician without moment's hesitation.” and this showed the huge impact of music on the human brain.

Until recently, this experience- and training-dependent brain plasticity have been thought to be a special property of the growing brain, and most neuroscientists have believed that it occurs only during memory formation in the adult brain. However, in the 1970s and 1980s, animal studies began to demonstrate that adult brain could change in response to experiences (Buonomano & Merzenich, 1998; Merrett & Wilson, 2011), and after that, researchers have found that brain plasticity occurs throughout the human lifetime. Nevertheless, there is evidence that the capacity of brain plasticity peaks in certain developmental periods (Knudsen, 2004). Musical experience, as well, has a possible sensitive period for inducing brain plasticity. Musical training that occurs during early, sensitive periods of development may have a greater impact on the human brain. It cannot be the case that the age at commencement of musical training associated with the degree of structural change in all part of the brain, but there is evidence that the earlier the age at commencement of musical training, the greater the corpus callous, precentral sulcus, central sulcus, and corticospinal tract (Amunts et al., 1997; Imfeld, Oechslin, Meyer, Loenneker, & Jancke, 2009; Li et al., 2010).

2.3.1. Structural Plasticity

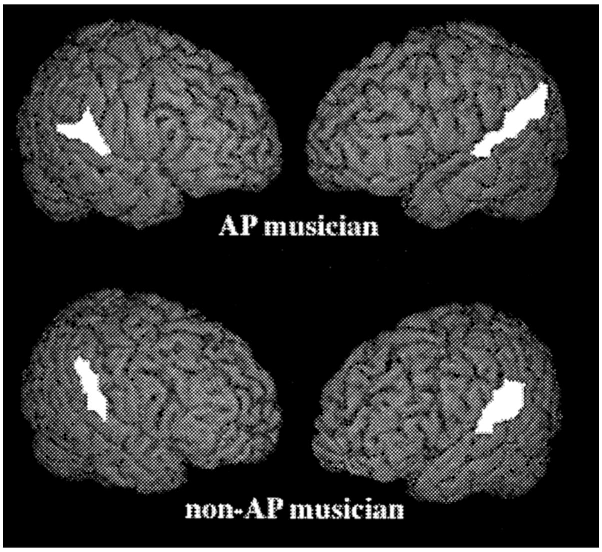
Professional and intensive music training over a long period of time causes remarkable changes in the structure of the musicians' brain. Therefore, musicians differ considerably from non-musicians in terms of brain shape, size, and connection. These structural changes of the brain induced by musical training occur in various brain areas and can be categorized into changes of gray matter and changes of white matter.

The gray matter is the area where the neurons' cell bodies are gathered. If the brain area is constantly used through a certain experience or training, the amount of gray matter in that brain area increases and the cerebral cortex grow thick. Thus, musicians have more gray matter than non-musicians in many brain areas. Without a doubt, music, the art of sound, changes the auditory area in the brain. Many previous studies have demonstrated that musicians have a larger gray matter in the auditory area compared to non-musicians. The primary auditory cortex in the temporal lobe, which primarily accepts auditory information, is a region with very distinct differences between musicians and non-musicians (Amunts et al., 1997; Bangert & Schlaug, 2006; Bermudez, Lerch, Evans, & Zatorre, 2009; Gaser & Schlaug, 2003; Li et al., 2010; Schlaug, 2001). Heschl's gyrus in the primary auditory cortex plays an important role in music processing by detecting auditory stimuli, accepting frequency information, perceiving pitch, and generating the meaning of a sound stimulus (Bermudez et al., 2009; Gaser & Schlaug, 2003; P. Schneider et al., 2002; P. Schneider et al., 2005).

The planum temporale of the secondary auditory cortex is also important for pitch and music perception. In general, the planum temporale of the human brain is larger in left hemisphere than right hemisphere. It is because the planum temporale in left hemisphere plays a crucial role in the perception and meaning generation of language. Musicians have a much greater leftward asymmetry of the planum temporale, indicating that the planum temporale is also involved in music processing (Bermudez et al., 2009; Keenan, Thangaraj, Halpern, & Schlaug, 2001; Schlaug, 2001; Schlaug, Jäncke, Huang, Staiger, & Steinmetz, 1995; Zatorre, Perry, Beckett, Westbury, & Evans, 1998). Furthermore, Schlaug (2001) compared the groups of absolute-pitch musicians and non-absolute-pitch musicians who started musical training at similar times and confirmed that an increased left-sided planum temporale asymmetry in musicians who have an absolute pitch that was not seen in the control group of non-absolute pitch musicians (Figure II-3). The greater leftward asymmetry of the planum temporale in absolute-pitch musicians shows that they have a strong capacity to perceive sounds as language.

Figure II-3

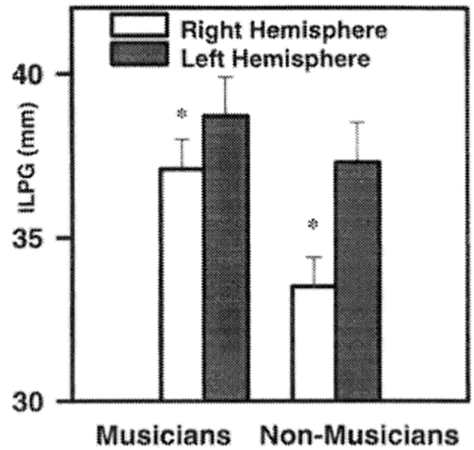
Greater leftward asymmetry of the planum temporale of absolute-pitch musicians



Musicians also have a greater amount of gray matter in the brain areas responsible for movement and somatosensory than non-musicians. This is because music production, such as singing and playing an instrument, requires finely-tuned motor movements and tactile and kinesthetic feedback (Merrett & Wilson, 2011). The differences of the finger area of the primary motor cortex involved in the voluntary movement are particularly evident between musicians (instrumentalists) and non-musicians (Amunts et al., 1997; Bangert & Schlaug, 2006; Bermudez et al., 2009; Gaser & Schlaug, 2003; Li et al., 2010). Figure II-4 shows that musicians have remarkably larger finger area of the motor cortex in both the left and right hemispheres. Another remarkable thing in this graph is that the differences in the size of the motor cortex between musicians and non-musicians are striking in the right hemisphere. In other words, the differences of the size between the left and right hemispheres of the musicians are far less than that of non-musicians. It suggests that musicians use both hands relatively similarly when they play the musical instruments, so their motor cortex of the left and right hemispheres developed in a balanced way.

Figure II-4

Difference of finger area in the primary motor cortex between musicians and non-musicians

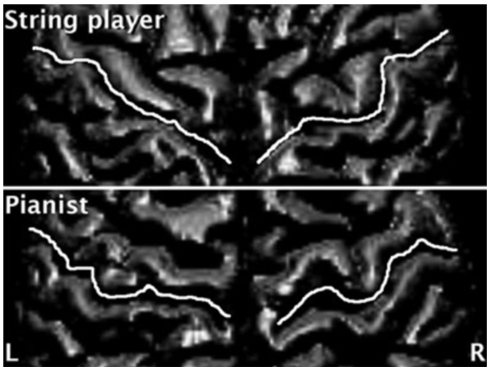


Note. Pairwise multiple tests showing a significantly greater right intrasulcal length in musicians than in controls, while there were no significant between-group differences in this measure for the left hemisphere (Schlaug, 2001).

And besides, this primary motor cortex also vary among musicians, depending on the instrument. Bangert and Schlaug (2006) found differences of Omega Sign (OS), an anatomical landmark of the precentral gyrus associated with hand movement representation, between keyboard-players and string-players. Figure II-5 and Figure II-6 demonstrate that keyboard-players have a prominent OS in the left hemisphere than right hemisphere, while string-players have an only prominent OS in the right hemisphere. These differences in the brain structure arise because keyboard-players move relatively more right fingers than left fingers when they play the keyboard, while string-players use their left fingers when they play the string.

Figure II-5

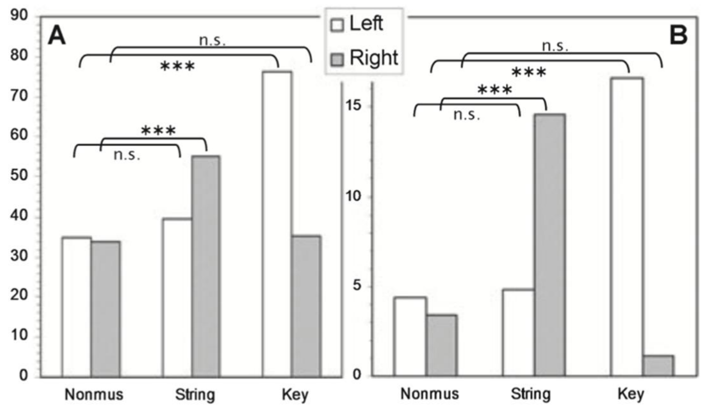
Difference of Omega Sign (OS) between string player and pianist



Note. 3D-surface renderings of the perirolandic region in a string-player (top) and a keyboard-player (bottom). A white line marked the location of the central sulcus, which was meant to serve as an orientation help for the blinded raters. While the string-player displays a prominent OS on the right hemisphere only, the keyboard-player shows a left more than right prominence of the OS (Bangert & Schlaug, 2006).

Figure II-6

Incidence of Omega Sign (OS) detections in non-musicians, string-players, and keyboard-players



Note. (A) Percentage of all visible OS. (B) Percentage of OS 2 ratings (i.e. exceptionally developed OS). White: left precentral gyrus, gray: right precentral gyrus [***P < 0.001 (v2 > 18); n.s. not significant (v2 < 2)] (Bangert & Schlaug, 2006).

In addition to the primary motor cortex, the supplementary motor area (Bermudez et al., 2009; Gaser & Schlaug, 2003; Han et al., 2009) involved in complicated movements (e.g., hand or finger movements), the cerebellum (Gaser & Schlaug, 2003; Han et al., 2009; Hutchinson, Lee, Gaab, & Schlaug, 2003; Schmithorst & Wilke, 2002) responsible for maintaining posture and balance and controlling the voluntary movement, and the somatosensory cortex (Amunts et al., 1997; Bangert & Schlaug, 2006; Bermudez et al., 2009; Gaser & Schlaug, 2003; Li et al., 2010) related to somatic sense are all representative areas where the gray matter is increased by music.

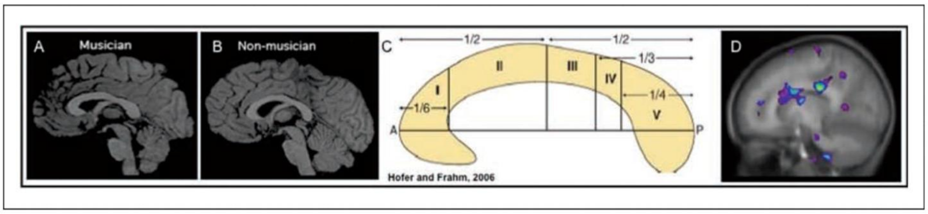
Music also affects the frontal lobe involved in higher-order cognitive processes such as working memory, planning, and monitoring. Among them, the inferior frontal gyrus, and in particular the region known as Broca's area, appears to play a significant role in music processing (Bermudez et al., 2009; Fauvel et al., 2014; Gaser & Schlaug, 2003; Han et al., 2009; Merrett & Wilson, 2011; Sluming et al., 2002), so musical training increases the size of these areas. Broca's area plays a major role in language production but is also involved in many music-related tasks. These include, but are not limited to, the sequential ordering of sound stimuli and the processing of music syntax and expectancy (Burkhard, Stefan, Thomas, & Angela, 2001; Merrett & Wilson, 2011). According to Zatorre and colleagues (2010), the inferior frontal gyrus is also involved in the mental manipulation of melodies. Further, the dorsolateral prefrontal cortex and polar frontal areas are the brain parts that also have differences between musicians and non-musicians (Bermudez et al., 2009). According to D'Esposite and colleagues (1995), the dorsolateral prefrontal cortex is involved in music processing because of their role in executive functioning skills like working memory.

The structural differences between the brains of musicians and non-musicians are seen not only in gray matter but also in white matter. The white matter is composed of nerve fibers and connects the gray matter of each region of the brain and transmits information. As communication between different brain regions increases, the tracts become thicker and thicker. In the previous studies, white matter tracts differing in the brains of musicians and non-musicians are the corpus callous, the inferior longitudinal fasciculus, the superior longitudinal fasciculus (arcuate fasciculus), and the corticospinal tract.

First, the corpus callosum, which is the most representative brain area showing differences between musicians and non-musicians, plays role in exchanging information between the left hemisphere and the right hemisphere. Compared to non-musicians, musicians have thick corpus callosum (Lee et al., 2003; Öztürk et al., 2002; Schlaug, 2001; Schlaug et al., 2009; Schlaug et al., 1995; Schlaug et al., 2005; Schmithorst & Wilke, 2002; Wan & Schlaug, 2010). As Figure II-7 suggests, musicians have the thicker anterior part of the corpus callosum which exchanges motor information (Schlaug, 2001; Schlaug et al., 2009; Schlaug et al., 1995; Wan & Schlaug, 2010). Several studies demonstrated that there is a sensitive period that musical training affects the corpus callosum (Schlaug et al., 1995; Steele, Bailey, Zatorre, & Penhune, 2013). According to Steel and colleagues (2013), beginning musical training before age 7 increases the volume of the corpus callosum, leading to an increased coordination of hands.

Figure II-7

Increased corpus callosum by musical training



Note. Corpus callosum differences in adults (musicians v. non-musicians) and changes over time in children. The midsagittal slice of an adult musician (A) and non-musician (B) shows a difference in the size of the anterior and midbody of the corpus callosum. (C) The major subdivisions of the corpus callosum and locations of the interhemispheric fibers connecting the motor hand regions on the right and left hemisphere through the corpus callosum according to a scheme used by Hofer and Frahm (2006). (D) Areas of significant difference in relative voxel size over 15 months comparing instrumental (n = 15) versus noninstrumental control children (n = 16) superimposed on an average image of all children. Interestingly, most changes over time were found in the midbody portion of the corpus callosum, representing parts of the corpus callosum that contain primary sensorimotor and premotor fibers (Wan & Schlaug, 2010).

Music makes the inferior and superior longitudinal fascicles thick as well. The inferior longitudinal fascicles, which generally recognize and distinguish objects, connect the temporal lobes responsible for the hearing and the occipital lobes responsible for the vision and help exchange information between them. The musical training uses both auditory and visual stimuli, so it affects the inferior longitudinal fasciculus (Schmithorst & Wilke, 2002). The arcuate fasciculus, which is part of the superior longitudinal fasciculus, connects Broca's area responsible for language production and Wernicke's area, which is involved in the comprehension or understanding of the written and spoken language. Broca's area and Wernicke's area, as previously stated, play an important role not only in language processing but also in music processing. Therefore, musical training makes the tract connecting the two big.

In addition, music influences on the corticospinal tract which is a white matter motor pathway starting at the cortex that terminates on motor neurons and interneurons in the spinal cord, controlling movements of the limbs and trunk (Kolb, 2009). Musicians also have the thicker corticospinal tract (Imfeld et al., 2009; Sara et al., 2005; Schmithorst & Wilke, 2002).

2.3.2. Functional Plasticity

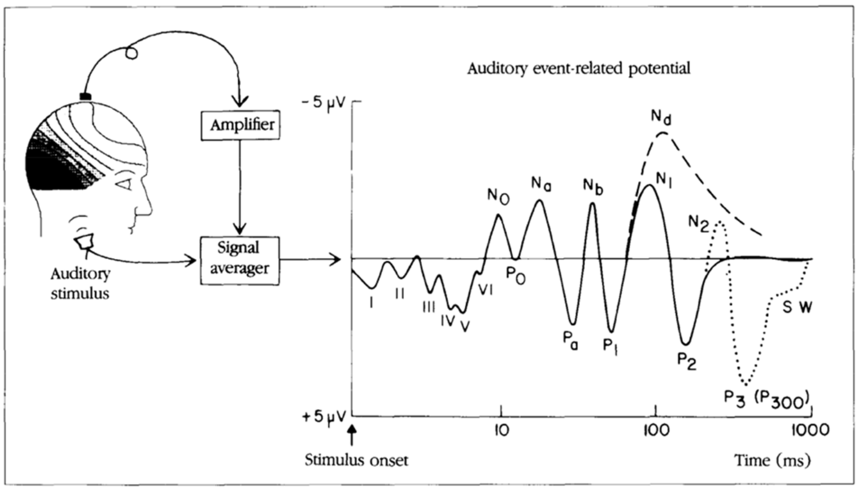
Music brings functional plasticity accompanying structural plasticity. Studies using functional brain imaging techniques such as EEG (electroencephalogram), MEG (magnetoencephalogram), PET (positron emission tomography), and fMRI (functional magnetic resonance imaging) show improved information processing, brain activation, and strong integration (connection) between different modalities in musicians. Such functional plasticity induced by musical training is especially prominent in the auditory and motor areas. This is because auditory and motor areas in our brain play crucial roles in musical activities. In addition, music production is a coordinated activity that requires the interaction of different modalities distributed throughout the brain and integration of motor and sensory, so it leads to strong cross-modal integration.

