The impact of competence in tonal and non-tonal languages on musical experience.

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Introduction

I grew up in a multilingual household where my parents often spoke three or more languages, especially around their friends, colleagues, and neighbors. Often, they would speak a language I could not understand when they wanted to have conversations that I should not pe a part of. My mother, who speaks 5 languages, is also a very skilled pianist and she was already taking lessons at the age of 3. This got me thinking at a very young age about if language could possibly influence how well someone played an instrument. Fast forward to years later when I had already been playing the piano for quite some time, I became very interested in languages. I started to try and learn all the languages that I could hear around me, although with varying successes. Today I speak 5 languages fluently and understand a handful more that I cannot speak fluently. As I started to learn and understand more and more languages, whether it be in school or by myself, I also became a better pianist. This led me to really focus my attention on music, and I sent my application to the Languagen high school which is the leading institution for music education in Bergen at the undergraduate level. After graduating from that school, I soon applied to and was accepted by the University of Agder's Bachelor Program for classical piano. As individuals who have had a higher education in music certainly know, one is often surrounded by different cultures in such a setting.

The moment I became interested in the role of tonal languages and music experience came when I was in the classroom taking account of two of my classmates playing Frédéric Chopin's étude No.1 Op.10, which is a fairly difficult piece to learn, both in terms of technicality and musical expression. Firstly, my Norwegian classmate started playing the piece. While he was doing a fairly good job, he had already practiced the piece for a week or so, and it did not sound as good as it should. Next on the stage was my classmate from Hong Kong, who spoke Cantonese (a tonal language) as her first language. She had only practiced the piece for less than 3 days at that point and was already playing it by heart and almost perfectly with minimal mistakes and a great expression. From that moment on, I remember thinking to myself that tonal language experience must have a positive effect and correlation with musical experience. These experiences therefore provide the initial incentive for the following hypothesis in this dissertation: Individuals with tonal language backgrounds have a higher understanding of music and enhanced musical experience.

I take reservations to the fact that this is not a pedagogical dissertation. I will rather be looking at empirical research papers that may or may not point to evidence supporting my hypothesis.

Methodology section

In this thesis I will attempt to find out the effect of tonal language background on musical experience. To achieve this, I discuss different empirical studies published in the field, drawing on key findings in order to answer my research question. These studies encompass several fields of study, which will be explained later in the text. Since the relationship between music and languages is a broad topic, I will delimit my study by selecting specific fields of research regarding the relationship between tonal languages and musical experience. This field is what is referred to as "pitch processing". Pitch processing is essentially how our brains decode or deal with pitch. This can be used to refer to both pitch in speech, but also in music. Both types of pitch processing are intrinsic to this dissertation, since I will attempt to find a correlation concerning their combined use in our brains. Pitch is processed in the auditory cortex of the brain. There it combines the information it receives to form our understanding of pitch (Plack, Barker, & Hall, 2014). Pitch processing is also explained in more detail and referred to multiple times later in this paper. Thereby granting the passage into more specific questions.

Other aspects which I will attempt to answer regarding the hypothesis, is which types of technologies are used to measure and give an exact reading as well as a clear picture of the brain activities when measuring pitch processing. There I have found that Event Related Potentials (ERPs) [1] provide an excellent insight into how our brains measure and react to changes in pitch, tones as well as speech. This type of measuring technology is also useful at determining musical experience based off how the participant(s) in the testing react to the musical input they are being fed. This is also presented in much more detail in the main part of my dissertation.

In the introductory section of this dissertation, I will attempt to explore and explain some methods and fields of study used in musicological research, as well as introduce the reader to linguistics, since it is also a central part of the hypothesis. I will discuss topics such as music psychology, music cognition and the different ways our brains process music. Furthermore, I will explain the differences between tonal and non-tonal languages, and how we can measure musical experience. The main part of this dissertation includes seven papers out of which six are studies. These studies are all similarly executed, although with varying outcomes, variables, and content.

[1] Explained on page 17

In this dissertation I refer to several important findings addressing my research question. Mireille Besson & Frédéric Faïta studied the response in musicians and non-musicians' brains when they were presented with linguistic and musical input. This study addresses the differences between musicians and non-musicians (An event-related potential (ERP) Study of Musical Expectancy: Comparison of Musicians with Nonmusicians, 1995).

Lutz Jäncke's paper is not a study as the other ones, being rather a discussion and compilation of other papers. It talks about how music and language were traditionally seen as different areas of neurological research and how that view has changed in the last couple of decades. He mentions three papers in his summary, of which I have chosen to include two in the main research section of this thesis (The Relationship Between Music and Language, 2012).

Ryan Giuliano, Peter Pfordresher, Emily Stanley, Shalini Narayana & Nicole Y. Wicha discuss how ERPs can be used to reveal if tonal language speakers have a better perception of pitch than non-tonal speakers. They present evidence that suggests native tonal language speakers having a general enhancement of pitch perception (Native Experience with a Tone Language Enchances Pitch Discrimination and the Timing of Neural Responses to Pitch Change, 2011).

The paper by Isabelle Peretz, Sebastien Nguyen & Stéphanie Cummings has a similar pretext as the study by Giuliano et al., although the outcome is vastly different. Using tonal language speakers and non-tonal language speakers as their participants, they present evidence suggesting that tonal language speakers may inherently possess an impairment towards perception of certain pitch changes (Tone Language Fluency Impairs Pitch Discrimination, 2011).

Mary Kim Ngo, Kim-Phuong L. Vu & Thomas Z. Strybel' examines both tonal language speakers as well as trained musicians to determine their pitch processing abilities. They tested the participants in two separate sessions. Results showed that musicians outperformed non-musicians on both tests, while tonal language speakers only outperformed the non-tonal speakers on one of the tests. Which may suggest that musicians have an overall better pitch perception than tonal language speakers (Effects of Music and Tonal Language Experience on Relative Pitch Performance., 2016).

C. Creel, Mengxing Weng, Genyue Fu, Gail D. Heimann & Kang Lee's study concerns itself with young children's ability to process musical pitch. They tested both children with tonal language backgrounds as well as non-tonal language speaking children. Their results showed an advanced pitch processing in tonal language speaking children. Thereby concluding with the fact that tonal language knowledge at an early stage in life benefits music perception.

The researchers also mention genetic influence being a possible contributor to their results. (Speaking a tone language enhances musical pitch perception in 3–5-year-olds, 2018).

The last research paper that I have analyzed is written by Patrick C. M. Wong, Xing Kang, Kay H. Y. Wong, Hong-Cheong So & Xiujuan Geng. The paper is different from the other studies wherein it aims to find a possible genetic connection. This may prove that a certain type of gene can enhance both linguistic and musical pitch perception in tone language speakers who possess this gene compared to non-tonal speakers who do not possess it. (ASPM-lexical tone association in speakers of a tone language: Direct evidence for the genetic-biasing hypothesis of language evolution, 2020).

These research papers are all empirical studies wherein the publishing researchers have tested individuals on their linguistic or musical abilities. Each of the studies analyzed concern themselves either with tonal languages, musical experience, or both[2]. The first paper [3] compares pitch processing music in musicians versus non-musicians' brains. This study was also among the first published to utilize ERPs in musical settings as it was mainly used in cognitive research in combination with electroencephalography [4]. By doing this experiment, they wanted to find out how musicians and non-musicians process musical expectancy. The second paper [5] talks about how music and language has traditionally been seen as highly diverging areas, and how their possible convergence had not been researched until recently. This study also compiles several other research articles in which the subject of tonal languages and musical experience is the main focus. Therefore, it is of utmost importance to this dissertation, as it provides a "launch-pad" for further analyses into this field.