Most commonly, the studies of auditory function measure electrophysiological response to a stimulus in the brain. In these studies, event-related potential (ERP) and mismatch negativity (MMN), which can be measured by EEG and MEG, are very important concepts. ERP is the measured brain response that is the direct result of a specific sensory, cognitive, or motor event (Luck, 2005). For example, N1 (N100) refers to a negative potential that occurs about 100 ms after stimulus onset, and P3 (P300) refers to a positive potential that appears about 300 ms after stimulus onset.

The electrical response to auditory stimuli is an auditory event-related potential (Figure II-8). It allows researchers to examine the brain responses to basic features of sound such as frequency, intensity, and timbre, and to more complex sound features that form the basis of music such as melody, harmony, and rhythm (Merrett & Wilson, 2011). Signals can be recorded from the brainstem and the cerebral cortex. Several ERP components for auditory stimuli, such as N1 (Pantev et al., 1998), N1c or P2 (Shahin, Bosnyak, Trainor, & Roberts, 2003), are larger and faster in musicians than non-musicians. Such larger and faster responses of musicians which are measured from the brainstem suggest that musicians show better encoding of sound characteristics in subcortical auditory processing, and which are measured from the cerebral cortex demonstrate that they have higher-level of cognitive processing for features of sound stimuli.

Figure II-8

Auditory event-related potential



Note. Characteristic waveform of the auditory ERP recorded from the scalp in response to a brief stimulus such as a click or tone (Hillyard, 1993).

MMN is a component of the ERP to an odd stimulus in a sequence of stimuli. Compared to non-musicians, musicians show much larger and earlier MMN responses when the deviant auditory stimuli - including deviations in frequency (pitch), intensity, timbre, rhythm, and so on - is presented suddenly in the middle of the sequence of standard auditory stimuli. It suggests that musicians have functional enhancements of auditory processing for changes of sound features, especially deviation in a familiar context. Studies on the differences in ERP components for auditory stimuli between musicians and non-musicians are listed in Table II-7.

Other studies using EEG or MEG have investigated the differences in oscillatory activity in specific frequency bands between musicians and non-musicians. Pantev and colleagues (2001) found timbre-specific enhancement of auditory cortical representations in musicians, and this is consistent with the findings of Shahin and colleagues (2008). They investigated musician - non-musician differences in timbre specificity in induced oscillatory gamma band activity. In addition, Trainor and colleagues (2009) musical training has a strong influence on induced gamma-band response that is related to the binding of sound features, such as pitch, timbre, and harmony (Bhattacharya, Petsche, & Pereda, 2001), matching of acoustical cues to representations in long-term memory (Hannemann, Obleser, & Eulitz, 2007; Lenz, Schadow, Thaerig, Busch, & Herrmann, 2007), and attention, anticipation, and expectation (Gurtubay, Alegre, Valencia, & Artieda, 2006; Snydera & Largeb, 2005; Sokolov, Pavlova, Lutzenberger, & Birbaumer, 2004; Zanto, Large, Fuchs, & Kelso, 2005). Also, Fujioka and Ross (2008) found that children taking music lessons have strong beta band activity compared to children not taking lessons.

Table II-7

Findings of studies investigating differences between musicians and non-musicians on components of the event-related potential in response to the presentation of auditory stimuli

Tone stimuli: individual sine tones, spectrally complex tones, or instrumental tones		
N19(m)-P30(m) complex	Schneider et al., 2002	
P50(m)	Schneider et al., 2005	
N1(m)	Pantev et al., 2001	
	Schultz et al., 2003	
	Kuriki et al., 2006	
	Baumann et al., 2008	
N1c	Shahin et al., 2003	
P2(m)	Shahin et al., 2003	
	Shahin et al., 2005	
	Kuriki et al., 2006	
Complex auditory stimuli: intervals, melodies, chords, noise, rhythms, and speech		
N1(m)	Regnault et al., 2001	consonant chords
	Kuriki et al., 2006	chords
N1-P2 complex	Schön et al., 2005	consonant vs. dissonant intervals
P2(m)	Müller et al., 2009	harmonic incongruity
	Regnault et al., 2001	dissonant chords
	Kuriki et al., 2006	chords
N2	Schön et al., 2005	consonant intervals
P300	Nager et al., 2003	attended noise
	Hantz et al., 1992	pitch interval or contour deviants
	Crummer et al., 1994	timbre
P3a	Trainor et al., 1999	pitch interval
P3b	Trainor et al., 1999	pitch interval
ERAN	James et al., 2008	harmonic incongruity
	Müller et al., 2009	
	Koelsch et al., 2002	
	Koelsch et al., 2007	
ND	Münte et al., 2001	spatial attention to noise
	Münte et al., 2003	attended pitch stream
N5	Poulin-Charronnat et al., 2006	harmonic incongruity
LPC	Besson et al., 1995	melodic and harmonic incongruity
	Schön et al., 2004	pitch incongruities in music and language

Note. N = negative waveform deflection; P = positive waveform deflection; numbers represent the approximate number of ms after stimulus onset that the deflection occurs (with 1, 2, 3, and 5 depicting 100, 200, 300, and 500 ms, respectively); m = magnetic counterpart of the auditory evoked potential; c = denotes a component that has similar latency to N1 but with a different source; letters (such as a and b) denote waveforms with similar latencies but different sources; ERAN = early right anterior negativity; ND = negative deflection; LPC = late positive component (Merrett & Wilson, 2011).

fMRI studies found that musicians show greater activation of their brain, compared to non-musicians, when they perform the task of detecting sound stimuli. Such differences in fMRI activation are apparent in the inferior frontolateral cortex, the right anterior superior temporal gyrus (Koelsch, Fritz, Schulze, Alsop, & Schlaug, 2005) and the anterior hippocampus (Herdener et al., 2010).

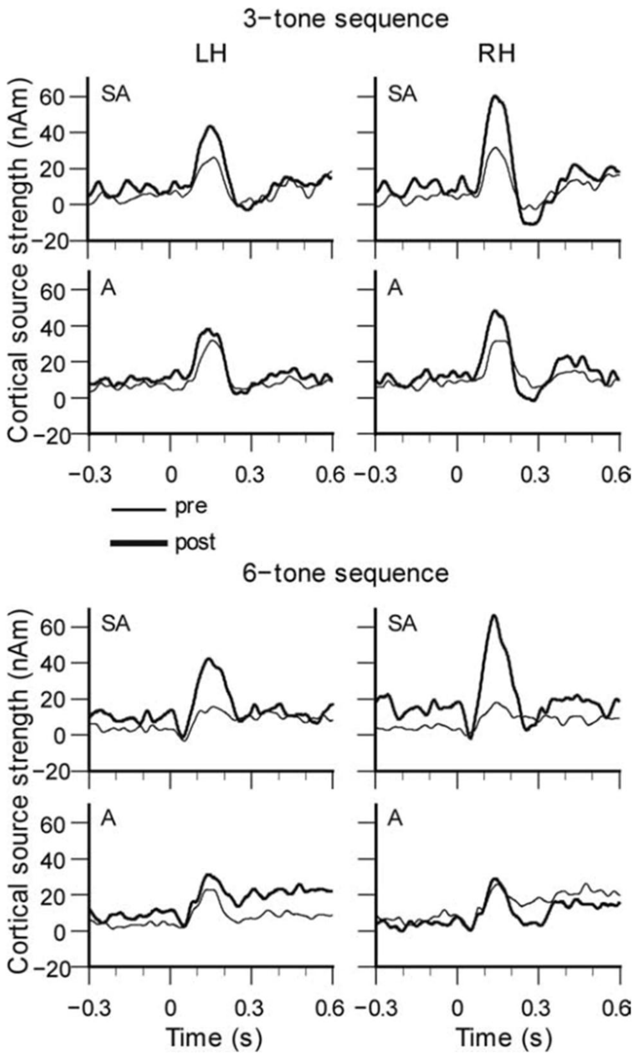
Musical training also affects sensorimotor functions. In comparison with non-musicians, musicians have enlarged cortical representation of hand and show strong primary and secondary motor activation during motor tasks (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995; Jäncke, Schlaug, & Steinmetz, 1997; Jäncke, Shah, & Peters, 2000; Schwenkreis et al., 2007). And many studies have found that while non-musicians showed increased activation in secondary motor areas with increased task complexity, activation in musicians remained constant in both simple and complex tasks (Koeneke, Lutz, Wüstenberg, & Jäncke, 2004; Meister et al., 2005). These results show that musicians have more efficient representation. It all suggests that musicians show superior performance of motor tasks.

Finally, influences of musical training can lead to cross-modal integration. Musical activity strongly connects sensor system and motor system. For example, musicians' motor areas, such as the primary motor cortex (Haueisen & Knösche, 2001), the dorsal premotor area, and the supplementary motor area (Baumann et al., 2007), are activated when they just listen to music (auditory only task). In contrast, when they make the movement of playing the instrument in silence condition (motor only task), their auditory areas, such as auditory cortices (Haslinger et al., 2005) and left planum temporale (Hasegawa et al., 2004), are activated along with the sensorimotor areas. This network for audio-motor integration includes dorsolateral and inferior frontal cortex, supplementary motor and premotor areas, and the superior temporal and supramarginal gyri.

Some studies investigated how instrumental training and auditory training have different effects on integration across the motor and multiple sensory modalities. According to Lappe and colleagues (2008), there is a difference in MMN response between the auditory only training group, which just listened to the broken chord sequence, and the sensorimotor-auditory training group, which played the sequence on the piano. In the sensorimotor-auditory training group, compared with the auditory only training group, MMN response to the deviation of chord sequence was much larger. In addition, the degree of improvement was also higher (Figure II-9). Similarly, Paraskevopoulos and colleagues (2012) compared the auditory-visual-sensorimotor (AVS) training group, which played a short melody on the piano while watching the notation, with the auditory-visual (AV) training group, which just listened the melody while watching the notation. There is audio-visual MMN response to deviant stimuli (a melody that is different from what is notated in the score) between the two groups. Figure II-8 illustrates that the AVS training group showed an increased response while the AV training group showed and decreased response compared to before training. Such MMN response to deviant stimuli appeared in the right superior temporal gyrus, suggesting cross-modal integration occurs in this area (Figure II-10).

Figure II-9

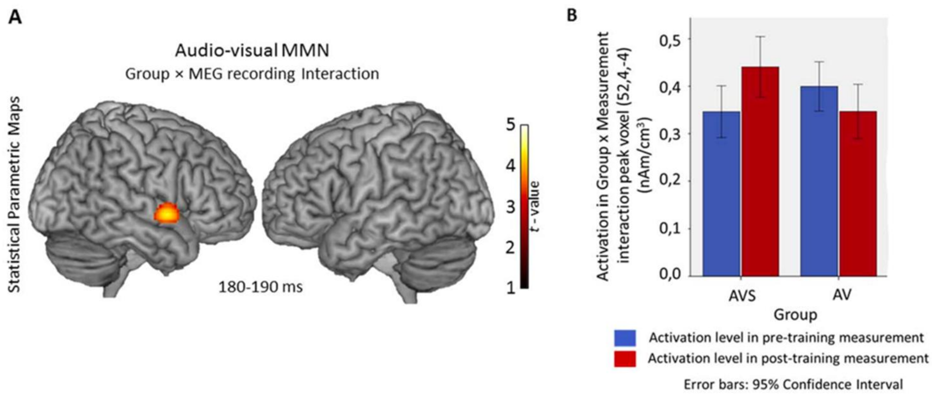
MMN response of sensorimotor-auditory training group and auditory only training group before and after the training



Note. Group averages of the source waveforms obtained after performing source-space projection before and after training for both groups, stimulus conditions, and hemispheres. Data for the three-tone sequences are shown in the top four panels and data for the six-tone sequences in the bottom four panels. Within each set of four panels, SA group data are shown in the top row, and A group data are shown in the bottom row. Data from the left hemisphere (LH) are presented on the left and those of the right hemisphere (RH) on the right. Thin lines indicate pretraining (pre) data and thick lines posttraining (post) data (Lappe et al., 2008).

Figure II-10

Auditory-visual MMN of auditory-visual-sensorimotor (AVS) training group and auditory-visual (AV) training group



Note. A: Rendering of the Statistical Parametric Maps of the interaction effects of Group x MEG recording in the audio-visual condition. Location of the Group x MEG recording interaction effect in the audio-visual condition: Right Superior Temporal Gyrus, BA 22; Threshold was AlphaSim corrected at $p < 0.001$ by tanking in to account the voxel peak significance (threshold $p < 0.001$ uncorrected) along with the cluster size (threshold size > 84 voxels). B: Bar plot of the activation in the peak voxel identified by the Group x MEG Recording interaction for each group in pre- and post-training recording. Error bars show 95% Confidence interval (Paraskevopoulos et al., 2012).

CHAPTER 3. METHOD

3.1. Participants

Pre-service music teachers and general college students in Korea participated in the survey. The total number of the participants was three hundred and seventy. Among them, 28 seemed to respond unfaithfully to the questions; they answered 'do not know' for more than half of all questions. After excluding those 28 participants, left 342 participants (*N* = 132 pre-service music teachers, 210 general college students) were included in the further analysis. Demographic features of final analyzed participants were presented in Table III-1. The average age of the participants was 22.0 years old (*SD* = 1.91). Of all participants, 141 (41.2%) were males and 201 (58.8%) were females.

Table III-1

Demographics of final analyzed participants

		age	Gender		Total
			male	female	
Pre-service music teachers	Elementary school	21.1	11 (28.2%)	28 (71.8%)	39 (11.4%)
	Middle school	22.4	13 (14.0%)	80 (86.0%)	93 (27.2%)
General college student		22.1	117 (55.7%)	93 (44.3%)	210 (61.4%)
Total		22.0	141 (41.2%)	201 (58.8%)	342 (100.0%)

3.1.1. Pre-service Music Teachers

Among all participants, 132 were pre-service music teachers. The mean age of pre-service music teachers was 22.0 years old (*SD* = 1.55). The number of males was 24 (18.2%) and 108 (81.8%) for females. Pre-service music teachers consisted of 39 (29.5%) elementary school pre-service teachers and 93 (70.5%) middle school pre-service teachers that majored in music education. The average age of elementary school pre-service teachers was 21.1 years old (*SD* = 0.82) and middle school pre-service teachers on average 22.4 years old (*SD* = 1.63). Among elementary school pre-service teachers, males were 11 (28.2%) and females were 28 (71.8%). And among middle school pre-service teachers, the number of males and females were 13 (14.0%) and 80 (86.0%), respectively.

3.1.2. General College Students

The total number of general college students was 210. The average age of the general college students was 22.1 years old (*SD* = 2.1). Among them, 117 (55.7%) were males and 93 (44.3%) were females.

Majors of general college students were distributed (Table III-2); 29 (13.8%) were from College of Agriculture & Life Sciences, 19 (9.0%) was from College of Business Administration, 17 (8.1%) was from College of Education, 49 (23.3%) was from College of Engineering, 7 (3.3%) was from College of Fine Arts, 11 (5.2%) was from College of Human Ecology, 9 (4.3%) was from College of Humanities, 5 (2.4%) was from College of Liberal Studies, 4 (1.9%) from College of Medicine, 18 (8.6%) was from College of Natural Science, 7 (3.3%) was from

College of Nursing, 32 (15.2%) was from College of Social Science, 1 (0.5%) was from College of Veterinary Medicine, and 2 (1.0%) was from College of Dentistry.

Table III-2

Frequency of general college students' majors

College	Department		*N* (%)
College of Agriculture & Life Sciences			29 (13.8%)
	Agricultural Economics and Rural Development	3	
	Biosystems & Biomaterials Science and Engineering	2	
	Forest Sciences	6	
	Plant Science	9	
	Food and Animal Biotechnology	3	
	Applied Biology and Chemistry	4	
	Landscape Architecture and Rural System Engineering	2	
College of Business Administration			19 (9.0%)
	Business Administration	19	
College of Education			17 (8.1%)
	Korean Language Education	1	
	German Language Education	1	
	Physics Education	4	
	French Language Education	1	
	Mathematics Education	1	
	English Education	3	
	Ethics Education	2	
	Earth Science Education	1	
	Physical Education	2	
	Chemistry Education	1	

College of Engineering		49 (23.3%)
Civil and Environmental Engineering	2	
Mechanical and Aerospace Engineering	13	
Industrial Engineering	1	
Energy Resources Engineering	1	
Nuclear Engineering	4	
Materials Science and Engineering	9	
Electrical and Computer Engineering	11	
Computer Science and Engineering	5	
Chemical and Biological Engineering	3	
College of Fine Arts		7 (3.3%)
Crafts and Design	6	
Painting	1	
College of Human Ecology		11 (5.2%)
Consumer and Child Studies	7	
Food and Nutrition	1	
Textiles, Merchandising and Fashion Design	3	
College of Humanities		9 (4.3%)
German Language and Literature	1	
Aesthetics	1	
Linguistics	1	
English Language and Literature	1	
Humanities	3	
Religious Studies	1	
Philosophy	1	
College of Liberal Studies		5 (2.4%)
Liberal Studies	5	
College of Medicine		4 (1.9%)
Medicine	4	

College of Natural Science		18 (8.6%)
Physics and Astronomy	1	
Biological Sciences	5	
Mathematical Sciences	5	
Statistics	3	
Chemistry	4	
College of Nursing		7 (3.3%)
Nursing	7	
College of Social Science		32 (15.2%)
Economics	12	
Sociology	3	
Psychology	2	
Communication	1	
Anthropology	1	
Political Science and International Relations	11	
Geography	2	
College of Veterinary Medicine		1 (0.5%)
Veterinary Medicine	1	
School of Dentistry		2 (1.0%)
Dentistry	2	
Total		210 (100%)

3.2. Measures

Questionnaire in this study was divided into four major sections: (1) Demographics Questionnaire, (2) Neuroscience Exposure, (3) Awareness of Importance of the Brain-related Knowledge in Music Education, and (4) Survey on Neuromyth / Neuroscience. The questionnaire was presented in Appendix A.

3.2.1. Demographics Questionnaire

Demographic questionnaire included the questions about age, gender, major, school type (elementary school / middle school). These person-characteristic variables were used to investigate what factor predicts neuromyths.

3.2.2. Neuroscience Exposure

Two questions on neuroscience exposure were presented. First, to the question “Have you ever taken a lecture or class that covers the brain-related topics?”, the participants answered with either ‘yes’ or ‘no’. Next, they asked to answer the question on the type of media as the main source of their knowledge of the brain. Five answer options were presented: (1) broadcasting, (2) newspaper, (3) internet, (4) journal, and (5) book. Multiple answers were allowed.

3.2.3. Awareness of Importance of the Brain-related Knowledge in Music Education

Participants were also asked to answer the question about the relationship between music education and neuroscience. To investigate the participants’ awareness of the importance of understanding the brain in the field of music education, the question “Do you think it is important to understand the workings of the brain when teaching or learning music?” was asked. Participants responded as a five-point Likert scale: ‘strongly disagree’ – ‘disagree’ – ‘neutral’ – ‘agree’ – ‘strongly agree’. And then, an open-ended question “Why did you answer as above?” was given to get the reasons for their responses.

3.2.4. Survey on Neuromyth / Neuroscience

To examine neuroscientific knowledge among pre-service music teachers and general college students, a survey on neuromyth / neuroscience was developed. The survey can be divided into three parts: (1) General Knowledge of the Brain, (2) Educational Neuroscience, and (3) Neuroscience of Music. 18, 12, and 16 statements were used in each category. A total of 46 statements were all extracted from the literature and modified through discussion by three neuroscientists. The statements were presented randomly and the participants were asked to evaluate each statement by choosing one of three options: 'true', 'false', or 'do not know'. Full items in English and Korean were presented in Appendix B.

General Knowledge of the Brain. General Knowledge of the Brain comprised 18 statements about the brain. The statements included following themes: structure and function, development, individuality, brain plasticity, pathology, intelligence, and memory. On the basis of previous studies (Dekker et al., 2012; Herculano-Houzel, 2002; Kleim & Jones, 2008), each statement was selected and translated into Korean. The wording of the adapted version was used with reference to the study by Park and colleagues (2016). A correct answer to each item was also determined by those previous studies. In the study by Herculano-Houzel (2002), the statement "When a brain region is damaged and dies, other parts of the brain can take up its function" (G16) were considered to be true. However, three neuroscientists demurred to the statement using an example of deaf people. According to their explanation, there exist some specific areas which cannot be replaced; for example, severe damage in auditory cortex cannot be replaced by other parts of the brain. Thus, in this study, correct answer of the G16 was determined to be 'false'.

Educational Neuroscience. 12 statements were used to investigate the prevalence of educational neuromyths. Typical examples of neuromyth in the field of education which have been referred to in the literature (Dekker et al., 2012; Geake, 2008; Howard-Jones, 2009; OECD, 2002; Purdy, 2008) were included; these are related to VAK learning style, hemisphere dominance, enriched learning environments, critical periods, transfer effect, 10% of the brain, the effect of certain types of food on the brain, and so on. And items for learning, brain plasticity, and genes vs. environment were added and tested in the survey. The translations of the statements, just like 'general knowledge of the brain' items, were also carried out based on the previous study by Park and colleagues (2016).

Neuroscience of Music. In the planning stage of the study, an abundant literature of the neuro-musical research was reviewed to design music-related neuromyth statements. In this way, about 30 statements about music and the brain were picked out. Among these, the results which were replicated in a significant number of studies selected as 'neuroscience of music' statements. 16 selected statements were evaluated by three neuroscientists once more and the wording of the statements was modified. After deliberation, 8 music-related neuromyth statements and 8 music-related neuroscience statements were finally used in the survey.

3.3. Procedures

The survey to identify the prevalence and predictors of neuromyths embedded in pre-service music teachers and general college students was conducted from March to September 2017. The survey was conducted offline or online. Participants received the printed copies of the survey or followed a link to an online survey. Pre-service music teachers and general college students participated in the survey anonymously and the survey was done with the consent of all participants.

This study appeared as a survey about knowledge about music and the brain and its application in school music class. The term neuromyth was not mentioned. The questionnaire was in Korean. The survey started with some sociodemographic questions including age, gender, and major. Subsequently, the questions on neuroscience exposure followed. Participants were asked to answer the questions on the experience of listening to brain-related lectures and the ways to obtain knowledge about the brain. Then, participants responded to the question about the importance of understanding the brain in music education and freely described why they responded like that. Finally, they were asked to evaluate the 46 statements in the survey on neuromyth / neuroscience by choosing from the response options: ‘true’, ‘false’, or ‘do not know’. Average completion time was 20 min.

3.4. Data Analysis

The data was analyzed using the Statistics and Machine Learning Toolbox in MATLAB (version 9.3.0 / R2017b) and also Microsoft Excel 2016 for some descriptive statistics. For all analysis, a type I error threshold of $\alpha = 0.05$ was applied.

Descriptive statistics, such as sample sizes, averages and standard deviations for each variable (age, gender, school types, and majors) were presented in Table III-1 and Table III-2. For the question of the importance of understanding the brain in music education, the descriptive statistics were also used to ascertain the distribution of the participants' responses. In order to determine whether there is a difference of the response rate between pre-service music teachers and general college students, a chi-square test was used.

The evaluation of 46 neuromyth / neuroscience statements by all participants was analyzed according to Signal Detection Theory (Macmillan & Creelman, 2005). Signal Detection Theory is used to measure the way people make decisions under conditions of uncertainty. It is difficult to confirm participants' decision-making performance just by calculating the proportion of their correct answers, because accidental correct answers cannot have any meaning to their discriminating ability. When the alternative options are perceptually similar to one another, the way to understand the perceiver's behavior more accurately is estimating his/her discrimination ability and decision bias. Therefore, in this study, sensitivity index d' and response bias c, indicators of discrimination performance, were calculated in order to measure the degree of neuromyth among the participants.

Based on Signal Detection theory, the participants in the study were under the following conditions (Table III-3):

Table III-3

The conditional probabilities

	Neuroscience Statement (Signal)	Neuromyth Statement (Noise)
Respond 'True'	Hit	False Alarm
Respond 'False'	Miss	Correct Rejection

Each outcome was coded as Hit = 1, Correct Rejection = 2, Miss = -1, False Alarm = -2, and 'do not know' = 0.

Sensitivity index d' is the standardized difference between the means of the Signal Present and Signal Absent distributions. It assumes that the standard deviations for signal and noise are equal. Thus, sensitivity index d' is calculated as follows:

$$d' = Z(\text{Hit Rate}) - Z(\text{False Alarm Rate})$$

(Macmillan & Creelman, 2005)

Sensitivity index d' values near zero indicate chance performance, because Z-score of chance level 0.5, at which performance is 50% correct by random guessing, is zero. Therefore, larger values of d' mean that a participant is more sensitive to the discrimination between neuroscience statement (signal) and neuromyth statement (noise).

However, sensitivity index d' is clearly not enough to figure out the participants' evaluation completely. So, response bias should also be considered. Response bias c defined as:

$$c = -\frac{Z(\text{Hit Rate}) + Z(\text{False Alarm Rate})}{2}$$

(Macmillan & Creelman, 2005)

Positive *c* values indicate bias towards 'no' response (more Correct Rejections and Misses), whereas negative *c* values mean bias towards 'yes' response (more Hits and False Alarms). In this study, therefore, larger negative values of *c* mean that a participant tends to evaluate neuromyth statement as neuroscience thesis.

In order to investigate the differences in the discrimination performance (sensitivity index d' and response bias *c*) between pre-service music teachers and general college students, a one-way analysis of variance (ANOVA) was used. And the Pearson correlation coefficient (*r*) was used to measure correlation among the participants' discrimination performance in three categories ('general knowledge of the brain', 'educational neuroscience', and 'neuroscience of music').

In addition, a multiple linear regression analysis was conducted to examine which factors predicted both the awareness of the importance of brain-related knowledge in music education and discrimination performance of the participants. To identify the factors of the awareness of the brain-related knowledge, the following predictor variables were entered: age, gender, brain-related education (experience listening to brain-related lectures), the number of media, and media types (the ways to obtain knowledge about the brain; broadcasting, newspaper, internet, journal, and book). And for the factors of discrimination performance, the response to the question about the importance of the knowledge of the brain was added.

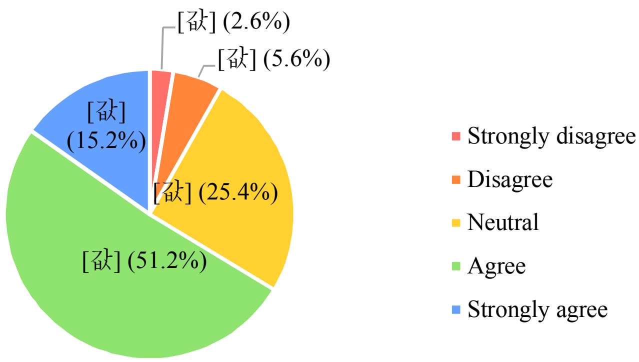
CHAPTER 4. RESULTS

4.1. The Awareness of the Importance of Understanding the Brain in Music Education

To the question "Do you think it is important to understand the workings of the brain when teaching or learning music?", 227 (66.4%) of all participants (*N* = 342) responded that they agreed or strongly agreed (Figure IV-1).

Figure IV-1

Proportion of the all participants' responses

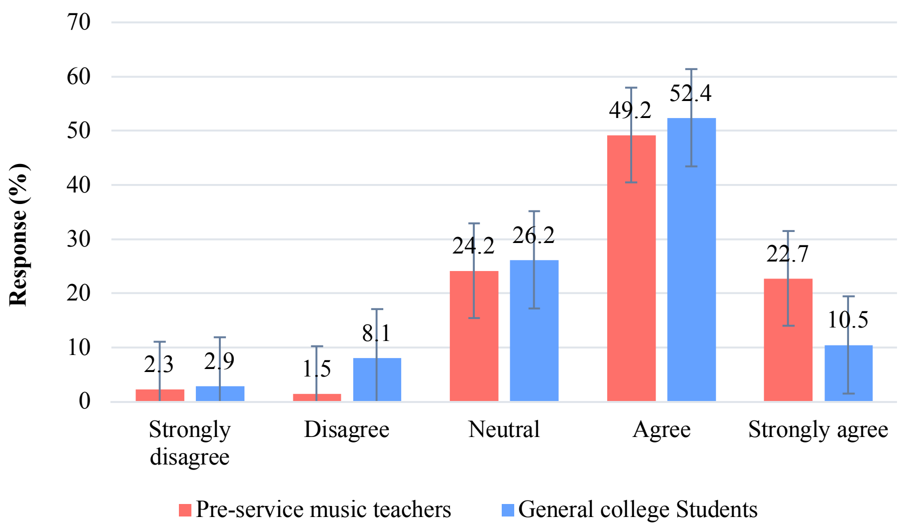


It means 95 (71.9%) of pre-service music teachers (*N* = 132) and 132 (62.9%) of general college students (*N* = 210) recognized the importance of the knowledge of the brain in the field of music education. On the other hand, 5 (3.8%) pre-service music teachers and 23 (11.0%) general college students responded that they did not agree its importance ('disagree' or 'strongly disagree'). The respondents who selected 'neutral' were 32 (24.2%) pre-service music teachers and 55 (26.2%)

general college students. Percentages of pre-service music teachers' and general college students' responses are presented in Figure IV-2. Compared to general college students, pre-service music teachers seem to weigh the difference importance of the understanding of brain-related knowledge in music education [X^2 (1, N = 342) = 17.10, p = 0.004].

Figure IV-2

Percentages of pre-service music teachers' and general college students' responses



The participants who responded that understanding the brain is helpful in teaching or learning music thought that "understanding how the human brain perceives and produces music is helpful in music education", "neuroscience of music can support the educational justification of music", or "brain-related knowledge related to music can help improve the environment of school music education today that repeats meaning less music class" On the other hand, the participants who chose 'disagree' or 'strongly disagree' wrote that "there is no meaningful correlation between music which is the domain of emotion and the brain which is the domain of reason", "good music class is possible without knowledge of the brain" or "it is difficult to apply knowledge of the brain to music educational practice". And the responses of the participants who selected 'neutral' are mainly "I have no idea how the brain is connected to music education" and "Brain-related knowledge can have some impact on music education, but that will be minimal".

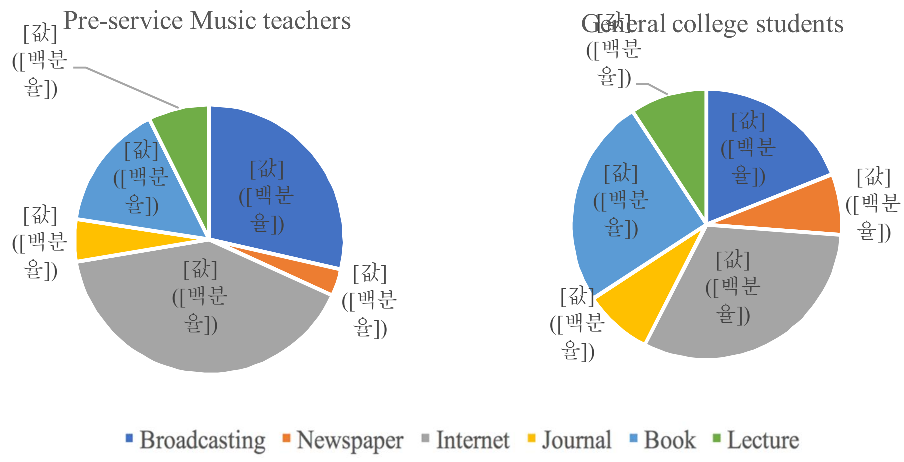
4.2. Neuroscience Exposure

Among both pre-service music teachers and general college students, the internet is the most commonly used media to gain brain-related knowledge. The second source of knowledge of the brain among pre-service music teachers is broadcasting, followed by book, journal, newspaper. Among general college students, book, broadcasting, journal, and newspaper followed.

The number of the participants, who responded that they gain knowledge of the brain from lecture or class is relatively small. Among both groups, people who gained the knowledge of the brain from lecture are more than people who selected journal or newspaper, but less than people who selected internet, broadcasting, or book. Figure IV-3 showed the participants' neuroscience exposure.

Figure IV-3

The participants' neuroscience exposure



4.3. Prevalence of Neuromyths

Overall, out of a total of 46 statements related to the brain, only 23 were correctly answered by more than 50% of both pre-service music teachers and general college students. For the remaining 23 statements, the participants either chose 'incorrect' or 'do not know'. The brain-related statements that more than 50% of the participants were mistaken or did not know included 5 of 18 items in 'general knowledge of the brain', 10 of 12 items in 'educational neuroscience', and 8 of 16 items in 'neuroscience of music': e.g., "Memory is stored in a tiny piece of the brain (G1)", "Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic) (E1)", and "During the prenatal period or childhood, listening to music of a particular genre or composer can enhance the development of the brain especially (M1)". This indicates that despite having a fairly high level of knowledge of the brain in general, both pre-service music teachers and general college students believed in neuromyths related to education or music. The percentages of correct answers for every single statement among pre-service music teachers and general college students were presented in Table IV-1.