From Jäncke's paper, we move on further into studies involving event-related potentials, although this time, it is the role of tonal vs non-tonal language speakers that is the focus of the study [6]. This particular study strongly correlates with the first paper in that the same outcomes were found in tonal language speakers, as in musicians. This study also mentions a possible genetic influence into how people process linguistic and musical input. However, the next study [7] although similarly executed, showed vast differences in the pitch processing of tone speakers. With results varying from tonal language speakers not being able to detect some pitch changes compared to non-tonal language speakers to tonal language speakers being equal to non-tonal speakers in terms of pitch perception, and possibly having an

[2] See (Ngo, Vu, & Strybel, 2016).
[3] See (Besson & Faïta, 1995)
[4] See (Berger, 1929)
[5] See (Jäncke, 2012)
[6] See (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011)
[7] See (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011)

impairment due to certain factors which are discussed more in depth in my analysis. The next paper [8], and the most detailed one, compares both tonal vs non-tonal language speakers as well as musicians vs. non-musicians in the same study. This outcome results in more accurate descriptions of the different processes that are involved in the main part of the experiment. They also use another type of index different from ERP's which is called the CWS index. This is again further explained in my analysis of the study. The study showed, among other things, that musicians were better at recognizing differences in pitch. As well as tonal language speakers having a higher level of relative pitch perception.

The results of this study are also extremely important to my own conclusion on the matter of tonal language speakers having enhanced musical experiences. The following paper [9] is similar to the previous one, albeit having quite a significant difference. That being the participants' age. This paper used children aged 3-5 to determine how young children process pitch. The children were separated into two groups, one tonal speaking and one non-tonal speaking. Their results showed that while young children were less accurate at detecting pitch changes, they could more accurately detect pitch contour. The researchers also mention that their outcome may have genetic implications as well, based on other studies that they mention in the paper. Thereby, we move on to the last paper [10]. In this study, the scientists wanted to show evidence of genetic factors having an impact on language evolution and musical training. They used tonal speaking individuals wherein they found that they had a gene called ASPM which aided their lexical tone processing. Again, these terms are further disclosed and explained in more detail in the analysis of this study. Although the genetic factors were there, it did not seem that it had a significant effect on musical training and experience. The results of this study are interesting to note in relation to previous studies, as well as the conclusion.

These are the studies shortly summarized which I have included in the main part of this dissertation. The results from all studies summarized, gave rise to the conclusion that all may not be as it seemed in the beginning of my hypothesis. Although to understand the analyses of these studies, we must first look at how and why these studies are important to the hypothesis. The way to do that, is by looking at which fields of study are of importance to the research papers, as well as my own hypothesis and conclusion. Below, you will find different areas of research which contributed to the development of this dissertation paper, as well as to musicological expertise.

[8] See (Ngo, Vu, & Strybel, 2016)
[9] See (Creel, Weng, Fu, Heyman, & Lee, 2018)
[10] See (Wong, Kang, Wong, So, & Geng, 2020)

Music psychology in relation to language

Music psychology is a field of study which aims to explain musical experiences through understanding how the mind responds to music. This definition encompasses the musical processes and everyday musical experiences that we as humans perceive. Music psychology in and of itself is a mostly empirical field, wherein researchers seek to study and observe different outcomes of musical perception (pitch, rhythm, harmony, and melody) in a group of people. This can help us better understand and further research in other areas such as musical performance, music education and musical therapy.

While music psychology is a rapidly evolving and vast field of study, I will draw on certain studies of particular relevance to understanding how we experience tonal and non-tonal languages and possible connections to music. Berry's acculturation theory is one such example. This theory also called "Barry's model of acculturation" is a model by John W. Berry a psychologist known for his work in cultural influences and behavior and also intercultural contact between immigrants and indigenous peoples (Worthy, Lavigne, & Romero, 2020). Its two key factors are as follows:

1. Cultural maintenance: maintaining a culture by valuing and preserving one's identity.
2. Participation and contact: wherein an immigrant culture has contact and involvement with the dominant culture and or other cultures.

These are further explained in the so called "acculturation strategies" proposed by Berry. There are four strategies which are classified followingly:

1. Assimilation: When a person or a people group has completely lost any evidence of belonging to an immigrant culture. They have assimilated into the native population and have no cultural ties to their own ethnicity.
2. Separation: When an immigrant culture does not want to participate in the native culture.
3. Integration: When the immigrant person or culture maintains some of their cultural heritage like language and politics but is an active member of the dominant society in which they live in.
4. Marginalization: When the foreign culture attempts to be a part of the dominant society but is unable to do so due to various socio-economic factors (Hernandez, 2017).

This acculturation theory can help us understand for example how musicians from different cultures may approach a piece of music, classical or otherwise. Although it was not possible to include this particular theory in more detail further in this dissertation, Berry's theory has led me to develop an interest in this field. This furthered a question into whether responses to a certain type of music by a specific group of listeners give us an insight into cognitive mechanisms that can be generalized across cultures. Or is it the case, for instance, that we as western listeners appreciate a certain kind of music associated with our own culture and does upbringing and environment determine our perceptions and taste in music? There are undoubtedly many socio-cultural factors that influence our tastes and perceptions, but my research focus in this dissertation is the connections between language, cognition and musical experience and the question as to whether tonal or non-tonal languages have an impact on musicality.

Music cognition

Music cognition is mixed branch of cognitive science and music psychology. It is how musical knowledge is represented and performed as well as the perception of music, pitch, rhythm, time, tonality and of course memory of music learning and maybe most importantly; language in its relation to musical syntax. To really understand what music cognition is and how it works, we must first look at the concept of cognitive science. Cognitive science is a field of research wherein an objective is understanding the processes and representations of intelligent actions. This is achieved through different types of studies, mostly involving testing models and their predictions in computational procedures (Thagard, 2018). Music cognition first and foremost consists of perception (our process of perceiving something mentally), memory, both short-term and long-term and lastly how we first acquire and then mentally adapt all auditory information.

A common theme in the music cognition seminars at UiO was music and language and comparing how these two processes are stored and how they function in the brain. World-renowned researcher in cognitive psychology, Professor Aniruddh D. Patel, writes in his 2003 review "Language, music, syntax and the brain" that language is a special ability of the human brain, and has therefore interested neuroscientists for a long time (Patel, 2003). Furthermore, Patel describes syntax as the governing principles of words and musical tones, whereby linguistic and musical sequences are formed (Patel, 2003, p. 674). Cognitive science is a factor in all the studies I will be comparing, as it is an integral part of how language and music work together.

Cognitive psychology

Cognitive psychology is, as its name implies, the branch or field of psychology that aims to explore the cognitive mental processes. Cognitive psychology research deals with how humans learn and perceive as well as store information. According to an online lecture published to The National Programme on Technology Enhanced Learning (NPTEL) in India, cognitive psychology can be defined as the branch of psychology that is concerned with how people acquire, store, transform and communicate language (National Programme on Technology Enhanced Learning, 2020). Cognitive psychology has helped researchers understand how the cognitive processes and theories of language are represented in the brain. This was achieved by combining laboratory data with information about the selective deficits of brain damaged patients (Carreiras, 2010, p. 1). Carreiras also concludes his article with the fact that different types of cognitive mechanisms as well as cognitive neuroscience can help us understand how language which he, like Patel, refers to as a specific human ability, works in our minds (Carreiras, 2010, p. 2).

Processing music

Music processing deals with how the brain processes the data that we as humans interpret as music. The brain does not, however, process music all in the same place. All the parts of a musical piece's parts get processed in different parts of the brain (McCollum, 2019). Our nerves deliver the musical signals to our skull, and from there on the music gets transferred to the different parts of the brain. Rhythm gets sent to the motor cortex and the cerebellum. Pitch and tone are handed over to the auditory cortex as this part of the brain analyses the song's melody and harmony. Anticipation, which in this context refers to how our brains create expectations when listening to a song, particularly concerning the beat and how the melody is comprised. This part of the musical analysis gets sent to the prefrontal cortex. Music memory, as in people's ability to recognize a song or preserve its melody and beat is thanks to the brain's hippocampus. Musical performance like playing a concert or reading music are more complex, as they require several parts of the brain to cooperate. These are the cerebellum, motor cortex, sensory cortex, and the visual cortex. And finally, the emotion we experience when listening to a certain piece of music are concentrated in the nucleus accumbens, amygdala and the cerebellum
(McCollum, 2019).