Table IV-1

Percentages of correct answers among pre-service music teachers and general college students for each of 46 neuromyth / neuroscience statements

	Pre-service music teachers (*n* = 132)			**General college students (*n* = 210)**		
Item #	**Correct (% / rank)**	**Incorrect (%)**	**Do not know (%)**	**Correct (% / rank)**	**Incorrect (%)**	**Do not know (%)**
General Knowledge of the Brain						
G1	1.5 (18)	94.0	4.5	12.9 (18)	71.4	15.7
G2	55.3 (14)	36.4	8.3	42.4 (14)	31.4	26.2
G3	57.6 (13)	35.6	6.8	69.5 (10)	16.7	13.8
G4	10.6 (17)	50.8	38.6	13.8 (17)	42.9	43.3
G5	68.9 (11)	21.3	9.8	71.4 (8)	19.1	9.5
G6	83.3 (6)	12.9	3.8	73.3 (7)	15.3	11.4
G7	88.6 (4)	9.0	2.4	86.7 (4)	4.7	8.6
G8	74.2 (8)	15.2	10.6	65.7 (11)	13.3	21.0
G9	72.7 (9)	16.7	10.6	60.0 (13)	16.7	23.3
G10	81.8 (7)	10.6	7.6	79.1 (5)	8.5	12.4
G11	71.2 (10)	9.9	18.9	65.2 (12)	10.5	24.3
G12	84.9 (5)	9.0	6.1	70.0 (9)	15.2	14.8
G13	89.4 (2)	5.3	5.3	87.1 (2)	4.8	8.1
G14	89.4 (2)	3.8	6.8	92.9 (1)	3.3	3.8
G15	95.5 (1)	1.5	3.0	87.1 (2)	4.8	8.1
G16	55.3 (14)	30.3	14.4	25.7 (16)	48.1	26.2
G17	59.9 (12)	28.0	12.1	75.2 (6)	8.1	16.7

G18	29.6 (16)	30.2	40.2	35.2 (15)	21.0	43.8

Educational Neuroscience						
E1	2.3 (12)	96.9	0.8	1.9 (12)	91.0	7.1
E2	3.8 (11)	94.7	1.5	3.8 (10)	91.4	4.8
E3	12.1 (9)	65.9	22.0	13.8 (8)	61.0	25.2
E4	12.1 (9)	72.0	15.9	3.8 (10)	72.9	23.3
E5	45.5 (6)	35.6	18.9	33.8 (6)	42.9	23.3
E6	47.0 (5)	40.9	12.1	50.0 (5)	34.3	15.7
E7	90.2 (1)	6.0	3.8	81.4 (3)	11.9	6.7
E8	85.6 (2)	4.6	9.8	83.3 (2)	6.2	10.5
E9	19.7 (7)	52.3	28.0	11.9 (9)	48.1	40.0
E10	15.9 (8)	75.0	9.1	33.3 (7)	39.6	27.1
E11	61.4 (4)	13.6	25.0	62.9 (4)	9.5	27.6
E12	85.6 (2)	5.3	9.1	89.5 (1)	2.9	7.6
Neuroscience of Music						
M1	4.6 (15)	86.3	9.1	11.9 (13)	63.3	24.8
M2	93.2 (2)	4.5	2.3	90.5 (1)	2.8	6.7
M3	11.4 (12)	78.8	9.8	8.1 (15)	67.6	24.3
M4	37.1 (10)	47.0	15.9	30.0 (10)	54.3	15.7
M5	40.2 (9)	54.5	5.3	38.6 (8)	42.4	19.0
M6	97.0 (1)	1.5	1.5	89.5 (2)	5.3	5.2
M7	58.3 (8)	26.7	15.0	41.9 (7)	22.9	35.2
M8	8.3 (14)	81.1	10.6	14.3 (12)	45.2	40.5
M9	36.4 (11)	30.3	33.3	19.1 (11)	36.1	44.8
M10	89.4 (3)	3.0	7.6	72.9 (4)	3.8	23.3
M11	59.1 (7)	22.0	18.9	31.0 (9)	35.2	33.8
M12	4.6 (15)	87.8	7.6	8.1 (15)	75.7	16.2
M13	73.5 (6)	19.7	6.8	74.3 (3)	11.4	14.3
M14	84.1 (4)	3.8	12.1	71.0 (5)	6.6	22.4
M15	84.1 (4)	1.5	14.4	59.5 (6)	8.6	31.9
M16	11.4 (12)	75.7	12.9	10.5 (14)	54.7	34.8

Note. Ranks are based on percentages of correct answers in each category among pre-service music teachers and general college students.

The evaluation of the neuromyth / neuroscience statements was analyzed according to Signal Detection Theory (Macmillan & Creelman, 2005). Indicators of discrimination performance (sensitivity index *d'* and response bias c) among pre-service music teachers and general college students were presented in Table IV-2.

Table IV-2

Average of sensitivity index *d'* and response bias c values among pre-service music teachers and general college students

	Discrimination performance					
	Pre-service music teachers		**General college students**		**Total (all participants)**	
Item ID	*d'*	*c*	*d'*	*c*	*d'*	*c*
General knowledge of the brain	0.93 (*SD* = 0.984)	-0.26 (*SD* = 0.375)	0.70 (*SD* = 1.061)	-0.15 (*SD* = 0.470)	0.79 (*SD* = 0.036)	-0.19 (*SD* = 0.438)
Educational neuroscience	1.15 (*SD* = 2.390)	-1.30 (*SD* = 1.122)	1.15 (*SD* = 2.365)	-1.37 (*SD* = 1.085)	1.15 (*SD* = 2.371)	-1.35 (*SD* = 1.098)
Neuroscience of music	0.09 (*SD* = 1.756)	-1.05 (*SD* = 0.757)	-0.70 (*SD* = 1.505)	-0.66 (*SD* = 0.695)	-0.40 (*SD* = 1.651)	-0.81 (*SD* = 0.744)
Total (46 items)	0.41 (*SD* = 0.812)	-0.56 (*SD* = 0.301)	0.07 (*SD* = 0.680)	-0.41 (*SD* = 0.293)	0.20 (*SD* = 0.751)	-0.46 (*SD* = 0.304)

The average sensitivity index *d'* for 46 statements among the participants was *d'* = 0.20 (*SD* = 0.751). This indicates that the participants showed poor discrimination performance for neuromyth / neuroscience statements. When two groups were compared, pre-service music teachers (*d'* = 0.41, *SD* = 0.812) distinguished well between neuroscience and neuromyth statements than general college students (*d'* = 0.07, *SD* = 0.680) [$t(340) = -4.178$, $p < 0.001$]. And their average response bias for 46 statements was c = -0.46 (SD = 0.304), and this negativity value of c means more ‘true’ answers than ‘false’ answers regardless of neuroscience statements or neuromyth statements. Therefore, this result shows that pre-service music teachers and general college students had a tendency to evaluate the neuromyth statements as ‘true’. And this tendency was more pronounced among pre-service music teachers [$t(340) = 4.600$, $p < 0.001$]. Distribution of sensitivity index d' and response bias c of pre-service music teachers and general college students in 46 statements were presented in Figure IV-4 and Figure IV-5.

Figure IV-4

Histogram (A) and the probability mass function (B) of sensitivity index *d′* of pre-service music teachers and general college students in all 46 statements

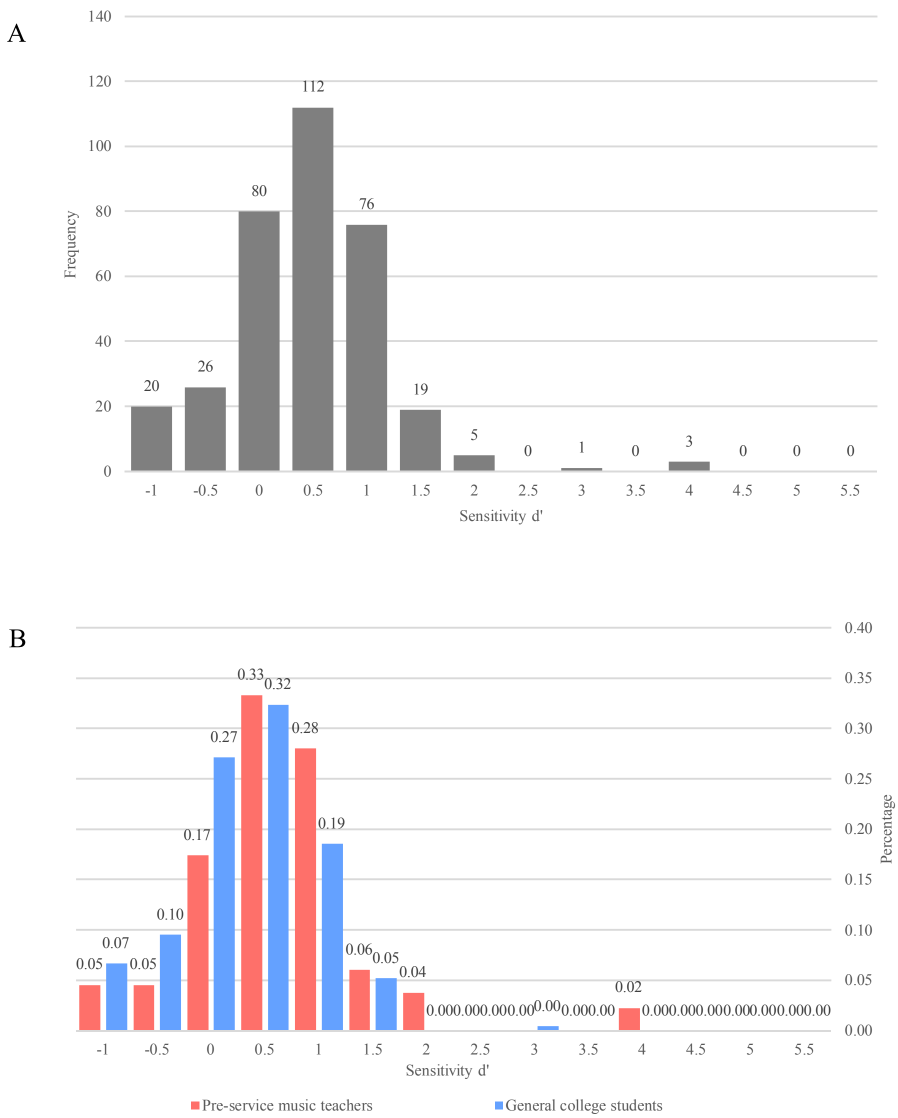
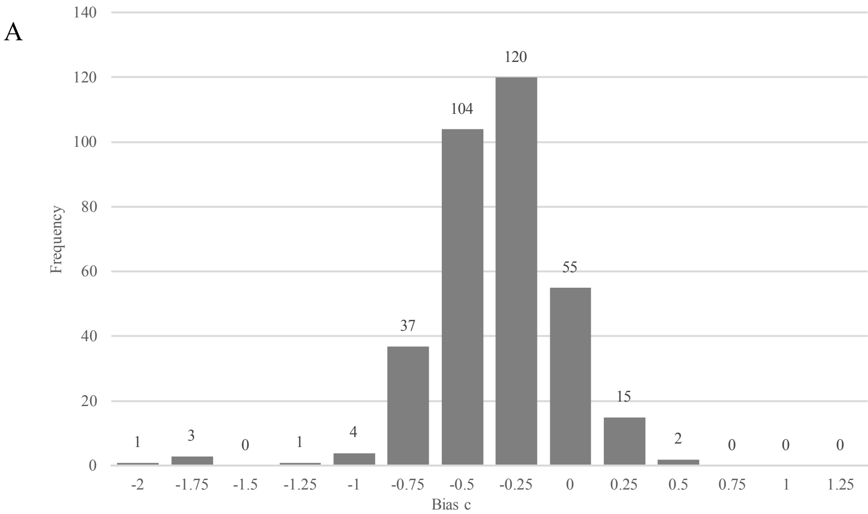
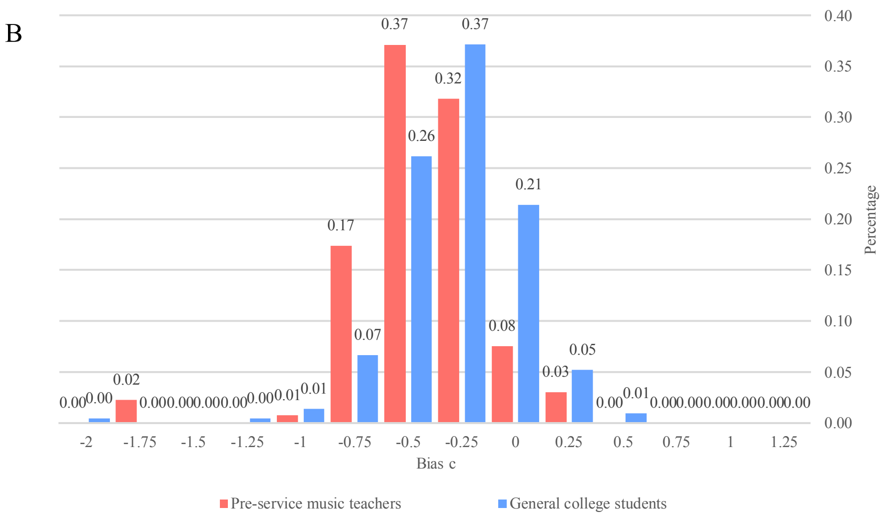


Figure IV-5

Histogram (A) and the probability mass function (B) of response bias *c* of pre-service music teachers and general college students in all 46 statements





To determine whether there were associations among outcomes of discrimination performance (correct answer rate, 'do not know' rate, sensitivity index d', and response bias c), correlation coefficients among them were calculated. As a result, there were close correlations among correct answer rate, 'do not know' rate, sensitivity index d', and response bias c (Table IV-3).

Table IV-3

Correlation among correct answer rate, 'do not know' rate, sensitivity index d', and response bias c for all participants

Correlation Coefficients *r*				
	Correct answer rate	**'Do not know' rate**	**Sensitivity** d'	**Response bias** c
Correct answer rate				
'Do not know' rate	-0.710 ($p < 0.001$***)			
Sensitivity d'	0.917 ($p < 0.001$***)	-0.744 ($p < 0.001$***)		
Response bias c	-0.254 ($p < 0.001$***)	0.365 ($p < 0.001$***)	-0.516 ($p < 0.001$***)	

Note. ***$p < 0.001$

4.3.1. General Knowledge of the Brain.

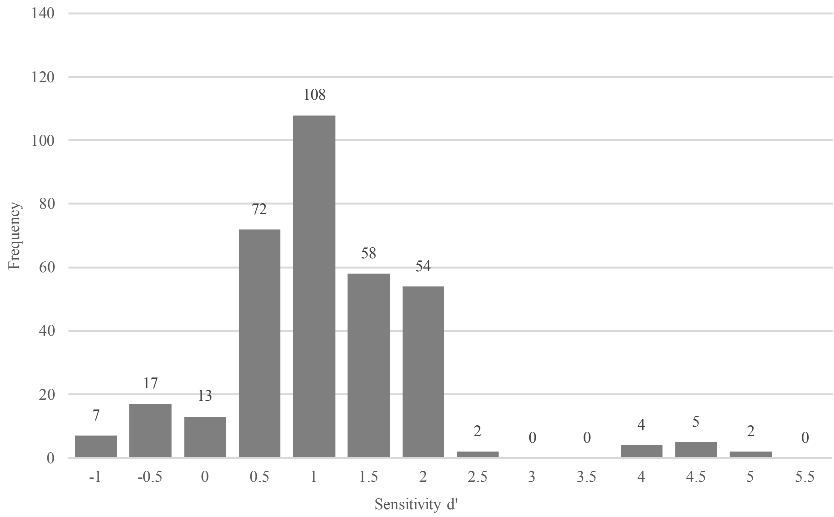
Among the pre-service music teachers and general college students, the average percentage of correct answers for 'general knowledge of the brain' statements was 63.1%. This indicates that the participants' general knowledge of the brain was much better than their knowledge of the educational neuroscience or neuroscience of music. Nevertheless, less than 15% of the participants answered correctly on the item G1 ("Memory is stored in a tiny piece of the brain") and G4 ("Boys have bigger brains than girls").

Sensitivity analysis revealed the average sensitivity index $d' = 0.79$ ($SD = 0.036$) for all participants in 'general knowledge of the brain'. There was significant difference of discrimination performance between pre-service music teachers ($d' = 0.93$, $SD = 0.984$) and general college students ($d' = 0.70$, $SD = 1.061$) [$t(340) = -1.999$, $p = 0.046$]. It indicates that pre-service music teachers had more accurate knowledge of the brain in general compared to general college students. Even for education-related statements, the participants were found to have a tendency to believe neuromyth as neuroscience (average response bias $c = -0.19$, $SD = 0.438$). Compared with general college students ($c = -0.15$, $SD = 0.470$), pre-service music teachers ($c = -0.26$, $SD = 0.375$) were more likely to choose 'true' rather than 'false' [$t(340) = -1.999$, $p = 0.046$]. Distribution of sensitivity index d' and response bias c of pre-service music teachers and general college students in 'general knowledge of the brain' was presented in Figure IV-6 and Figure IV-7.

Figure IV-6

Histogram (A) and the probability mass function (B) of sensitivity index *d′* of pre-service music teachers and general college students in ‘general knowledge of the brain’

A



B

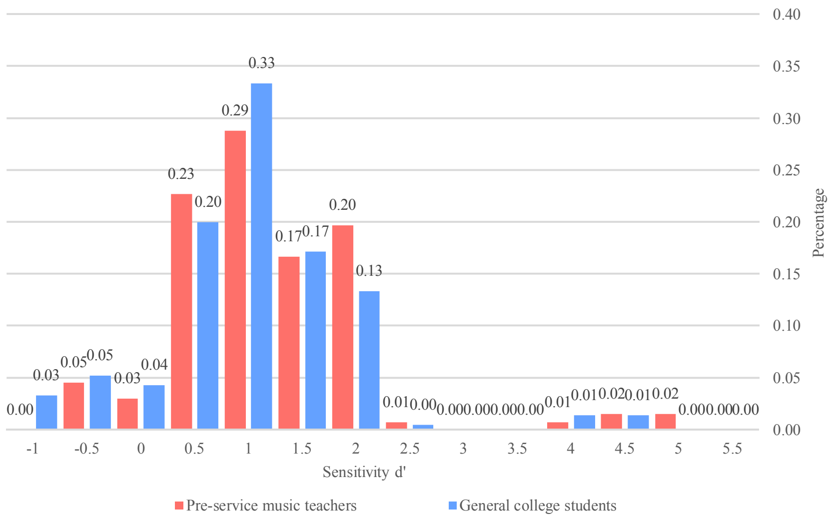
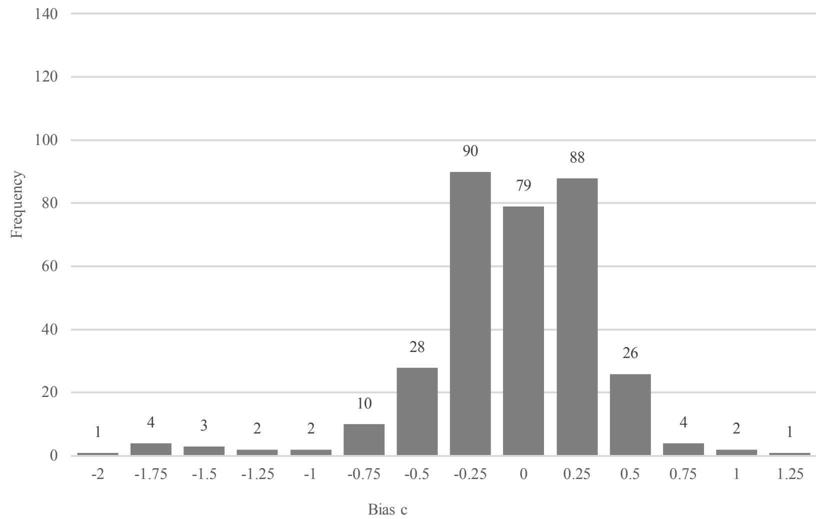


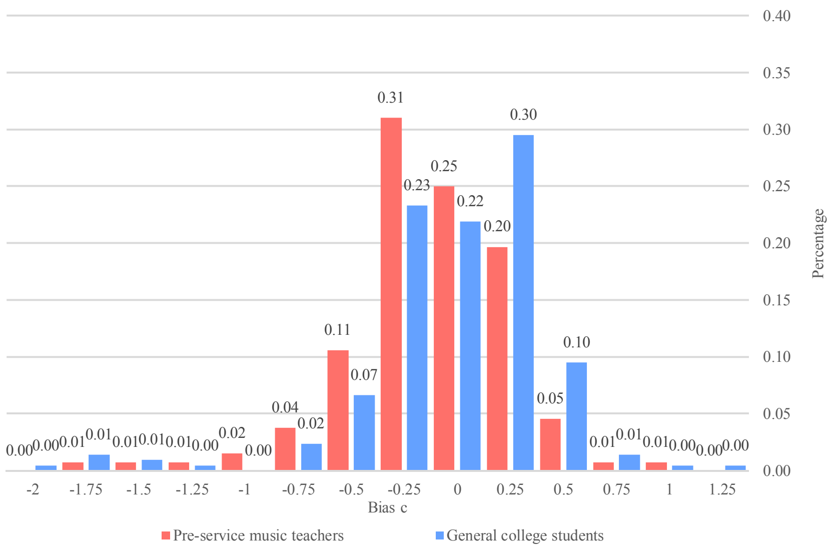
Figure IV-7

Histogram (A) and the probability mass function (B) of response bias *c* of pre-service music teachers and general college students in ‘general knowledge of the brain’

A



B



4.3.2. Educational Neuroscience

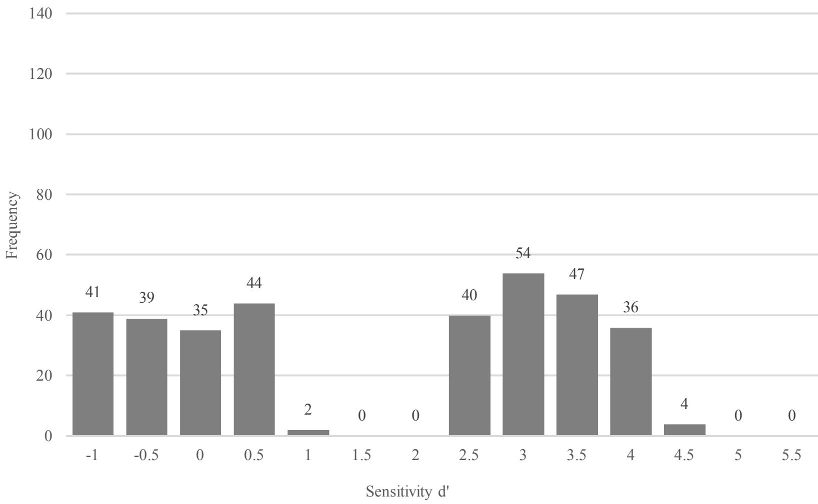
The average percentage of correct answers for ‘educational neuroscience’ statements was 39.5%. The most prevalent of educational neuromyths were (1) Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic) (E1), (2) Environments that are rich in stimulus improve the brains of pre-school children (E2), (3) Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners (E3), (4) Exercises that rehearse co-ordination of motor-perception skills can improve literacy skills (E4), and (5) It has been scientifically proven that fatty acid supplements (omega-3 and omega-6) have a positive effect on academic achievement (E9). More than 85% of the participants believed these statements were scientifically substantiated.

Contrary to the very low correct answer rates for these many items, the average sensitivity index of the participants was higher in ‘educational neuroscience’ ($d' = 1.15$, $SD = 2.371$) than in ‘general knowledge of the brain’ ($d' = 0.79$, $SD = 0.036$) or ‘neuroscience of music’ ($d' = -0.40$, $SD = 1.651$). And there was no significant difference between pre-service music teachers ($d' = 1.15$, $SD = 2.390$) and general college students ($d' = 1.15$, $SD = 2.365$). In addition, the participants were more likely to evaluate neuromyth statement as true in ‘educational neuroscience’ (average response bias $c = -1.35$, $SD = 1.098$) than in another two categories. But it made no difference between pre-service music teachers (response bias $c = -1.30$, $SD = 1.122$) and general college students (response bias $c = -1.37$, $SD = 1.085$). Distribution of sensitivity index d' and response bias c of pre-service music teachers and general college students in ‘educational neuroscience’ was presented in Figure IV-8 and Figure IV-9.

Figure IV-8

Histogram (A) and the probability mass function (B) of sensitivity index *d′* of pre-service music teachers and general college students in ‘educational neuroscience’

A



B

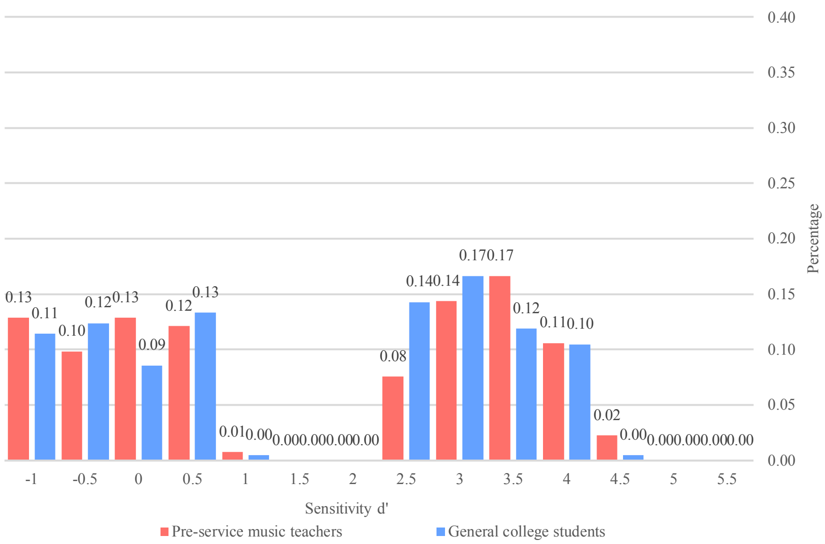
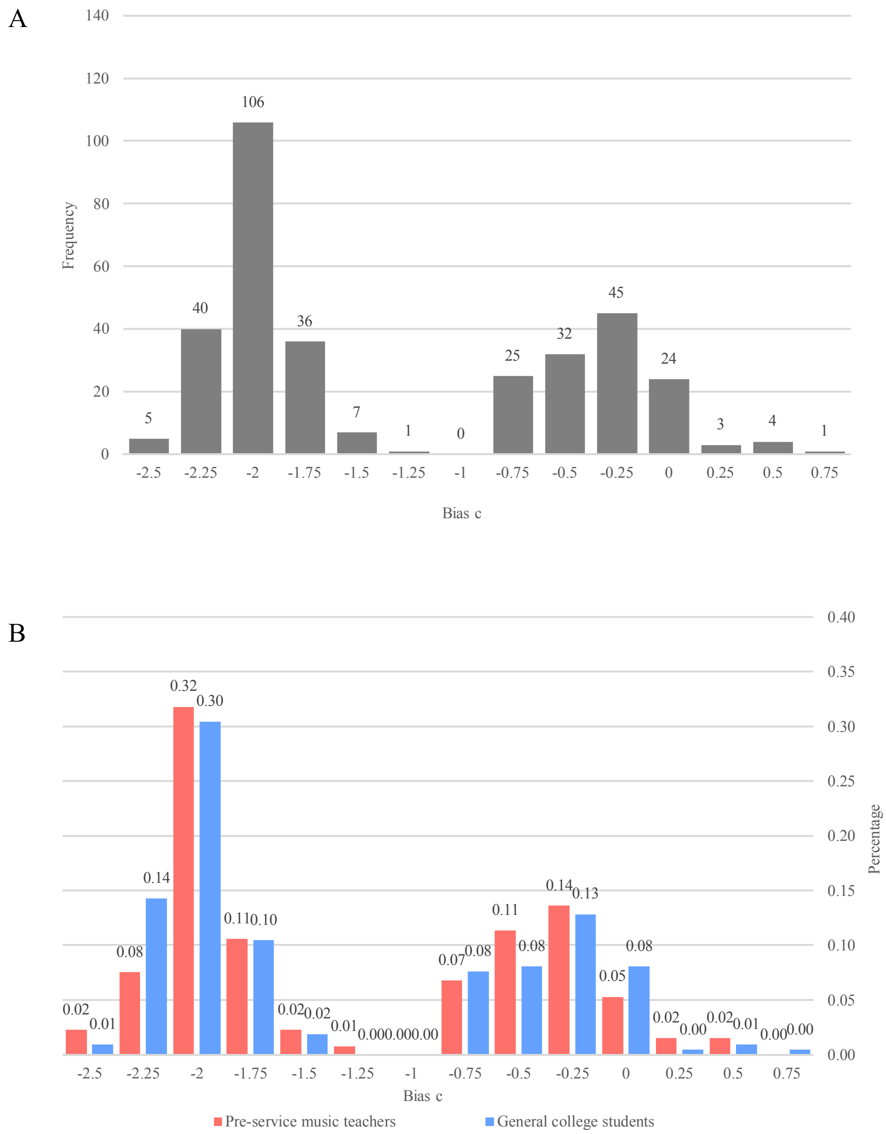


Figure IV-9

Histogram (A) and the probability mass function (B) of response bias *c* of pre-service music teachers and general college students in ‘educational neuroscience



Distribution of sensitivity index *d′* and response bias *c* of pre-service music teachers and general college students in ‘educational neuroscience’ (Figure IV-8 and Figure IV-9) showed not the bell shape (normal distribution) but the bimodal shape. To explain this unusual aspect, the non-parametric statistic was performed. The participants were divided into two groups based on sensitivity index value $d' = 2.00$ and response bias value $c = -1.00$ and the differences between them in brain-related education and the number of media was examined. As a result, there was a difference of brain-related education between two groups separated by sensitivity index value [$t(340) = 17.10$, $p = 0.004$]. And difference of brain-related education was also found between two groups separated by response bias value [$t(340) = 9.35$, $p = 0.002$]. The participants on the left side of the criteria ($d' < 2.00$; $c < -1.00$) were not instructed on neuroscience or experienced in listening to lecture related to the brain, whereas the participants on the right side of the criteria ($d' > 2.00$; $c > -1.00$) had experience with brain science. However, there was no difference in the number of media.

4.3.3. Neuroscience of Music

The average percentage of the participants’ correct answers for ‘music-related neuroscience’ statements were 44.9% (*SD* = 0.31). Most prevalent neuromyths among pre-service music teachers and general college students were: (1) “Students can improve not only musical ability but also mathematical ability through musical training” (M12), (2) “During the prenatal period or childhood, listening to music of a particular genre or composer can enhance the development of the brain especially” (M1), (3) “Musical activities, such as listening to music or playing musical instruments use right brain dominantly” (M3), (4) “Compared to left-brained students, right-brained students have a great aptitude or talent in music" (M16), and (5) "Compared to listening to music, playing musical instruments activates more areas of the brain" (M8). More than 85% of the participants answered incorrectly or chose 'do not know' for these statements. In addition, for M9, M4, M5, M11, and M7, less than 50% of the participants answered correctly.

Average sensitivity among all participants for 16 statements of 'neuroscience of music' was $d' = -0.40$ ($SD = 1.651$). Discrimination performance of the participants was lowest on music-related statements. There was statistically significant difference in sensitivity index (pre-service music teachers: $d' = 0.09$, $SD = 1.756$; general college students: $d' = -0.70$, $SD = 1.505$) [$t(340) = -4.51$, $p < 0.001$]. This indicates that general college students had more difficulties in picking out myths from music-related statements compared to pre-service music teachers. In addition, both groups had a strong tendency to evaluate the neuromyth statements as neuroscience statements (average bias $c = -0.81$, $SD = 0.744$), even though there was difference in response bias c between two groups (pre-service music teachers: $c = -1.05$, $SD = 0.757$; general college students: -0.66, $SD = 0.695$) [$t(340) = 4.95$, $p < 0.001$]. Distribution of sensitivity index d' and response bias c of pre-service music teachers and general college students in 'neuroscience of music' was presented in Figure IV-10 and Figure IV-11.

Figure IV-10

Histogram (A) and the probability mass function (B) of sensitivity index *d′* of pre-service music teachers and general college students in ‘neuroscience of music’