Example 1. *Visual representation of the aforementioned areas and their respective processes.*

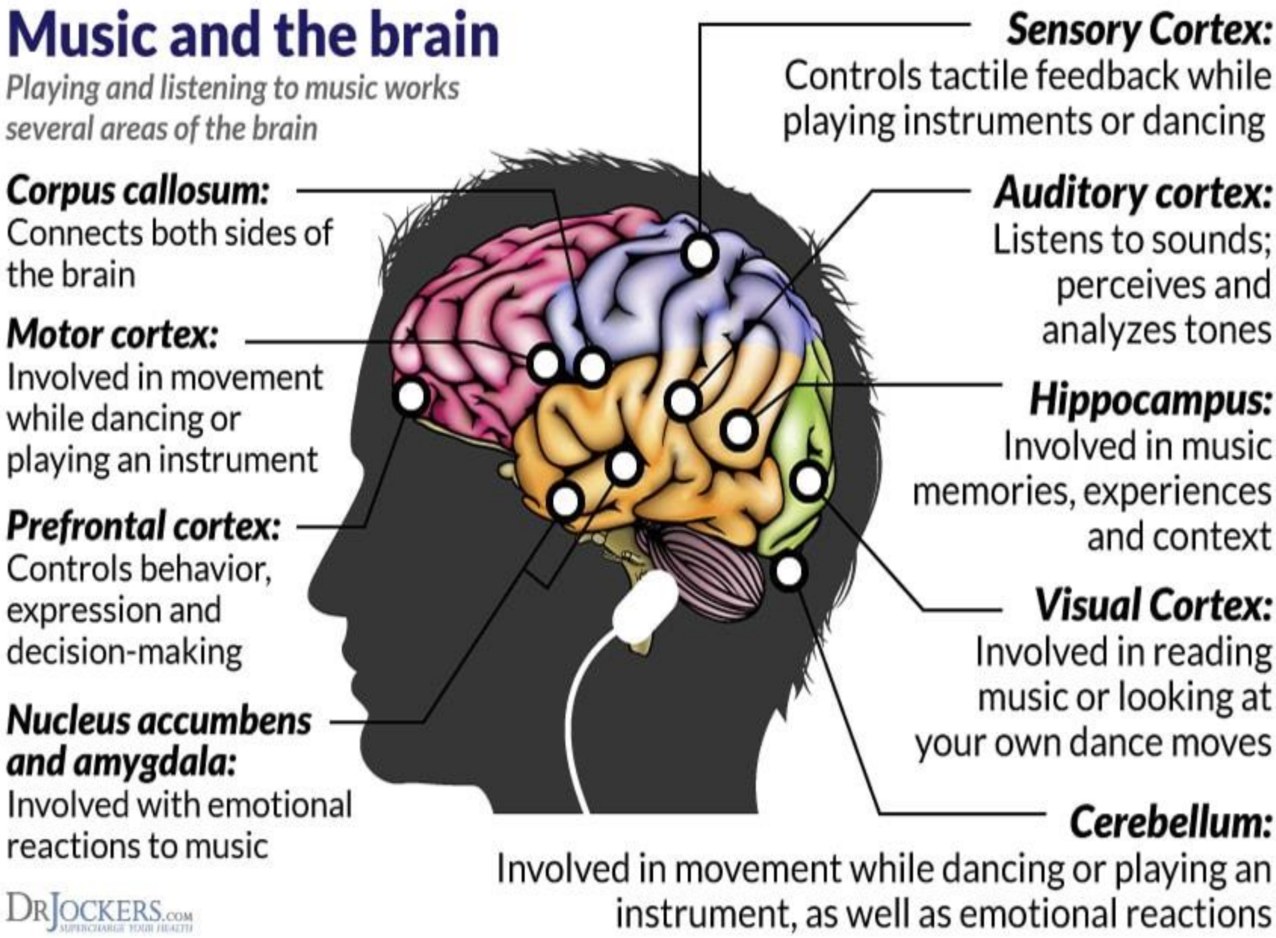

image reproduced from: https://www.guardiannurses.com/music-and-the-brain-listen-closely/ (accessed 26.04.22)

Linguistics

As mentioned, music cognition and linguistics play an intrinsic role in understanding how the brain works when comparing it to the focus of this thesis and my attempt to highlight how tonal and non-tonal language competency may influence musical experience. Music cognition as a rapidly expanding discipline within musicology includes research perspectives on the connection between music and language. The Oxford Dictionary categorizes linguistics as "The scientific study of languages and its structures, including the study of grammar, syntax and phonetics." (Oxford Learner's Dictionary, 2022).

The possible connections between music and language from a cognitive approach are complex, but a brief introduction to the topic will highlight relevant perspectives in order to answer my research questions. Among relevant perspectives are sociolinguistics and psycholinguistics. Sociolinguistics deals for example with how some humans are bilingual or multilingual more easily than others, what language choices they make when choosing whom they communicate with. It also touches subjects such as dialects and regional differences between people who speak the same language and linguistic interaction between people. (Crossmann, 2019). Psycholinguistics deals for example more with how language or multiple languages are formed and organized in the individual's brain. It also seeks to explain how injuries in the brain affect language learning behavior. (Nordquist, 2019).

Throughout history, it has been explained how humans rose above the great apes and what makes us different from them, our language. The fact that humans have linguistic capabilities makes us unique. Seyed Hadi Mirvahedi, one of our lecturers in the linguistic course I attended in 2021, explained just how different apes and humans are at socializing. Apes may be able to understand some behaviors only if they are brought up in a zoo or a circus but are not able to and will never be able to adapt to these kinds of behavioral changes out in nature without human interaction (Herrmann & Tomasello, 2006, p. 523). The fact that language is so important to understanding music and vice versa, is because language, like music, can in many ways be used to communicate certain objects that are not present in space and time. Thereby can a small amount of input be put together and interpreted in hundreds of different ways.

Tonal languages

A central theme in this thesis will be what linguists call “tonal languages”.
A tonal language is a language where not only pronunciation, but also the tone in which an individual expresses the word in marks the final meaning of that word. (Serrano, 2022) Words may be written the same but due to different tonalities the meaning of said word may differ either slightly or extensively. An example of this is the four tones of the Mandarin Chinese language. In Mandarin, a word can have four different meanings depending on the way it is pronounced. By simply googling “the four tones in mandarin Chinese” I came across an example of a Chinese set of syllables “ma” which when pronounced differently mean vastly different things. As illustrated, the apostrophes on the vocals (letter a) signifies the direction of where the tone is headed:

1. MĀ means “mom” and is the first tone in mandarin. It both begins and stays high in pitch. (Du Chinese, 2020)
2. MÁ means “hemp” and it begins at a middle range and ends in a higher range. (Du Chinese, 2020)
3. MĂ means “horse” and it begins at the mid-range, goes lower, and comes back up to the middle range. (Du Chinese, 2020)
4. MÀ means to “scold”. Here the tone begins in the high pitch and ends in the low pitch. (Du Chinese, 2020)

There are numerous tonal languages, most of them found in Asia and Africa. It is however not correct to categorize Norwegian, for example, as a tone language because of the different pronunciations of words that are written the same way. An example of this is the word “pannen” which in the Bergen dialect is pronounced differently when talking about a cooking pan, or a forehead (pannen vs pann’n). The reason Norwegian, or more specifically the Bergen dialect, cannot be considered tonal, is because there aren’t enough words in the language that are pronounced differently for it to be tonal. What constitutes a tonal language is explained in (Serrano, 2022).

Non-tonal languages

Non-tonal or atonal languages are languages where a word does not change meaning depending on the tone it is pronounced in. Apart from the aforementioned words in the Bergen dialect, Norwegian is not considered a tonal language. Other non-tonal languages include English, French and German just to name a few. However, non-tonal languages may still be classified as so-called *pitch-accent* languages. These are languages which usually only have a few tone distinctions (like the words in Norwegian mentioned on page 13) that can alter a word in one different way. Norwegian and Swedish are therefore classified as pitch-accent languages (Serrano, 2022).