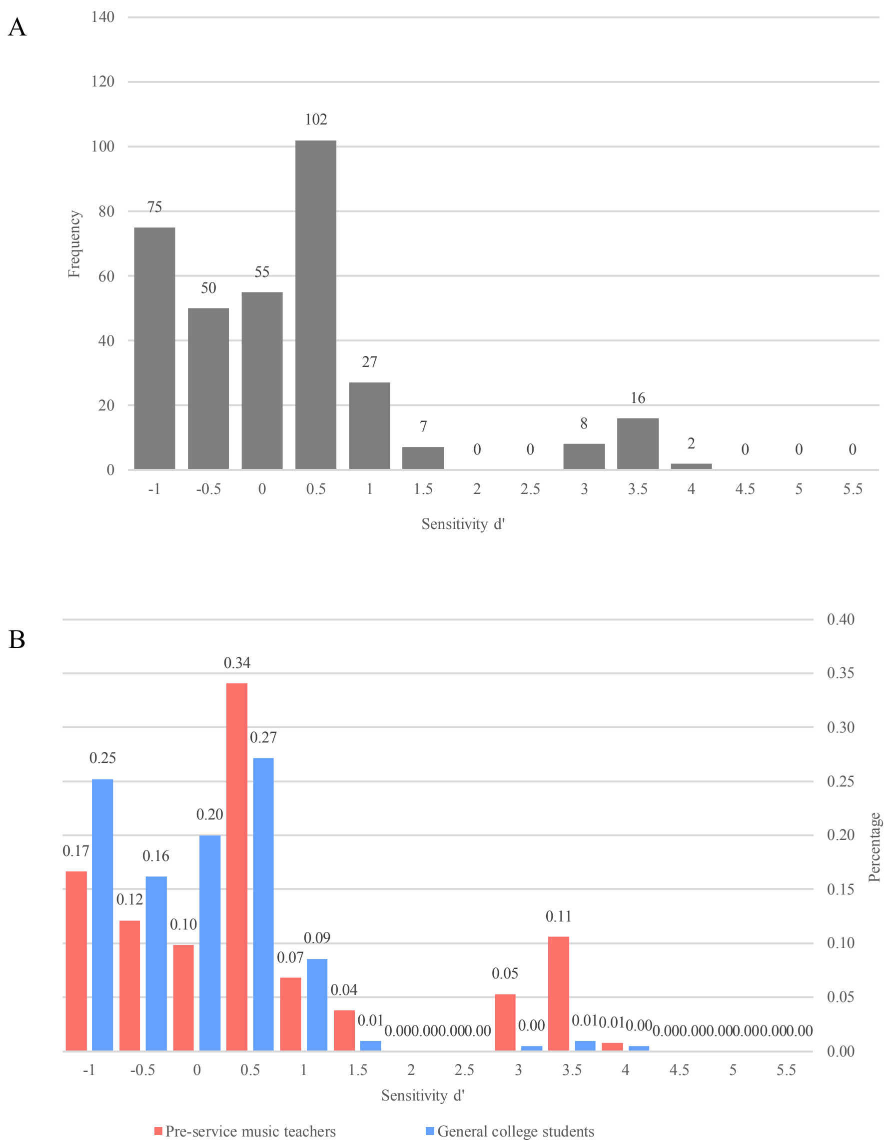
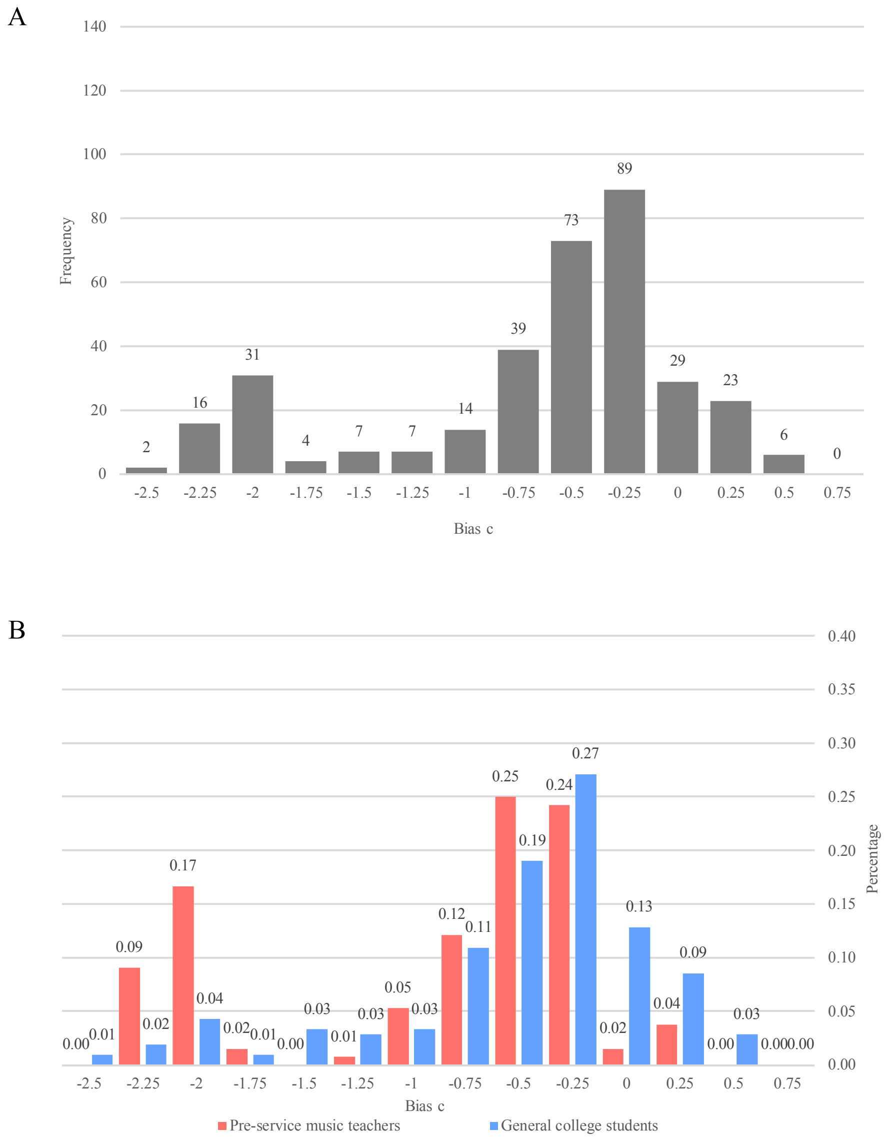


Figure IV-11

Histogram (A) and the probability mass function (B) of response bias *c* of pre-service music teachers and general college students in ‘neuroscience of music’



To determine whether there were associations among discrimination performance (sensitivity index d' and response bias c) in three categories ('general knowledge of the brain', 'educational neuroscience', and 'neuroscience of music'), correlation coefficients among them were calculated. As a result, there were very close associations among them (Table IV-4 and Table IV-5). This indicates that if a participant was good at discriminating neuroscience from neuromyth in one category, he / she was also showed superior performance in another two categories. In other words, if a participant had the tendency not to reject myth as 'false', they showed that tendency in all categories.

Table IV-4

Correlation among all participants' sensitivity index d' in three categories ('general knowledge of the brain', 'educational neuroscience', and 'neuroscience of music')

Correlation Coefficients *r*			
	d' in G itmes	**d' in E items**	**d' in M items**
d' in G itmes			
d' in E itmes	0.3488 ($p < 0.001$***)		
d' in M itmes	0.3823 ($p < 0.001$***)	0.3936 ($p < 0.001$***)	

Note. ***$p < 0.001$

Table IV-5

Correlation among all participants' response bias *c*' in three categories ('general knowledge of the brain', 'educational neuroscience', and 'neuroscience of music')

Correlation Coefficients *r*			
	***c* in G itmes**	***c* in E items**	***c* in M items**
***c* in G itmes**			
***c* in E itmes**	0.1458 (p = 0.006**)		
***c* in M itmes**	0.1832 (p < 0.001***)	0.1495 (p = 0.005**)	

Note. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

4.4. Predictors of Neuromyths

An overall discrimination performance (sensitivity index *d'* and response bias *c*) of neuromyth / neuroscience survey among pre-service music teachers and general college students was significantly predicted by brain-related education (*d'*: $p < 0.001$; *c*: $p = 0.044$) and the awareness of the importance of knowledge of the brain in music education (*d'*: $p = 0.002$; *c*: $p < 0.001$). None of the factors (age, gender, number of media, and type of media; broadcasting, newspaper, internet, journal, and book) predicted belief in myths. For sensitivity index *d'*, the model explained 10% of the variance which was significant, $F(9, 331) = 4.81$, p < 0.001 (Table IV-6). And the model explained a significant proportion of variance ($R^2 = 0.085$) in response bias *c* values, $F(9, 331) = 4.19$, p < 0.001 (Table IV-6).

Table IV-6

Predictors of discrimination performance of all 46 statements among pre-service music teachers and general college students

Predictors	Sensitivity index d'			Response bias c		
	B **(SE)**	***t***	***p***	***B*** **(SE)**	***t***	***p***
(Intercept)	-0.317 (0.173)	-1.833	0.068	-0.272 (0.071)	-3.847	0.0001
Age	-0.006 (0.021)	-0.303	0.762	0.0002 (0.009)	0.021	0.983
Gender	-0.016 (0.083)	-0.191	0.849	-0.040 (0.034)	-1.184	0.237
Brain-related Education	0.543 (0.111)	4.882	***	-0.092 (0.045)	-2.021	0.044*
Number of media	0.275 (0.295)	0.932	0.352	0.117 (0.120)	0.970	0.333
Broadcasting (media type)	-0.096 (0.299)	-0.320	0.749	-0.189 (0.122)	-1.548	0.122
Newspaper (media type)	-0.350 (0.324)	-1.080	0.281	-0.150 (0.132)	-1.130	0.259
Internet (media type)	-0.246 (0.297)	-0.826	0.410	-0.059 (0.122)	-0.489	0.625
Journal (media type)	-0.071 (0.315)	-0.225	0.822	-0.218 (0.129)	-1.692	0.092
Book (media type)	-0.280 (0.301)	-0.929	0.354	-0.034 (0.123)	-0.273	0.785
Awareness	0.134 (0.043)	3.097	0.002**	-0.067 (0.018)	-3.803	***
	Adjusted R^2 = 0.100 p-value < 0.001***			Adjusted R^2 = 0.085 p-value < 0.001***		

Note. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

To examine how the predictors differed in three categories of neuromyth / neuroscience survey (‘general knowledge of the brain’, ‘educational neuroscience’, and ‘music-related neuroscience’), the multiple regression was conducted additionally (Table IV-7, Table IV-8, and Table IV-9). As a result, sensitivity index d' in three categories were predicted by brain-related education ($p < 0.001$ for ‘general knowledge of the brain’, Table IV-7; $p = 0.008$ for ‘educational neuroscience’, Table IV-9; and $p < 0.001$ for ‘neuroscience of music’, Table IV-9) and the level of awareness of understanding the brain ($p = 0.009$ for ‘general knowledge of the brain’, Table IV-7; $p = 0.001$ for ‘educational neuroscience’, Table IV-8; and $p = 0.027$ for ‘neuroscience of music’, Table IV-9). And the awareness of importance of the knowledge of the brain predicted response bias c for ‘educational neuroscience’ ($p < 0.001$, Table IV-8) ‘neuroscience of music’ ($p = 0.009$, Table IV-9). In addition, bias c for ‘neuroscience of music’ was predicted by gender ($p = 0.022$, Table IV-9). However, none of the factors predicted the participants’ response bias in ‘general knowledge of the brain’ (Table IV-7).

Table IV-7

Predictors of discrimination performance of 'general knowledge of the brain' among pre-service music teachers and general college students

	Sensitivity index *d'*			Response bias *c*		
Predictors	***B* (SE)**	***t***	***p***	***B* (SE)**	***t***	***p***
(Intercept)	0.178 (0.243)	0.733	0.464	-0.223 (0.105)	-2.132	0.034
Age	0.007 (0.030)	0.236	0.814	0.006 (0.013)	0.484	0.629
Gender	-0.161 (0.116)	-1.385	0.167	0.041 (0.050)	0.813	0.417
Brain-related Education	0.611 (0.156)	3.914	***	0.008 (0.067)	0.125	0.901
Number of media	0.417 (0.414)	1.007	0.315	0.112 (0.178)	0.626	0.532
Broadcasting (media type)	-0.176 (0.421)	-0.418	0.677	-0.153 (0.181)	-0.847	0.398
Newspaper (media type)	-0.323 (0.455)	-0.711	0.478	-0.300 (0.196)	-1.534	0.126
Internet (media type)	-0.381 (0.418)	-0.912	0.363	0.053 (0.180)	0.294	0.769
Journal (media type)	-0.165 (0.443)	-0.373	0.709	-0.165 (0.190)	-0.869	0.386
Book (media type)	-0.454 (0.423)	-1.072	0.284	-0.0005 (0.182)	-0.002	0.998
Awareness	0.0158 (0.061)	2.602	0.0097**	-0.050 (0.026)	-1.919	0.056
		Adjusted R^2 = 0.067 *p*-value < 0.001***			Adjusted R^2 = 0.035 *p*-value = 0.015*	

Note. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table IV-8

Predictors of discrimination performance of 'educational neuroscience' among pre-service music teachers and general college students

	Sensitivity index *d'*			Response bias *c*		
Predictors	***B*** **(SE)**	***t***	***p***	***B*** **(SE)**	***t***	***p***
(Intercept)	-0.056 (0.554)	-0.101	0.919	-0.696 (0.259)	-2.688	0.008
Age	-0.0004 (0.068)	-0.006	0.995	-0.005 (0.032)	-0.153	0.879
Gender	-0.399 (0.265)	-1.507	0.133	0.126 (0.124)	1.018	0.310
Brain-related Education	0.945 (0.356)	2.652	0.008**	-0.259 (0.166)	-1.559	0.120
Number of media	0.135 (0.945)	0.143	0.887	0.001 (0.441)	0.003	0.997
Broadcasting (media type)	-0.016 (0.960)	-0.017	0.986	-0.201 (0.448)	-0.449	0.654
Newspaper (media type)	-0.066 (1.039)	-0.064	0.949	-0.116 (0.485)	-0.239	0.811
Internet (media type)	-0.412 (0.953)	-0.432	0.666	0.138 (0.445)	0.311	0.756
Journal (media type)	0.908 (1.010)	0.899	0.370	-0.493 (0.471)	-1.045	0.297
Book (media type)	-0.040 (0.966)	-0.041	0.967	-0.019 (0.451)	-0.041	0.967
Awareness	0.457 (0.139)	3.293	0.001**	-0.216 (0.065)	-3.334	***
		Adjusted R^2 = 0.071 *p*-value < 0.001***			Adjusted R^2 = 0.056 *p*-value = 0.001**	

Note. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table IV-9

Predictors of discrimination performance of 'neuroscience of music' among pre-service music teachers and general college students

Predictors	Sensitivity index d'			Response bias c		
	***B* (SE)**	***t***	***p***	***B* (SE)**	***t***	***p***
(Intercept)	-1.417 (0.390)	-3.630	0.0003	-0.456 (0.177)	-2.576	0.010
Age	-0.010 (0.048)	-0.207	0.836	-0.0001 (0.022)	-0.005	0.996
Gender	0.188 (0.186)	1.007	0.315	-0.193 (0.084)	-2.285	0.023*
Brain-related Education	0.955 (0.251)	3.805	***	-0.141 (0.114)	-1.240	0.023*
Number of media	0.505 (0.666)	0.759	0.448	0.394 (0.301)	1.308	0.192
Broadcasting (media type)	-0.147 (0.676)	-0.218	0.828	-0.397 (0.306)	-1.297	0.196
Newspaper (media type)	-0.704 (0.731)	-0.963	0.336	-0.372 (0.331)	-1.125	0.262
Internet (media type)	-0.422 (0.671)	-0.629	0.530	-0.379 (0.304)	-1.246	0.214
Journal (media type)	-0.478 (0.711)	-0.672	0.502	-0.478 (0.322)	-1.484	0.139
Book (media type)	-0.424 (0.780)	-0.623	0.534	-0.170 (0.308)	-0.554	0.580
Awareness	0.216 (0.098)	2.215	0.027*	-0.115 (0.044)	-2.600	0.0097*
	Adjusted R^2 = 0.050 p-value = 0.002*			Adjusted R^2 = 0.041 p-value = 0.007**		

Note. *p < 0.05; **p < 0.01; ***p < 0.001

CHAPTER 5. DISCUSSION

The purpose of the current study was to investigate the level of knowledge about the brain and music-related neuromyths among pre-service music teachers as well as the factors predicting the degree of neuromyth were identified. The current study can help prevent the misconception of the brain from being applied improperly to the field of music education. The main findings of this study are discussed in the following paragraphs.

5.1. Summary and Discussion of Main Findings

5.1.1. Music-related Neuromyths Embedded in Pre-service Music Teachers

According to the investigation on awareness of the importance of the knowledge of the brain in music education, 71.9% of pre-service music teachers thought that knowledge about brain could assist in learning or teaching music. This result is consistent with a previous study that confirmed that teachers generally have high interest in the brain (Radin, 2009). In most studies about the role of the brain-related knowledge in general education, about 90% of teachers responded that understanding the brain is helpful to education (Karakus et al., 2015; S. W. Park et al., 2016; Pickering & Howard-Jones, 2007; Serpati & Loughan, 2012). Considering the previous results, the result of the current study is relatively low. It showed that people still cannot easily find the relationship between music and the brain. It is also supported by the result that a number of the participants in this study responded that music does not relate to the brain because it is an emotional realm.

Nevertheless, the result that more than half of pre-service music teachers think knowledge of the brain is important in the field of music education brings us to a positive perspective. If the pre-service music teachers do not agree with the necessity of the knowledge of the brain in music education, brain-related educational program for teachers might be less effective. In order for pre-service music teachers to acquire accurate knowledge of the brain, their motivational factor is more important than anything else (S. W. Park et al., 2016). Thus, an affirmative attitude toward the knowledge of the brain among many pre-service music teachers in the current study indicates that providing pre-service music teachers with appropriate educational program can be effective to increase their level of knowledge of the brain.

Despite their affirmative attitudes, they had the low level of knowledge of the brain and false beliefs about the brain. This implies that neuromyths are widespread among teachers in Korea and this situation is not much different from other countries around the world (Dekker et al., 2012; Deligiannidi & Howard-Jones, 2015; Düvel et al., 2017; Gleichgerrcht et al., 2015; Herculano-Houzel, 2002; Karakus et al., 2015; Kelly et al., 2017; Marietta et al., 2017; Pei et al., 2015; Rato et al., 2013). Therefore, initial assumption of the current study, which pre-service music teachers would have a high degree of neuromyth was substantiated.

In the current study, four measurements - correct answer rate, ‘do not know’ rate, sensitivity index d', and response bias c - were used as indicators to investigate the knowledge of the brain among the pre-service music teachers. First, the correctly answered statements by more than 50% of the pre-service music teachers were only 27 out of 46 neuromyth / neuroscience statements. The average percentage of correct answers for three categories were the highest in ‘general knowledge of the brain’ followed by ‘neuroscience of music’ and ‘educational neuroscience’. The average correct answer rate of pre-service music teachers for each category is 65.0% for ‘general knowledge of the brain’, 40.1% for ‘educational neuroscience’, and 49.5% for ‘neuroscience of music’. Pre-service music teachers were well informed about brain-related knowledge in general but had misconceptions about education- or music-related knowledge of the brain.

In ‘educational neuroscience’ category, less than 15% of pre-service music teachers correctly answered to E1 (“Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic”), E2 (“Environments that are rich in stimulus improve the brains of pre-school children.”), E3 (Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners”), and E4 (Exercise that rehearse co-ordination of motor-perception skills can improve literacy skills”). These statements were identified as neuromyths by OECD in 2002 and were found to be the most prevalent neuromyths in the previous studies (Dekker et al., 2012; Deligiannidi & Howard-Jones, 2015; Gleichgerrcht et al., 2015; Karakus et al., 2015; Kelly et al., 2017; S. W. Park et al., 2016; Pei et al., 2015; Rato et al., 2013). This suggests that neuromyths are still widespread in educational settings and little effort has been made to lower these neuromyths, even though the increased awareness of neuromyths by many studies in recent years.