How can we measure musical experience?

There are a multitude of ways to define what we might mean by musicality, and if it can be measured or even compared to musical experience. According to the Merriam-Webster dictionary, musicality is defined as “sensitivity to, knowledge of, or talent for music” and also “the quality or state of being musical” (Merriam-Webster, 2022). If you ask a musician, they will probably answer something along the lines of; musicality is playing by ear, playing technically well and being able to feel and control the rhythm as well as improvising musically and expressing yourself to the fullest. Dutch music researcher Henkjan Honing argues in his 2012 paper (Without it no music: beat induction as a fundamental musical trait.) that it is difficult to say what music truly is to begin with. To question whether we can call animal sounds music would be to shoot oneself in the foot in a way (Honing, 2012). He notes that there is a set of traits based on our biological system which contributes to how we interact with music, but there is also a set of social and cultural constructs based on musicality, like I mentioned above. However, Honing denotes that there simply is no music without musicality (Honing, 2012). Musicality is, as evidenced, a difficult term to use without certain implications. I will therefore follow Honing’s definition of musicality to describe musical experience from now on.

Amusia

On the other side of the spectrum from musical experience, you have what is called **amusia.** Amusia can be classified as the literal opposite of what is often considered musicality as it is a disorder that affects music perception as well as pitch processing (Peretz, et al., 2002).
There are two types of recorded amusia among individuals. Congenital amusia is a disorder that is inherited at birth. It only affects persons in the way that they have difficulty recognizing melodies and detecting pitch changes, while retaining normal hearing and speech as well as no other cognitive deficits (Peretz, et al., 2002). Congenital amusia is also called **tone deafness** in layman’s terms. The way that congenital amusia is often discovered is by testing infants in how they respond to dissonant chords in a melodic context. If they do not show signs of discomfort when hearing a dissonant sounding chord, then they might exhibit one of the hallmarks of congenital amusia (Peretz & Hyde, What is specific to music processing? Insights from congenital amusia., 2003).

Acquired amusia is characteristically like congenital amusia but is the result of the brain becoming damaged (Särkämö, et al., 2009). According to the same paper, it is also more common than congenital amusia (Särkämö, et al., 2009). Acquired amusia is frequently present in recent sufferers of a stroke. As many as 35-69% of individuals who had suffered strokes showed symptoms of amusia (Sihvonen, et al., 2016). The results of the 2009 study by Särkämö et al, however, demonstrated that there were higher number of lesions or damage to the frontal lobe and the auditory cortex in individuals who had recently had a stroke, than those who hadn't (Särkämö, et al., 2009). The auditory cortex (as shown on page 11) is the part of the brain that interprets and analyzes tones as well as having a central role in listening to sounds.

Event Related Potential (ERP)-studies

One of the research methods used to determine amusia and, what is often referred to as "musicality", is called EEG technology which shows event-related potentials in correlation with auditory information. In the central part of this thesis, I will be looking at ERP-studies with different approaches to the matter of musical experience being interconnected with tonal language use. Event-Related Potentials or ERPs are miniscule voltages that occur in the brain when exposed to specific events or external stimuli and are measured using electroencephalography or EEG (Sur, 2009). Electroencephalography is a method used to measure electric activity in the brain. The way in which this is measured is by attaching electrodes along the scalp of a person. The electrodes are then connected to a computer screen which shows the communication of the braincells as well as brain activity (Johns Hopkins Medicine, 2022). EEG's (although not called by that name at the time) were already discovered in the 19-th century by a researcher called Richard Caton, who in 1874 wrote about how he experimented with the brains of dogs and apes. He did this by measuring the currents using a galvanometer, an electromechanical instrument used to measure currents. Caton saw that the currents had strong variations when the test-subjects were sleeping, close to death or when they shined bright lights into their eyes. Caton then argued that this could be used as a basis to localize currents withing the cranial cortex (Berger, 1929). Hans Berger, a German psychiatrist, is often somewhat erroneously called the "inventor" of the EEG. Although Berger was the first scientist to record the first human electroencephalogram (Sack, 2017) it is more correct to call him the discoverer of EEGs. Berger was so filled with doubt when this recording took place in 1924, that he spent five years contemplating if he should publish it. He finally published his first paper in 1929 wherein he demonstrated the technique for "recording the electrical activity of the human brain from the surface of the head" (Sack, 2017). Unfortunately, his article was not very well received and many in the German medical and scientific establishments did not give him credibility. It was not until 1934 when two British electrophysiologists Edgar Douglas Adrian and B.H.C. Matthews confirmed Berger's observations. And only in 1937 was the importance of electroencephalography finally recognized internationally (Sack, 2017). Hans Berger's findings also included a suggestion by him that the complex EEG wave was composed of two waveforms: The Alpha and Beta waves. the Alpha wave rhythm (7.312-13.28Hz) is often called the "Berger's wave". Berger was also the first scientist to find correlation between epilepsy and alterations in the brain using EEG (Sack, 2017). The ERP method was not used at all in studies to measure pitch in tones and language before the following research paper that I will be analyzing on the next page. Therefore, the paper that is mentioned on the next page is of utmost importance to the whole notion of language and music having a higher cross relevance than previously thought.

An Event-Related Potential (ERP) Study of Musical Expectancy: Comparison of Musicians with Non-musicians.

I will now be taking an extensive look at a few related, but separate papers based around the understanding of event-related potentials. This may help us understand if and why music and language play an intrinsic role in our brain's processing of these separate, but interconnected subjects. Event-related potentials were first described in the 1995 paper by Mireille Besson and Frédérique Faïta, called "An Event-Related Potential (ERP) Study of Musical Expectancy: Comparison of Musicians with Nonmusicians". Besson mentions that few studies have examined music perception or even compared language and music using psychophysiological measures (1995, p. 1278). In this paper, a study was conducted by the scientists to determine whether musicians and non-musicians had any differences in musical expectancy. This was measured by looking at the individuals approaches to word endings or the tones of word endings. Participants were to determine if said element was perceived as logical or illogical in the context that it was presented in (Besson & Faïta, 1995, p. 1278). In addition to the said illogical tones, the participants also had to differentiate between irregularities in the tone endings. These irregularities were identifiable by the fact if the tones were diatonic, non-diatonic or rhythmical.

A short explanatory note: diatonic scales are musical scales where all the seven steps in an octave is used. An example of a diatonic scale is of course the major scale. Leading up to this study, the researchers had selected some musical material that they themselves thought sounded familiar. Among the musical phrases mentioned in the appendix of the article are: Johannes Brahms's *Hungarian Dance no. 2*, Edward Elgar's *Pomp and Circumstance*, Bartok's *Romanian dances* and over half a dozen of Frederic Chopin's Waltzes and Nocturnes. (Besson & Faïta, 1995, p. 1295). These are by my own experience, extremely well-known pieces to musicians regardless of their instruments of choice. This was then presented to another group of individuals in a preparatory study. The conclusion of this preparatory study was that the participants also deemed the tracks to be familiar sounding (Besson & Faïta, 1995, pp. 1280-1281). There were also so-called preparatory studies carried out to determine the logical and illogical endings of both words and tones.

If we now go back to the main study itself, we will find that the participants were in fact grouped together, and not separated by relation to musicianship i.e., one musician and one non-musician group (Besson & Faïta, 1995, p. 1282). This meant that the individuals were equal parts musician and non-musician. Researchers Besson and Faïta then studied the answers comparing them to figure out how well the participants fared in identifying the logical and illogical endings and if there were any differences in the number of right and wrong answers (Besson & Faïta, 1995, p. 1281). Percentage wise, the musicians recognized more of the illogical endings than the non-musicians. Nevertheless, the researchers could not find any significant differences between the groups regarding the recognition of the melodies (Besson & Faïta, 1995, p. 1281 & 1282). This is interesting to note due to the altered melodic endings being either diatonic, non-diatonic or rhythmically incorrect. Moving on to the linguistic parts of the study, the irregular endings of words were connected to something called the N400-component. This component is an event-related potential which refers to a negativity in the EEG that peaks at around 400 milliseconds after the onset of stimuli (NeuRA, 2020). The N400 component has later been used in schizophrenia research where it showed that people with the disease have a large increase in the N400 peak latency compared to healthy subjects (NeuRA, 2020). Besson & Faïta argue that the results of the N400 component is useful in researching word recognition and sentence processing (1995, p. 1293).

Results from the linguistic part (Exp 2) showed that, that the irregular end-tones of the musical excerpts showed signs of an ERP component called “Late Positive Component” (LPC). LPC is a component which shows a late reaction to emotional stimuli. Before Besson and Faïta’s study, Late Positive Components were often associated with the determination process of the brain’s function. However, Besson and Faïta propose that it is rather linked to the perception process of the brain (Besson & Faïta, 1995, p. 1278 & 1287). LPC’ are since the late 2000’s called LPP which stands for Late Positive Potential. It is nowadays used to research emotion regulation in children and depression in young adults (Dennis & Hajcak, 2009). Besson & Faïta’s conclusion was that the part of the research which was concerned with speech showed irregularities that were reflected by negative components while the research’s musical part had irregularities reflected by positive components (LPC) (1995, p. 1293).

What is interesting to note further in this study is that the researchers concluded that the LPC’s latency and amplitude changed substantially. The changes were attributed to the participants musical expertise (Besson & Faïta, 1995, p. 1293). It showed that subjects who had received musical training had, quite logically, greater knowledge of the musical phrases used in the experiment as well as a more adept ability to discover deviations in the end-elements of both the musical phrases as well as the verbal ones (Besson & Faïta, 1995). Besson and Faïta also write that since these LPC changes were so significant, they may influence something called the post-perceptual determination process. Post-perceptual determination process is a part of the perceptual process of the brain. Our sensory receptors encounter stimuli like for example sounds, and we can focus our attention on that particular stimulus and interpret its meaning based on cognitive processing. Although, if we are exposed to the same stimuli too many times, we become desensitized to it. (Niosi, 2021). Post-perceptual processes, as the name implies, happen milliseconds after the brain has picked up an event. My definition of these changes in LPC has to do with the fact that since the musicians were so used to the musical phrases, having heard them probably a dozen times before, they were more attentive towards the changes in the musical phrases as opposed to the non-musicians who maybe had not heard it quite as often.It is interesting to note that in the third and final part of this experiment, scientists Besson & Faïta wanted to reduce the impact of these determination and perceptional processes. The way they went about doing this is that they asked the participants to not react to the musical phrases played to them (Besson & Faïta, 1995, p. 1287). Musical phrases and excerpts were the same as in the former parts of the experiment. This was done to compare results of the event-related potential(s) and try to determine if they indeed were free of said processes or not. Negative ERP-components were measured between two to six hundred milliseconds and remained alike between experiments (Besson & Faïta, 1995, p. 1293).

The way Besson and Faïta interpret this is that the outcome of the LPC changes occurred regardless of post-perceptual processes, which in turn means that it reflects differences in perception of the end-tones whether or not the person listening to them reacts physically or not. It seems it is all stored in the brain regardless and one cannot be completely free of the determination or perceptual processes even when one tries to disregard them. In conclusion, although it may seem clear throughout this paper that musical training has an advantage when talking about how one perceives musical processing as well as language processing, it does not mention which language any of the participants spoke. Therefore, we must delve further into understanding the role of languages, and of course tonal languages in relation to musical experience. It is important to note that while this paper in its own rights is very comprehensive and important to both later ERP-studies and the whole hypothesis of this thesis, it must be considered that it is a somewhat outdated in certain ways. What I mean by that is Mireille Besson laid down the groundwork for ERP- studies in this paper, and provided scientists, researchers as well as students such as myself with well formulated information to further their field of studies. The paper, although now 27 years old, provides an excellent introduction for establishing an understanding of Event Related Potentials. Now that the components of ERP have have been laid down, it is important to take a closer look at another study concerning the relationship between music and language.

Lutz Jäncke's approach to music and language

In an article from 2012, Professor Lutz Jäncke, a neuropsychologist and cognitive scientist at the University of Zurich (Department of Psychology - Neuropsychology , 2018) investigates the historical view on music and language, as well as compiled some research papers, two of which I have chosen to further analyse later in the dissertation. The abstract begins with Jäncke describing how music and language were always treated as different faculties or areas of study. (The Relationship Between Music and Language, 2012). He wants the reader to understand that this theory is incorrect. Jäncke states that in 1974 there were efforts by researchers to explain how the brain's two hemispheres each their own dedicated roles had in processing the information of music and languages and that they were not mentioned as being interconnected (Bever & Chiarello, 1974) mentioned in (Jäncke, 2012). There, he writes, that the 1974 paper describes "the left hemisphere considered more specialized for propositional, analytic, and serial processing and the right-hemisphere more specialized for appositional, holistic, and synthetic relations." (Jäncke, 2012, p. 1)

This view clearly states that music and language are too different when looked at from a neurological standpoint. We of course know now almost 50 years later that this isn't true due to, as Lutz Jäncke puts it, great development in modern brain imaging techniques and neuropsychological measure to investigate brain functions (Jäncke, 2012). Lutz's paper describes 12 other research papers summarized in one where each of the papers has a significant effect on our understanding of the relationship between music and language. Out of these twelve, three of them are written about the cooperation of tonal languages and musical pitch perception, more specifically the question of whether deficits in pitch processing could influence perception in tonal languages (Jäncke, 2012). I will be summarily comparing two of these three papers named by Jäncke in order to understand more about our brains process musical and linguistic input, as well as the correlation between these seemingly very different types of input. These papers are the key to understanding how speakers of tonal languages versus speakers of non-tonal languages may process pitch, and how it could give them an edge in pitch processing compared to non-tonal speakers. These papers are an excellent starting point for further analyses of studies which I have compiled later on.

Native experience with a tone language enhances pitch discrimination and the timing of neural responses to pitch change

The first paper's focus is the perception of language pitch with regards to linguistic and non-linguistic tones. It is an ERP-based study wherein the researchers recorded the data from native speakers of the Mandarin language and a control group who did not speak Mandarin (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011). The researcher's based the hypothesis of their study on earlier research papers from all the way back to 1997. The first evidence they mention concerns the perceptual and categorization abilities of native tone speakers (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 1). Giuliano et. al then continue with examples that Mandarin speakers are better at distinguishing pitch and melody than English speakers. Here they give an example of two research papers, (Pfordresher & Brown, 2009) (Hove, Sutherland, & Krumhansl, 2010) but do not give information about whether this concerns native speakers of these languages or just people who have knowledge of the language (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 1).

The researchers acknowledge that they do not yet know if the neural processes that are mentioned in the quoted papers have this advantage, or if this advantage (which tone language speakers may or may not have) only transfers to pure tonal (musical) pitch as well as linguistic pitch processing which is already evident from earlier studies (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 1). Their goal with this paper is to determine how tonal vs. non-tonal language speakers, or intonation language speakers as they refer to them here, process different stimuli and how the evidence is concluded in an ERP study. Giuliano et al then continue to use examples of the mandarin Chinese tones by using the syllable *"ma"*. This is of course the same word that is used as an example of mandarin language tones [11]. When talking about how pitch processing influences language, the authors reference a slew of research papers dating all the way back to 1967, which talk about how speech is a specialized modular ability (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 1).

The authors then also mention that tonal language speakers *may* demonstrate enhanced pitch processing when regarding stimuli that is non-linguistic, which the authors call "pure tones" (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 1). The study goes on to explain how there is more evidence that suggests that Asian tone-language speakers are better

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at discriminating pitch intervals than non-tonal language speakers (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 1). One of the more important information in this research paper occurs when the authors point to evidence which suggests that people with absolute pitch are more numerous among the Chinese students than the American music students (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 1). Absolute pitch (also called perfect pitch) is the ability to recognize and precisely point out a random musical note when it is played to an individual (WordNet 3.0, Farlex clipart collection., 2003-2008). Giuliano and his colleagues then continue to give examples of studies showing that absolute pitch is more accurately represented in fluent tonal-language speakers compared to those who are not fluent or moderately fluent (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 1). The paper then points to the fact that there has been documented cases (research papers) where speakers of Mandarin who had deficits in processing musical pitch also had trouble differentiating tones in their native language compared to non-Mandarin speakers (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 2). The authors then acknowledge to an extent that they might be wrong about their initial hypothesis but continue with the fact that additional questions need to be raised about how the neural system may undergo changes which then lead to deficits in pitch processing (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 2).