In particular, the low percentage of correct answers for the statements related to the VAK learning style (E1) and hemisphere dominance (E3) shows that there are many attempts to classify learners depending on their learning style and provide teaching-learning methods for each style. According to Park and colleagues (2016), such classification is the consequence of educators' high demand for strategies that can be applied to the practical field. By earlier research, it has been discovered that teachers think applications of knowledge of the brain to the field is the most important factor in realizing brain-based education (S. W. Park, 2016; Pickering & Howard-Jones, 2007). However, classifying students may cause problems to the student with restricted education. Moreover, it makes teachers believe that a student's learning ability is innate. Also, a false belief in enriched learning environments (E2) and transfer effect (E4) make teachers waste their times and efforts on ineffective educational practices. Therefore, pre-service teachers need more careful about the neuromyths. In addition, the accurate knowledge about the brain should be provided for them in teacher education program.

In 'neuroscience of music' category, M1 ("During the prenatal period or childhood, listening to music of a particular genre or composer can enhance the development of the brain especially"), M3 ("Musical activities, such as listening to music or playing musical instruments use right brain dominantly"), M8 ("Compared to listening to music, playing musical instruments more activates or change more parts of the brain"), M12 ("Students can improve not only musical ability but also mathematical ability through musical training"), and M16 ("Compared to left-brained students, right-brained students have a great aptitude or talent in music") were evaluated incorrectly or answered for 'do not know' by more than 85% of pre-service music teachers. M12, M3, and M16 have the same topics as the theses of the study by Düvel and colleagues (2017), that music teachers and students showed the low percentage of correct answers. It shows that music teachers have a strong belief especially in the neuromyths associated with 'music processing in the right brain' and 'transfer effect of musical abilities'.

In fact, these topics of music-related neuromyths were consistent with the topics of educational neuromyths, which were found to be prevalent in the field of general education (E2, E3, E4). M3, M16, and E3 are related to 'hemispheric dominance' and M12 and E4 are related to 'transfer effect'. And also, M1 and M8, E2 are related to 'stimulus of learning environment'. This result clearly shows what topics should be addressed in the brain-related education for teachers. The result of the current study that the participants' discrimination abilities in three categories were correlated to each other can support common topics of neuromyths that is prevalent in several academic fields.

Furthermore, the present study identified the pre-service music teachers' discrimination ability for neuromyth / neuroscience statements and response tendency, based on signal detection theory (Macmillan & Creelman, 2005). Sensitivity analysis showed that pre-service music teachers had poor discrimination ability. In comparison with general college students, pre-service music teachers were better at discrimination, but this is a relative difference and cannot be said that pre-service music teachers had good discrimination ability. In the previous research, Düvel and colleagues (2017) interpreted discrimination performance of music teachers ($d' = 1.25$, $SD = 1.12$) and music students ($d' = 1.48$, $SD = 1.22$) as a medium to large ability of discrimination. Considering their results, sensitivity index d' among pre-service music teachers in the current study ($d' = 0.41$, $SD = 0.812$) indicates that their discrimination abilities were very low. For music-related statements in the 'neuroscience of music' category, pre-service music teachers in the current study (d' = 0.09, *SD* = 1.756) had worse discrimination ability than music teachers and students of the study by Düvel and colleagues (2017).

The poor discrimination ability of the pre-service music teachers is not because of the ignorance of neuroscience, but because of neuromyths. This is supported by the result that the participants with good discrimination ability (high values for sensitivity index d') tend to be less inclined to believe in neuromyths (high values for response bias *c*) ($r = -0.516$, $p < 0.001$). Response bias *c* among pre-service music teachers ($c = -0.56$, *SD* = 0.301) shows that they seemed to evaluate statements as scientifically proven. Since a low level of the knowledge of the brain means both rejecting neuroscientific statement as 'false' and evaluating neuromyth statement as 'true', pre-service music teachers in the current study showed that they had a general tendency to evaluate neuromyth statements as scientifically proven. Pre-service music teachers had a larger tendency to evaluate neuromyth statement as 'true' than general college students ($c = -0.41$, *SD* = 0.293). And this tendency of the pre-service music teachers was more prominent in 'educational neuroscience' ($c = -1.30$, *SD* = 1.122) and 'neuroscience of music' ($c = -1.05$, *SD* = 0.757) than 'general knowledge of the brain' ($c = -0.26$, *SD* = 0.375). These results imply that pre-service music teachers are easily misled by brain-related myths, especially music-related neuromyths. This may have contributed to their low level of ability for discrimination between neuromyth and neuroscience.

Also noteworthy is that despite the presence of the 'do not know' option, a high percentage of pre-service music teachers agreed with neuromyth statements that have not been scientifically substantiated. This implies the concern that neuromyths are prevalent in educational settings more clearly (OECD, 2002; S. W.

Park et al., 2016). A strong positive correlation between ‘do not know’ rate and tendency to believe neuromyths (response bias *c*) also supports this result.

5.1.2. Predictors of Neuromyths

In the present study, good discrimination performance, high level of discrimination ability for neuromyth / neuroscience and neutrality of response, were predicted by the experience of listening lecture to a related to the brain and high level of awareness of the importance of knowledge of the brain in music education. First, participants who acquired knowledge about the brain from the lecture had good discrimination ability for neuromyth / neuroscience statements, and lower tendency to believe neuromyths. On the other hand, media, such as broadcasting, newspaper, internet, journal, and book, did not predict neuromyths significantly. A large number of the participants gained knowledge of the brain through internet, broadcasting, and book, but they couldn’t get accurate information related to brain from such media. This result implies that the media is not effective in increasing the knowledge of the brain among people. It suggests that the brain-related contents covered by the media are not clear and can lead to the risk of misconception and misunderstanding in accepting those contents.

Along with the public’s high interest in the brain, much of the brain-related contents covered in mass media such as broadcasting and the internet (van Atteveldt, van Aalderen-Smeets, Jacobi, & Ruigrok, 2014). However, the contents provided by the popular press are often misleading and this is one cause of increasing mistaken knowledge about the brain among the public, including teachers (Beck, 2010). Also, an academic journal is not a good way for raising the level of knowledge of the brain because it is difficult for non-experts to understand professional terms, methods, and results of research in neuroscientific journals. To overcome these problems, many researchers emphasize the need for active communication between neuroscientists and educators (Goswami, 2004; Howard-Jones, 2014). In the study by Park and colleagues (2016), the results that pre-service teachers, who got brain-related knowledge from broadcasting or academic journals, had a higher degree of neuromyth supports these problems.

In addition, participants, who responded that brain-related knowledge is important in the field of music education, had good discrimination ability and lower degree of neuromyth. However, this result is contrary to the findings in the previous study by Park and colleagues (2016) that participants who had the affirmative attitude toward knowledge of the brain were also had a high degree of neuromyth. This difference could exist because questions used in the previous study (S. W. Park et al., 2016) were related to general education but the question of the current study was related to music education. Since there is no empirical research on the relationship between the brain-related knowledge and the awareness of the importance of knowledge of the brain, it is necessary that it be investigated empirically and to be considered in further studies.

Additionally, another important point is that pre-service music teachers, who acquired brain-related knowledge from lecture, also had a high level of awareness of the importance of brain-related knowledge in music education. This suggests that lecture (educational programs) may be the most effective source to lower the degree of neuromyth and provide accurate knowledge of the brain in the entire education field, including music education. It is consistent with the findings of Ansari and Coch (2006) that educational program which provides information about the brain is one of the best ways to raise the level of neuroscientific literacy among teachers.

Therefore, it is necessary to provide teachers or pre-service teachers with opportunities to acquire correct knowledge about the brain and to learn strategies with scientific basis through appropriate educational programs. It is expected that brain-related educational program for music teachers will also raise awareness of the importance of the knowledge of the brain in the field of music education.

5.2. Implications of Knowledge about Music and brain for Music Education

For a long time, discussion of the value of music education has been made within an aesthetic frame. Music educators have drawn the educational value of music from the value of music as an art. With the necessity for music education that gained in doing so, music education built an abstract-wall around itself and made the scientific approach to music education difficult. In fact, unscientific and backward ideas on education do not exist only in the field of music education. Slavin (2002) criticized the inefficiency of unscientific paradigm of education, which is not based on rational thinking with the collection and analysis of objective data. Because of its characteristics, music education, in particular, is still in abstract philosophy of education or humanistic thought. Of course, there is no gainsaying the metaphysical value of music and it cannot be said that the existing philosophy of music education is wrong. However, in these days of diminishing the importance of music education and requiring fundamental and innovative changes itself, research on neuroscience of music suggests a new paradigm in the field of music education.

First, the results of neuroscientific research support the belief that musical aptitude can be acquired by learning or training. In general, musical aptitude is often thought to be an inborn talent. However, studies of brain plasticity provide scientific evidence that musical experience or learning can change a learner's brain. The belief that an ability is not innate but acquired is important to both learners and educators. According to Dweck (2012), students who learn that the brain can change have a growth mindset, be motivated, and improve their achievement level. Additionally, Dubinsky and colleagues (2013) emphasize that learning knowledge of the brain is effective in enhancing teaching competence. Therefore, neuroscientific research on brain plasticity, which shows that musical experience or training change the human brain, can strengthen the value of music education.

Neuro-musical research also suggests a direction of the way of music education to proceed. In a neuroscientific context, the reason that music is the good food for the brain is that playing musical instruments is a complex task, requiring finely-tuned motor movements, highly developed sensory abilities (in auditory, visual, tactile, and kinesthetic modalities), the integration of motor and sensory information to monitor and correct performance, and higher-order executive and attentional functions (Herholz & Zatorre, 2012; Merrett & Wilson, 2011; Schlaug et al., 2005; Wan & Schlaug, 2010; Zatorre et al., 2007). Thus, students should have more opportunities to learn musical instruments in the music educational settings. Unlike traditional learning theories that focus on conceptual understanding and memory, principles related to brain-based learning emphasize active semantic learning and a richness and a variety of experiences (Kim, 2006). This suggests that music education should not stay within teaching of musical theories.

Moreover, Neuroscientific studies give scientific evidence of the competence which is highlighted in the field of education. Today, educators aim not only to help their students have academic achievement within the subject, but also to help them develop their capacities in crosscurricula or holistically. Transfer effect, which neuroscientists have been interested for a long time, is in line with the competence. Neuroscientific research on the effects of musical training on other cognitive or behavioral abilities can help to design a competency-centered teaching-learning environment. It will also contribute to the development of integrated curriculum that integrates various learning contents.

The present study suggested that teachers' clear understanding of the brain is the most basic and essential for effective integration of music education and neuroscience. For this, music teachers or pre-service music teachers should be aware of the importance of the brain-related knowledge and learn accurate knowledge of the brain through educational programs. Scholars should identify what knowledge of the brain is of value to educators and be careful to prevent misuse or abuse of that knowledge. Also, in the long term, professional manpower training for brain-based education should be done at national level.

5.3. Limitations and Suggestions for Further Studies

Some suggestions for future studies are as follows. First, in order to ensure the representativeness of the samples, pre-service music teachers majoring in elementary or secondary education and general college students with various majors except music education were sampled. However, because the sampling is not done at the national level, it is still difficult to generalize from the findings of the study. Also, there is a lack of homogeneity between two groups in terms of gender and age. In particular, a very small number of males were included in the group of pre-service music teachers, due to the nature of the major. Therefore, it cannot be excluded the possibility that the differences in discrimination performance for neuromyth / neuroscience survey neuromyth between two groups might be due to gender difference. In further studies, it is necessary to raise the possibility of generalization of the results using sampling at national level and systematic sampling considering genders and ages of the sample.

Second, in the present study, the group of general college students included a few of students majoring in education, but not music education. However, the degree of neuromyth among pre-service teachers who major in education and general college students need to be verified separately, because majoring in education can affect the degree of neuromyth. Thus, investigation of the effect of majoring in education on the level of brain-related knowledge remains to be examined further.

Third, the survey of the study was conducted on pre-service music teachers. Pre-service teachers with current connections to the academic world are considered to be more interested in the brain and to have more opportunities for scientific education than current teachers. Nevertheless, pre-service music teachers in the current study showed poor ability to distinguish neuroscientific statements from neuromyth statements. So, it is feared that current teachers have a higher degree of neuromyth than pre-service teachers. Further studies should investigate whether there are differences in the degree of neuromyth between pre-service music teachers and current music teachers.

Fourth, this study selected the neuromyth / neuroscience statements that have been used in previous studies (Dekker et al., 2012; Deligiannidi & Howard-Jones, 2015; Gleichgerrcht et al., 2015; Karakus et al., 2015; Kelly et al., 2017; S. W. Park et al., 2016; Pei et al., 2015; Rato et al., 2013) for their validity and modified some statements through consultations with neuroscientists. However, some statements still remain controversial; there are some studies that show evidence against several statements in this study and some recent studies scientifically prove the statement that has long been known as neuromyth. Also, the wording of the statements could influence how the participants answered (‘agree’ or ‘disagree’). Therefore, further study needs to select statements through more extensive literature research and sufficient discussion with experts and to be more careful in the wording of the statements.

In addition, one of the drawbacks of the present study is the unbalanced number of neuromyth statements and neuroscience statements in ‘educational neuroscience’ category of neuromyth / neuroscience survey. This is a problem caused by using the neuromyth statements used in previous studies (Dekker et al., 2012; Deligiannidi & Howard-Jones, 2015; Gleichgerrcht et al., 2015; Karakus et al., 2015; Kelly et al., 2017; S. W. Park et al., 2016; Pei et al., 2015; Rato et al., 2013) as-is. In future research, it is necessary to use the same number of statements of neuromyth and neuroscience by modifying the statements of previous studies as appropriate.

Lastly, the present study investigated only the personal factors predicting the degree of neuromyth. However, there are various contextual factors that spread neuromyths; for example, brain images have a particularly persuasive influence on the public perception of brain research (McCabe & Castel, 2008) and the use of the term ‘brain-based’ is effective to stimulate the public’s interest in neuroscientific research (Lindell & Kidd, 2011). Therefore, multidirectional understanding of the various factors, which increase neuromyths can effectively contribute to lowering the degree of neuromyth in the field of education.

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APPENDIX

A. Questionnaire in Korean

안녕하세요.

본 설문은 예비음악교사들과 대학생들을 대상으로 음악과 뇌에 관한 인식 및 지식을 알아보기 위해 제작되었습니다. 각 문항에서 설명하고 있는 내용을 잘 읽고 한 문항도 빠짐없이 성실하게 답변해주시기 부탁드립니다. 여러분이 응답하신 내용은 관련 연구를 진행하는 데 소중한 자료로 활용될 것입니다.

본 설문은 오직 연구의 목적에만 사용됩니다.

응답하는 데 걸리는 시간은 약 15분 정도입니다.

연구에 협조해 주셔서 감사합니다.

연구자: 윤수민

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※ 개인 정보를 조사하는 것은 성별, 연령 및 전공과 같은 개인적인 요소가 음악과 뇌에 관한 인식 및 지식과 어떤 관련이 있는지를 살펴보기 위함입니다.

1. ______________대학 _________과 _________전공
2. 출생년도: _________년
3. 성별: □남자 □여자
4. 교직 과목 이수: □예 □아니오

※ 음악교육 경험이 음악과 뇌에 관한 인식 및 지식과 어떤 관련이 있는지를 살펴보기 위한 내용입니다.

1. 학교 정규음악수업 외의 음악교육 경험 (정기적으로 꾸준히 받아온 음악교육만 해당합니다.)

   □ 없음 (아래의 세 개 질문에 응답하지 않으셔도 되며, 바로 다음 문항으로 넘어가주세요.)

   □ 1 년 미만 □ 1 년 이상 □ 5 년 이상

   □ 10 년 이상 □ 20 년 이상

2. 음악교육 유형: □ 기악 (악기: ______________) □ 성악

3. 음악교육을 시작한 나이: 만 ______세

※ 뇌에 대한 이해가 음악교육에 도움이 된다고 생각하는지에 대한 내용입니다. 이 문항에는 정답이 있는 것이 아니므로 자신의 생각을 솔직하고 성실하게 답변해주시기 바랍니다.

1. 뇌를 이해하는 것이 음악교육을 받거나 행하는 데 있어 도움이 된다고 생각하십니까?

1	2	3	4	5
전혀 아니다	아니다	보통이다	그렇다	매우 그렇다

2. 위와 같은 답을 한 이유는 무엇입니까?

   ____

   ____

※ 뇌와 관련된 교육을 받은 적이 있는지의 여부와 뇌와 관련된 지식을 주로 얻는 방법에 대한 내용입니다. 솔직하게 응답해주시기 바랍니다.

1. 뇌과학 및 신경과학적 내용을 다루는 수업을 수강하는 등 뇌와 관련된 교육을 받은 적이 있습니까?

   □ 예 □ 아니오

2. 뇌와 관련된 지식을 주로 얻는 방법은 무엇입니까? (중복 응답 가능)

□방송 □신문 □인터넷 □학문저널 □책

※ 음악과 뇌, 그리고 학습에 관한 내용입니다. 다음에 제시되는 내용을 잘 읽고 한 문항도 빠짐없이 응답해주시기 바랍니다. 도저히 모르겠는 경우에는 '모르겠다' 로 응답하실 수 있습니다.