The paper mentions that studies have demonstrated native tone-language speakers having visible changes in pitch processing which is already detected in the brainstem. They point to studies which have used something called frequency following response, or FFR as it is also referred to here (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 2). FFR is explained as a measuring system which targets the brainstem where researchers have observed stronger pitch representations as well as smoother pitch tracking in native Mandarin speakers when compared to English speakers (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 2). Musicality is important to this study as well, since the authors chose to include the fact that musical training has possible correlation to the extraction of pitch information. In the study they reference (Wong P. S., 2007) it is again the Mandarin language that is the subject of study. What they write about this study is that even individuals with no knowledge of the Mandarin language have enhanced extraction of pitch information from Mandarin tones (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 2).

Giuliano et al.'s study focuses mainly on how native tone-language speakers process pitch during an **active** discrimination task, they quote other studies which have **passive** tasks as the focus of the paper. One of the papers they mention concerns what is called "Mismatch

Negativity". Mismatch Negativity or MMN is described as is an event-related potential linked to the interruption of a sound that isn't necessarily supposed to be there. Thereby differing the frequency and duration (Jones, Gartlon, Minassian, Perry, & Geyer, 2008). The mismatch negativity observed in this paper was larger in deviating tones in Mandarin speakers than English speakers. Thereby concluding that the MMN was larger in tone-language speakers than the non-tone speakers (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011). According to the authors, this suggests that speaking a tonal or tone-language from birth gives way to enhanced pre-attentive neural representation of pitch-relevant information (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 2). This means that if one is brought up with a tonal language as an infant, then that person is automatically more attentive and alert towards small changes in pitch.

The research they quote also mentions that the mismatch negativity was observed in Thai lexical tones (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 2). Both Thai and Mandarin are tonal languages, which explains the MMN being observed in Thai as well. Although, the deviating lexical tones were also observed in native speakers of Mandarin and English in addition to Thai speakers. This suggests that speakers of all languages can pre-attentively discriminate among tones (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 2). Similar studies mentioned by Giuliano and his colleagues describe how training of the perceptual identification process can also improve the performance of the discrimination tasks that are presented to the participants in these tests (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 2). Before the main part of this study, the researchers mention that they predict a pitch processing advantage due to the ERP components being sensitive to pitch modulations and that this advantage will be reflected in early ERP's (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 2).

The researchers then conducted two experiments in which both resulted in evidence supporting an advantage for tone language speakers (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011). In the closing of the experiments Giuliano writes that native tone speakers, as he calls them, could more accurately detect changes in the 200-400ms range of pitch intervals, similarly to what Besson and Faita experienced in their 1995 study (N400 component). Furthermore, they mention that the tonal language native speakers did show more sensitivity in these trials and show evidence of their ERP's showing the reader that they indeed were faster to react to changes in the trials than the control group (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 7).

In the discussion part of their study, Giuliano and his colleagues indicate that the native tone language speakers taking part in this study were more accurate at detecting pitch changes (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 9). The participant's ERPs demonstrated in fact that the tone language speakers could detect changes in the stimuli earlier on than the non-tone language speakers. They also mention that previous research on how language experience is involved with sound processing in the brain correlates with their own study in this paper. The way that this is achieved is by activating the brain's response to auditory stimuli at the early stages of processing such information, by giving it the stimuli presented in the experiments (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 9). Native tone speakers also have more sensitivity towards pitch height information when compared to bilingual persons who do not speak a tone-based language (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 9). According to the study, this outcome is also true when the participants were presented with the tones that did not resemble the real linguistic tones of Mandarin Chinese (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 9). Further on, the researchers comment that the findings prove that growing up as a native speaker of a tonal language leads to general enhancements in pitch processing that are not specific to linguistic input (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 9).

What this means, in essence, is that natively speaking a tonal language makes a person inherently better at detecting small tone variations. Continuing the discussion part, the researchers mention that there have been earlier studies wherein the participants included monolingual English speakers as well as native tone language speakers, but not bilingual ones (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 9). Therefore, they wanted to include bilinguals as a control group to potentially have a different outcome in the pitch processing ERP's. Obviously, this did not happen, as the evidence shows (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 10). It is also highly important to note, as Giuliano et al write, that all the tonal language speakers were of the same ethnicity, while the non-tonal speakers were of different ethnicities (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 10). Therefore, they cannot rule out that ethnicity or genetics influence the findings (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 10).

I find it interesting that they include this part while referencing another study (Hove, Sutherland, & Krumhansl, 2010) in (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 10) then directly stating that there is stronger evidence that genetics do not really play a critical role in pitch processing, rather that experience is the leading factor regarding that matter (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 10).
Giuliano, Pfordresher, Stanley, Narayana and Wicha then go on to write that the trial they conducted was more quantitative than previous similar trials owing to the data needed for ERP's and their analysis. (p. 10). This of course also gives an indication to the fact that the study was conducted with more information allowing the outcome to be studied more in depth than previous studies.

"Native experience with a tone language enhances pitch discrimination and the timing of neural responses to pitch change" was the first study to demonstrate the advantage that tone language speakers had in pitch processing linguistic and non-linguistic input (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011). Using ERP's to accurately measure changes in the perception of the participants at an instant, the researchers show the reader that tonal language speakers have quite an advantage over non-tonal speakers, even when the latter group was bilingual. Their findings show a clear connection between language experience and the processing of non-linguistic information, essentially tones, which then leads them to conclude with the fact that language, and especially tonal languages enhance the brain's cortical representation of pitch when compared to non-tonal language speakers (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011, p. 11).

Tone language fluency impairs pitch discrimination

Both of the papers mentioned by Lutz Jäncke take a similar approach, comparing native tone language speakers with non-tone language speakers. However, the outcomes are notably different (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011). Like the previous study, the participants were asked to detect pitch changes in tones. Unlike the previous study, the tones used as stimuli were monotonic and isochronous (meaning that they always occurred at equal time intervals) and split into sequences of five tones (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 1). The participants had to detect displacement of the fourth tone in these sequences, both in pitch and time (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 1).

As the name of the paper suggests, speakers of tonal languages had more trouble detecting pitch changes. However, this is only true when talking about *downward* pitch changes. Peretz et al., did not observe poor performance in detecting upward pitch changes neither in the tonal group nor the non-tonal control group (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 1). Neither did they detect any difference in the perception of subtle time changes (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 1&4). The fact of the matter is, as Peretz and her colleagues write, that the impairment cannot be misconstrued as affecting musical ability in a negative way because it stays the same when differences in musical pitch-based processing are included (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 1&4).

The publishing researchers mention that this idea of a shared connection between music and language is a hot topic. Using the transfer effects of linguistic and musical abilities is one of the methods that is viable in studying and finding the answer to the questions (Peretz, Nguyen, & Cummings, 2011, p. 1). Peretz and her colleagues wanted to re-examine the issue of the fact that tone language speakers possess a prerequisite enhanced musicality when comparing pitch patterns in both music and language (Peretz, Nguyen, & Cummings, 2011, p. 1). The paper mentions a study (Slevc & Miyake, 2006) in (Peretz, Nguyen, & Cummings, 2011, p. 1) that showed evidence of native Japanese speakers who had musical training and aptitude also demonstrated more precise pronunciation of spoken English.

Peretz et al., also mention another study wherein the participants who were native speakers of tonal languages were better at correctly displaying the pitch patterns in song when compared to native English speakers (Pfordresher & Brown, 2009) in (Peretz, Nguyen, & Cummings, 2011, p. 1). Like in the previous study, the current setting involved testing of whether early exposure to tonal languages resulted in an advantage in detecting discreet pitch changes in non-speech tones (Peretz, Nguyen, & Cummings, 2011, p. 1). Again, like the previous studies of both Besson & Faita and Giuliano et al., participants of the study were asked to detect pitch changes. The participants used in this study were also Mandarin speakers (tone language) and the non-tonal language speakers were "mostly French." (Peretz, Nguyen, & Cummings, 2011, p. 1 para. 2). The task given to the participants were as follows: They had to detect changes in the fourth tone of a sequence that consisted of five tones played on a piano. These tones were either presented with a constant pitch or isochronously.

They also had to compare sequences where the fourth tone deviated from the others in either pitch or time (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 1). Due to enhanced attention and control capabilities demonstrated by musicians in other studies mentioned by Peretz et al, musicians were not included in this study since they felt that they would outperform the other participants in both linguistic and maybe highly logically, tonal processing of the stimuli that was presented (Peretz, Nguyen, & Cummings, 2011, p. 1). All of this is correlated to contributing factors that surround the positive transfer effect in music and language being influenced by trained musicians. That is why the writers mention that non-musicians might differ in musical capability. (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 1).

The participants of the study were 24 tonal language speakers, and twenty-five non-tonal language speakers. Eighteen of the subjects spoke Mandarin, four spoke Vietnamese and two spoke Cantonese. In this study, the publishers/researchers also include the fact that the tonal language speakers had moved to Canada later in life and spoke either French, English or both as second language for an average of six years. Peretz, Nguyen & Cummings use what is called a battery of tests to check for eventual musical deficits such as amusia. According to an English dictionary, "a battery of tests is a set of tests used to determine aspects of something such as health." (Reverso Dictionary, 2022). Isabelle Peretz invented a series of six tests in 2003 called the "*Montreal Battery for the Evaluation of Amusia"* abbreviated as MBEA. It is a tool that uses quantitative research methods in musical tests to check for congenital amusia in individuals (Vuvan, et al., 2018).

The MBEA tests conducted by Peretz and her colleagues in this study had different four different areas of study: melodic, rhythm, metric, and memory. Each of these areas then had 30 trials in which standard melodies were compared to another different melody by the participants (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 2). Several changes were made for the melodies in these tests. In some of the trials, the melody differed only by one note: the note either belonging to another scale than the melody itself but preserving the contour or changing the contour of the melody but preserving the scale, vice versa (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 2). Musical contour is a term that refers to the motions that notes in a melody perform. The term is used to measure how melodies move between individual notes (Study.com, 2017).

Rhythm-tests included changing the rhythmic grouping of the melodies and metric tests involved changing the musical meter aka the time in which the music is played in. Examples of include 4/4 beats where each “meter” is accentuated on the beat, and 3/4 beat where only 3 of the 4 metric values are accentuated. Participants had to classify the trials as either marches or waltzes, (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 2) which coincide with namely the 4/4 and 3/4 meters. (I would argue that this is correct). The last part of the test was simply to differentiate between melodies from earlier parts of the study and new melodies presented to the participants. The melodies were all similar in structure to the old ones and written in western musical system with a 10-note average (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 2).

The MBEA showed the researchers that one of the tonal language speakers had amusia due to the data revealed by the study and their data was excluded, possibly since the participant was unable to tell the difference between two melodies. Lastly, it is important to note that the scores were very similar across the groups, except for the fact that the tone language speakers had more trouble in the scale tests involving the melodic contours (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 2).

The stimuli were played in 21 different sequences, and like mentioned previously, contained five successive tones, meaning that each one was played right after the other. (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011). Each of the participants were individually tested and the researchers made sure to separate the pitch and time sessions (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 2).

The study included random trials wherein half of them had no change, aka a monotonic sequence. A “yes” and a “no” button was placed in front of the subjects to indicate press when they could detect a change or not (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 2). The subjects were only informed of the outcomes of the tones change or location but did not receive any feedback after they made their choices (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 2). Peretz also notes that the participants were all in a quiet room with headphones as the source of the musical stimuli. (p. 2). She mentions this to disclose the fact that there most likely were no external stimuli involved in the trial’s outcome. Results of the study showed that the groups had no difference in correctly rejecting the pitch change stimuli (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 2). Furthermore, the tests outcomes showed that the tonal language speakers regularly performed sub-par compared to the non-tonal speakers regarding the experiments concerning downward pitch changes (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 3). This difference, however, was not recorded by the ERPs in the upward pitch changes, neither in the tonal nor the non-tonal group (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 3). Moreover, there were few to no differences in pitch change detection. Peretz et al, used information from all the MBEA test to predict the performance in the pitch changes (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 3).

Using this information, they concluded with the evidence that showed correlation between small pitch changes and musical pitch discrimination (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 3) also mentioning that musical aptitude is not related to the tone language speakers failing to discriminate between the downward pitches (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 3).

Compiling all the data from the experiments as well as the MBEA trials, the scientists could not find any evidence of enhanced pitch perception in native speakers of tonal languages (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 4). However, data also showed that their impairment, as mentioned earlier, only concerns downward pitch changes and that this impairment was only present in the tonal language speakers since the perception in upward pitch did not differ from the non-tone language speakers (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 4).

It is also not related or relevant to musicality since it is present in musical pitch processing as well (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 4). Somewhat interestingly, they conclude this part of the study with the notion that tonal language fluency interferes with falling pitch perception in a musical or tonal setting (Peretz, Nguyen, & Cummings, 2011, p. 4). Mentioning studies written previously, they note that this outcome is not an isolated finding. The paper that they mention (Bent, Bradlow, & Wright, 2006) in (Peretz, Nguyen, & Cummings, 2011, p. 4) used Mandarin and English speakers, similarly to the paper by Giuliano et al, and found that they all performed similarly, owing to the outcome being the same as in the current paper (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011). Peretz and her colleagues state that this impairment occurs because Mandarin speakers, linguistically have a larger pitch range in falling tones when compared to rising tones (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 4).

What this means, in essence is that Peretz et al., assume that the Mandarin speakers used language-based pitch regulation instead of non-linguistic pitch processing when listening to and discriminating the falling musical tones played on the piano, and that this strategy may always be present in a non-speech context (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 4). Quoting a study (Tillmann, et al., 2011) in (Peretz, Nguyen, & Cummings, 2011, p. 4) wherein the results showed that amusics (individuals with amusia) performed better on linguistic inputs than on musical ones. (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 4). Peretz quotes more studies like the present on. These studies explain that speech-specific processes can influence the perception of pitch when the differences are miniscule (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 4). Thereby, the scientists conclude with the fact that as of this study, they cannot show evidence that supports the notion of tonal language experience enhancing pitch perception, but that there is evidence that shows small individual differences in pitch perception that are carried over from linguistic to musical perception (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011, p. 4). Evidence to support this fact was possible thanks to the MBEA trials. Summarily they write that what they call a “fine-tuned” pitch perception may be required to an individual obtaining higher melodic abilities, and that amusia as a speech-specific process also contributes to the discrimination process of a task, but less effectively than musicality (Peretz, Nguyen, & Cummings, Tone Language Fluency Impairs Pitch Discrimination, 2011).