		그렇다	그렇지 않다	모르겠다
1	좌뇌 혹은 우뇌를 더 잘 사용하는 반구 우월성은 학생 간 개인차를 설명하는 데 도움이 된다.			
2	뇌의 특정 기능을 계속해서 사용하면 그 기능이 강화되고, 반대로 사용하지 않으면 그 기능을 잃는다.			
3	음악을 듣거나 악기를 연주하는 등 음악과 관련된 활동은 우뇌를 주로 사용한다.			
4	아동기에는 무엇을 배우기에 조금 더 수월한 민감기가 존재한다.			
5	일반적으로 남학생의 뇌가 여학생의 뇌보다 크다.			
6	학습은 새로운 뇌세포를 생성시킨다.			
7	어린 나이에 악기를 배우는 것은 좌뇌와 우뇌 기능의 통합을 크게 향상시킬 수 있다.			
8	큰 뇌를 가진 동물일수록 높은 지능을 보인다.			
9	음악적 경험은 아동과 성인 모두의 뇌에 영향을 미친다.			
10	어떠한 경험에 의한 뇌의 변화는 다른 행동의 습득을 강화시키거나 방해할 수 있다.			
11	음악적 경험 및 훈련은 뇌를 변화시킬 수 있다.			
12	자극이 풍부한 학습 환경은 아동의 뇌를 더욱 발달시킨다.			
13	특정 과제를 반복 훈련하면 뇌의 특정 부분의 모양과 구조를 변화시킬 수 있			

	다.			

14	음악을 들을 때에는 청각을 담당하는 뇌 영역만이 활성화 된다.			
15	좌뇌와 우뇌는 항상 함께 작용한다.			
16	좌뇌에 비해 우뇌가 더 발달된 학생들은 음악에 더 많은 소질 및 재능을 보인다.			
17	지능은 유전적이며 환경이나 경험에 의해 변하지 않는다.			
18	음악 교육으로 인한 뇌의 발달은 음악적 능력 뿐만 아니라 수학적 능력 또한 향상시킨다.			
19	성장기가 지난 뇌는 거의 정지 상태이며 변하지 않는다.			
20	비타민 보충제나 지방산 보충제(오메가-3와 오메가-6)가 아동의 뇌 발달 및 학습에 긍정적인 영향을 미친다는 것은 과학적으로 증명된 사실이다.			
21	음악 교육을 시작하는 나이가 어릴수록 뇌가 더 쉽게 변화한다.			
22	시각 장애인의 뇌의 시각 담당 영역은 손상되어 아무런 역할도 하지 못한다.			
23	음악적 경험은 유아 및 언어 장애를 가진 사람들의 언어적 능력 향상에 도움을 줄 수 있다.			
24	뇌의 변화는 어릴수록 더욱 쉽게 일어난다.			
25	기억은 뇌의 특정 부분에 저장된다.			
26	음악 활동은 뇌의 특정 부분을 사용한다.			
27	우리는 뇌의 10% 정도만 사용한다.			
28	뇌는 24시간 활동한다.			
29	절대음고를 가지고 있는 학생들의 뇌와 상대음고를 가지고 있는 학생들의 뇌는 해부학적으로 차이가 있다.			
30	학습은 뇌의 신경연결망의 변화를 일으킬 수 있다.			

31	특정 기능을 담당하는 뇌 영역이 손상되면 다른 뇌 영역이 그 기능을 대신할 수 있다.			
32	신경세포의 밀도는 성인이 될수록 높아진다.			
33	악기 연습으로 인한 손가락 움직임의 발달은 손가락 근육 그 자체의 발달을 의미한다.			
34	일반적으로 뇌의 발달이란 새로운 신경세포의 생성 및 소실, 그리고 신경세포 간의 연결인 시냅스의 증가 및 감소 등을 의미한다.			
35	뇌는 환경이나 경험에 의해 스스로 변화한다.			
36	태아기 또는 아동기에 특정 장르나 작곡가의 음악을 들으면 뇌의 발달이 특별히 촉진될 수 있다.			
37	아동기에는 특정 시점이 지나면 무엇을 배울 수 없는 결정적 시기가 존재한다.			
38	성인 이후가 되면 뇌에서 새로운 연결은 더이상 일어나지 않는다.			
39	운동-지각 협응 훈련은 학생들의 글 읽고 쓰는 능력을 증진시킬 수 있다.			
40	음악가의 뇌와 비음악가의 뇌는 구조적 및 기능적으로 큰 차이를 보인다.			
41	우리가 잠이 들면 뇌도 활동을 멈춘다.			
42	학생들은 그들이 선호하는 학습양식 (예: 시각적, 청각적, 운동적)에 맞게 정보를 받을 때 더 잘 학습한다.			
43	음악을 수동적으로 듣기만 할 때 보다 악기를 연주할 때, 뇌의 더 많은 부분이 활성화 된다.			
44	뇌에서 발생하는 신경세포 간 새로운 연결은 나이가 들어도 계속된다.			
45	단지 몇 번 음악을 반복해서 듣는 것만으로도 뇌의 기능이 변화할 수 있다.			

46	좌뇌와 우뇌의 역할은 완전히 독립적이다.			

B. Statements of Neuromyth / Neuroscience Survey in English and Korean

Item #	Statements	Answer
General Knowledge of the Brain		
G1	Memory is stored in a tiny piece of the brain. 기억은 뇌의 특정 부분에 저장된다.	False
G2	The left and right hemispheres work together. 좌뇌와 우뇌는 항상 함께 작용한다.	True
G3	The roles of the left and right hemisphere of the brain is independent. 좌뇌와 우뇌의 역할은 완전히 독립적이다.	False
G4	Boys have bigger brains than girls. 일반적으로 남학생의 뇌가 여학생의 뇌보다 크다.	True
G5	Animals with a big brain are more likely to have a high level of intelligence. 큰 뇌를 가진 동물일수록 높은 지능을 보인다.	False
G6	We use our brains 24 h a day. 뇌는 24시간 활동한다.	True
G7	When we sleep, the brain shuts down. 우리가 잠이 들면 뇌도 활동을 멈춘다.	False
G8	Repetitive training for a certain task can change the shape and structure of the brain. 특정 과제를 반복 훈련하면 뇌의 특정 부분의 모양과 구조를 변화시킬 수 있다.	True
G9	New connections in brain do not occur in old age. 성인 이후가 되면 뇌에서 새로운 연결은 더이상 일어나지 않는다.	False
G10	After the growing periods, brain development has also finished. 성장기가 지난 뇌는 거의 정지 상태이며 변하지 않는다.	False

G11	Production of new connections in the brain can continue into old age. 뇌에서 발생하는 신경세포 간 새로운 연결은 나이가 들어도 계속된다.	True
G12	Continued use of a specific brain function can lead to an enhancement of that function, while a lack of use can degrade brain function. 뇌의 특정 기능을 계속해서 사용하면 그 기능이 강화되고, 반대로 사용하지 않으면 그 기능을 잃는다.	True
G13	Human brain self-organizes in response to environment or experience. 뇌는 환경이나 경험에 의해 스스로 변화한다.	True
G14	Brain plasticity occurs more readily in younger brains. 뇌의 변화는 어릴수록 더욱 쉽게 일어난다.	True
G15	Experience-dependent changes in the brain can enhance or impede the acquisition of other behaviors. 어떠한 경험에 의한 뇌의 변화는 다른 행동의 습득을 강화시키거나 방해할 수 있다.	True
G16	When a brain region is damaged, other parts can take up its function. 특정 기능을 담당하는 뇌 영역이 손상되면 다른 뇌 영역이 그 기능을 대신할 수 있다.	False
G17	Visual area of the blind person's brain is damaged and does nothing. 시각 장애인의 뇌의 시각 담당 영역은 손상되어 아무런 역할도 하지 못한다.	False
G18	The density of brain cells increases with age. 신경세포의 밀도는 성인이 될수록 높아진다.	False

Educational Neuroscience		
E1	Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic).	False
	학생들은 그들이 선호하는 학습양식 (예: 시각적, 청각적, 운동적)에 맞게 정보를 받T을 때 더 잘 학습한다.	
E2	Environments that are rich in stimulus improve the brains of pre-school children.	False
	자극이 풍부한 학습 환경은 아동의 뇌를 더욱 발달시킨다.	
E3	Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners.	False
	좌뇌 혹은 우뇌를 더 잘 사용하는 반구 우월성은 학생 간 개인차를 설명하는 데 도움이 된다.	
E4	Exercise that rehearse co-ordination of motor-perception skills can improve literacy skills.	False
	운동-지각 협응 훈련은 학생들의 글 읽고 쓰는 능력을 증진시킬 수 있다.	
E5	We only use 10% of our brain.	False
	우리는 뇌의 10% 정도만 사용한다.	
E6	There are critical periods in childhood after which certain things can no longer be learned.	False
	아동기에는 특정 시점이 지나면 무엇을 배울 수 없는 결정적 시기가 존재한다.	
E7	Mental capacity is genetic and cannot be changed by environment or experience.	False
	지능은 유전적이며 환경이나 경험에 의해 변하지 않는다.	
E8	Learning occurs through changes to the connections between brain cells.	True
	학습은 뇌의 신경연결망의 변화를 일으킬 수 있다.	
E9	It has been scientifically proven that fatty acid supplements (omega-3 and omega-6) have a positive effect on academic achievement.	False
	비타민 보충제나 지방산 보충제(오메가-3와 오메가-6)가 아동의 뇌 발달 및 학습에 긍정적인 영향을 미친다는 것은 과학적으로 증명된 사실이다.	
E10	Learning stimulates the creation of new brain cells.	False

	학습은 새로운 뇌세포를 생성시킨다.	

E11	Normal brain development involves the birth / death of brain cells and increase / decrease of synapses. 일반적으로 뇌의 발달이란 새로운 신경세포의 생성 및 소실, 그리고 신경세포 간의 연결인 시냅스의 증가 및 감소 등을 의미한다.	True
E12	There are sensitive periods in childhood when it’s easier to learn certain things. 아동기에는 무엇을 배우기에 조금 더 수월한 민감기가 존재한다.	True

Neuroscience of Music		
M1	During the prenatal period or childhood, listening to music of a particular genre or composer can enhance the development of the brain especially. 태아기 또는 아동기에 특정 장르나 작곡가의 음악을 들으면 뇌의 발달이 특별히 촉진될 수 있다.	False
M2	Musical experience or training can change human brain. 음악적 경험 및 훈련은 뇌를 변화시킬 수 있다.	True
M3	Musical activities, such as listening to music or playing musical instruments use right brain dominantly. 음악을 듣거나 악기를 연주하는 등 음악과 관련된 활동은 우뇌를 주로 사용한다.	False
M4	Musical activities use only specific parts of the brain. 음악 활동은 뇌의 특정 부분을 사용한다.	False
M5	The acquisition of fine finger movements that result from the instrumental training means development of the finger muscles themselves. 악기 연습으로 인한 손가락 움직임의 발달은 손가락 근육 그 자체의 발달을 의미한다.	False
M6	Musical experience affects the brain of both children and adults. 음악적 경험은 아동과 성인 모두의 뇌에 영향을 미친다.	True
M7	Even just listening to music several times over can change brain function. 단지 몇 번 음악을 반복해서 듣는 것만으로도 뇌의 기능이 변화할 수 있다.	True
M8	Compared to listening to music, playing musical instruments activates more areas of the brain. 음악을 수동적으로 듣기만 할 때 보다 악기를 연주할 때, 뇌의 더 많은 부분이 활성화 된다.	False
M9	There are structural differences between students with absolute pitch and relative pitch. 절대음고를 가지고 있는 학생들의 뇌와 상대음고를 가지고 있는 학생들의 뇌는 해부학적으로 차이가 있다.	True
M10	Active engagement with music can help improve linguistic ability in children and people with a speech disorder.	True

	음악적 경험은 유아 및 언어 장애를 가진 사람들의 언어적 능력 향상에 도움을 줄 수 있다.	
M11	Structural and functional differences have been found in the brains of musicians and non-musicians. 음악가의 뇌와 비음악가의 뇌는 구조적 및 기능적으로 큰 차이를 보인다.	True
M12	Students can improve not only musical ability but also mathematical ability through musical training. 음악 교육으로 인한 뇌의 발달은 음악적 능력 뿐만 아니라 수학적 능력 또한 향상시킨다.	False
M13	When we listen to music, only auditory-related parts of the brain are activated. 음악을 들을 때에는 청각을 담당하는 뇌 영역만이 활성화 된다.	False
M14	The younger the age of onset of music education, the easier the brain change. 음악 교육을 시작하는 나이가 어릴수록 뇌가 더 쉽게 변화 한다.	True
M15	Learning musical instruments at an early age can improve integration of left and right hemispheric brain function. 어린 나이에 악기를 배우는 것은 좌뇌와 우뇌 기능의 통합을 크게 향상시킬 수 있다.	True
M16	Compared to left-brained students, right-brained students have a great aptitude or talent in music. 좌뇌에 비해 우뇌가 더 발달된 학생들은 음악에 더 많은 소질 및 재능을 보인다.	False

국문 초록

신경계 신화에서 신경과학으로
- 예비음악교사들의 음악 관련 신경계 신화 수준과 예측요인을 중심으로 -

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최근 30 년 간 뇌 과학의 발전은 다양한 학문 분야의 패러다임을 바꾸어 놓았다. 교육 분야에는 교육신경과학(educational neuroscience)이라는 새로운 학문이 등장하여 교육과 신경과학의 융합을 시도하고 있으며, 음악 분야에서는 음악신경과학(neuroscience of music)이라는 새로운 연구 분야에서 음악을 하는 인간의 뇌에 대한 연구가 활발히 이루어지고 있다. 이러한 배경 속에 음악교사들도 올바른 뇌 지식을 갖출 것이 요구되고 있다. 그러나 이러한 학문적 융합의 과정에서 뇌와 관련된 잘못된 믿음인 신경계 신화가 발생하고 있으며, 이러한 교사들의 잘못된 지식이 교수학습방법에 적용되고 있어 경각심을 불러일으키고 있다.

본 연구는 음악예비교사들을 대상으로 그들의 신경계 신화 수준을 확인하기 위해 선행 연구들을 바탕으로 '뇌에 대한 기본적인 지식'과 '교육신경과학', 그리고 '음악신경과학'의 세 가지 주제에 대해 과학적으로 증명되거나 증명되지 않은 46 개의 설문 문항을 만들어 사용하였다. 총 132 명의 예비음악교사들이 설문에 참여하였으며, 이들의 신경계 신화 수준은 210 명의 일반대학생들과 비교되었다.

연구결과, 참여자들의 50% 이상이 정답을 맞춘 문항은 전체 46 개의 문항 중 23 개에 불과했다. 예비음악교사와 일반대학생 모두

‘뇌에 대한 기본적인 지식’에 비해 ‘교육신경과학’과 ‘음악신경과학’ 영역에서 더 낮은 평균 정답률을 보였다. 신호탐지이론(signal detection theory)에 의한 민감도 분석을 통해 참여자들의 신경과학/신경계 신화 구별 능력을 확인한 결과, 전체 설문 문항에 대해 예비음악교사는 평균 민감도 지수 $d' = 0.41$ ($SD = 0.81$), 일반대학생은 평균 $d' = 0.07$ ($SD = 0.68$)이었다. 전반적으로 참여자들은 신경계 신화 문항을 잘 구별해 내지 못했지만, 일반대학생보다는 예비음악교사들의 구별 능력이 더 우수했다. 이러한 구별 능력은 음악과 관련된 문항에서 현저하게 낮은 것으로 나타났다. 또한 예비음악교사와 일반대학생은 세 개의 영역 모두에서 문항들을 과학적으로 증명된 것으로 인식하고 있는 경향이 있었다(예비음악교사: 평균 반응 편향 $c = -0.56$, 일반대학생: 평균 반응 편향 $c = -0.41$). 참여자들의 이러한 신경계 신화는 뇌와 관련된 교육 경험 여부와 음악교육에서의 뇌 지식의 중요성에 대한 인식 수준에 의해 예측되었다($R^2 = 0.10$). 강의나 기타 교육 프로그램을 통해 뇌와 관련된 지식을 습득할 수록, 음악교육에서 뇌에 대해 이해하는 것이 중요하다고 생각할 수록 신경계 신화 수준이 낮은 것으로 나타났다.

이러한 연구결과는 예비음악교사들에게 음악교육에서의 뇌 지식의 중요성을 알리고 그들의 신경계 신화 수준을 낮추는 동시에 신경과학적 문식을 높이는 데 교육 프로그램이 가장 좋은 방법일 수 있음을 보여준다. 예비음악교사들은 그들의 신경계 신화가 올바르지 않은 교수방법으로 이어질 수 있음을 주지하고, 신경과학적 지식을 습득하는 데 있어 과학적 사실과 사실이 아닌 것을 구별해 내는 역량을 갖추기 위해 노력해야 할 것이다. 또한 교원양성과정에서 예비교사들을 대상으로 뇌 관련 교육이 이루어져야 하며, 신경과학자와 교육자, 그리고 음악학자 등 관련 분야의 연구자들은 소통을 통해 두 학문 분야 간의 거리를 좁히기 위해 노력해야 한다.

주요어: 신경계 신화, 예비교사, 음악신경과학, 교육신경과학, 뇌

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