Effects of Music and Tonal Language Experience on Relative Pitch Performance

To further understand the relationship between music and language, I decided to include a review of a study which explores in more detail how speaking tonal languages can affect musicality measured in pitch processing tasks. This study is noteworthy since it mentions the relationship between language and music more in depth referring to pitch perception as essentially being the backbone of the appreciation of music (Ngo, Vu, & Strybel, 2016, p. 125). The study at hand examined the interaction between tonal language use and musical experience (Ngo, Vu, & Strybel, 2016). Participants of the study were asked to judge both the direction as well as the magnitude of pitch changes in a pitch task (Ngo, Vu, & Strybel, 2016). In addition to the Montreal Battery of Evaluation of Amusia (MBEA) which was mentioned in the previous study, scientists Ngo, Vu and Strybel measured the pitch changes with a tool called the Cochran-Weiss-Shanteau index or CWS (Ngo, Vu, & Strybel, 2016). CWS a tool used to assess expertise based on pure data. It carries a preexisting notion that to have expert judgement, one must also be able to discriminate between the changes in stimuli. CWS is described by the authors as discrimination divided by inconsistency (Weiss & Shanteau, 2003). The tests were conducted in two session taking place over separate days. This was done to check if the participants would have different outcomes on the second day after practicing (Ngo, Vu, & Strybel, 2016, p. 125). MBEA was used to measure the participants pitch processing abilities, and the results showed that trained musicians performed better than non-musicians on both the CWS index and the MBEA (Ngo, Vu, & Strybel, 2016). Once again, very similarly to all the other studies mentioned in this thesis, the results of the language comparison pitch study showed the tonal language speakers were better at discriminating pitch relative tasks than non-tonal language speakers, although only on the MBEA (Ngo, Vu, & Strybel, 2016). Results of the CWS index could tell the scientists that musicians were also better at recognizing difference in pitch compared to their non-musician counterparts. They were also more consistent in the answers than their counterparts when choosing answers based on direction and magnitude of pitch change stimuli (Ngo, Vu, & Strybel, 2016). In the introductory part of the study, Ngo and colleagues mention Vietnamese and Chinese (not specified if Mandarin or Cantonese) as being languages that require high levels of pitch perception to comprehend its prosodic feature. Prosody being the musical elements of a language (Gross, 2017).

According to the current paper, relative pitch perception is of utmost importance for tonal language users. Relative pitch meaning is the expression used when people describe the pitch of a tone in relation to another tone. Thereby using the ability to recognize a tone by establishing where another tone, played earlier, lies on a musical scale (American Heritage® Dictionary of the English Language, 2011). Ngo, Vu and Strybel give an example of a Vietnamese word *"môt"* that can have different meanings based on the intonation being upwards, or glottalized, meaning that it is spoken with a "stop" on the vowel (Ngo, Vu, & Strybel, 2016). The scientists argue that it would be nearly impossible for a speaker of such a language to fail at the kind of pitch perception that requires both the production of language as well as the comprehension of other languages (Ngo, Vu, & Strybel, 2016, p. 126). This is also the second study relevant to this thesis that mentions absolute pitch. What the researchers mention by including absolute pitch, is that when musicians who started taking lessons before the age of four (very early in relative terms) reportedly had absolute pitch 40% of the time. While only 3% of the musicians that started music lessons after 9 years of age had absolute pitch (Ngo, Vu, & Strybel, 2016). As well as referring to previous research that achieved results linked to the enhanced pitch processing ability of absolute pitch individuals, also included in this study is evidence pointing to the fact that speaking a tonal language earlier in life should contribute to absolute pitch abilities (Ngo, Vu, & Strybel, 2016, p. 126). Continuing their introductory phase of the study, a plethora of research papers are mentioned which include Chinese music students having a higher prevalence of absolute pitch than students from the United States (Ngo, Vu, & Strybel, 2016, p. 126) based on a western music notational tests wherein random notes were presented by the researchers (Deutsch D. , Henthorn, Marvin, & Xu, 2006) in (Ngo, Vu, & Strybel, 2016, p. 126).

Adding that there are benefits from both linguistic and musical training according to these results, Ngo et al also mention a noteworthy study from 2013 that summarized the effects of pitch discrimination in Cantonese and English speakers (Ngo, Vu, & Strybel, 2016, p. 126). The participants of that study were musicians who spoke English as their first language and non-musicians who were Cantonese speaking. Results of the study showed that musical training and experience in speaking a tonal language cross-influence each other, meaning that having a beforehand knowledge of either domain improves the processing and knowledge of the other (Ngo, Vu, & Strybel, 2016). Sharing evidence from a 2008 study by Lee & Hung, Ngo and her colleagues give examples of musicians being more accurate in the identification of mandarin tones (Ngo, Vu, & Strybel, 2016, p. 127). This could mean that musicians are better than non-musicians at learning an entirely new language as well.

Ngo supports the evidence from the studies mentioned in her paper that show that musical training can in-fact carry over to language knowledge and more often than not it benefits tonal language experience and vice-versa (Ngo, Vu, & Strybel, 2016). The study by Pfordresher and Brown from 2009, which is included in the Peretz et al 2011 study [12] , is again mentioned by Ngo et al, owing to the fact that there is still limited research as well as knowledge in this field of study compared to many others. The researchers mention that while these examples of interdisciplinary connections are well established by now, there are not many studies that can show a combined effect of musical training and tonal language experience (Ngo, Vu, & Strybel, 2016, p. 127). However, the researchers include one study which does in fact examine the interaction between musicality and experience in tonal languages (Ngo, Vu, & Strybel, 2016). The study mentioned by Ngo et al (Cooper and Wang 2012) examined said interaction based on lexical pitch tasks. A lexical tone is the distinctive pitch in which a single syllable of a word exists. This pitch is therefore an essential feature in the final meaning of said word. (SIL Glossary of Linguistic Terms, 2022). The participants were grouped in to four and tested based on musical training and tonal language fluency. These tests were done to determine word identification and perception of lexical tones.

Results showed that although musical training and tonal language experience did lead to better performance, individuals who had musical expertise *and* spoke a tonal language fluently still did *not* outperform those who only had knowledge in one of the two areas (Ngo, Vu, & Strybel, 2016, p. 127). A result like this may seem very logical and including it may seem a bit counter intuitive to include it after the fact, but further on the researchers note that there was no added benefit to having experience in both domains (p. 127). The authors inform the reader that no paper of study has up until that point been able to include relevant musical and linguistic input pertaining to the results they wish to achieve on the current test (Ngo, Vu, & Strybel, 2016). According to the researchers of the current paper, the MBEA test is not capable of pinpointing the exact nature of musical or tonal language experience having an advantage over one another. They are therefore using the Cochran-Weiss-Shanteau (CWS) index which combines both the ability to discriminate between pitch as well as more accurately the performance of the participants in the pitch perception tests (Ngo, Vu, & Strybel, 2016). The reason for using CWS as the base of the tests, according to Ngo et al, is due to pitch perception only being accurate enough without it when the participants or subjects of the study are trained in music theory (Ngo, Vu, & Strybel, 2016, p. 127). Individuals who have an understanding of music theory can use music notation to show the pitch sensations experienced during a

[12] Page 28

hypothetical test. CWS however, does not require the participants to have any knowledge of music theory and is therefore more appropriate to use on a general-public test (Ngo, Vu, & Strybel, 2016). Participants of the study were given a relative pitch task which according to the researchers, did not require musical training or knowledge of tonal languages (Ngo, Vu, & Strybel, 2016, p. 127). The participants had to show the direction of the change in pitch as well as the magnitude of the change compared to a standard tone. Using the CWS index made it possible for the researchers to look separately at each stage of the pitch processing (Ngo, Vu, & Strybel, 2016, p. 128). In the study they were going to conduct, they used two different types of scales when playing the melodies. One of the scales was tick-marked like the intervals on a piano and the other scale was just continuous. Predictions were that the musicians would perform better than the non-musicians, at least on the tick-marked scales (Ngo, Vu, & Strybel, 2016, p. 128). All in all, the study included 32 participants.

All the participants were from California, although from different areas of the state and assumedly from different ethnicities, although it is unclear (Ngo, Vu, & Strybel, 2016, p. 128). The participants ages ranged from eighteen to thirty-two and all of them reportedly had normal hearing and vision, although some of them wore glasses. (Ngo, Vu, & Strybel, 2016). Sixteen of the thirty-two participants were musicians. Musicianship was classified as having seven or more years of vocal and or instrumental training and being currently an active in playing or singing music (Ngo, Vu, & Strybel, 2016, p. 128). How they measured being and "active" musicians is not mentioned, but personally I would have liked to have seen it included, as musicianship is not that easy to classify to begin with. Someone with seven years of instrumental or vocal lessons may not essentially be an objectively good singer or instrumentalist solely based on the fact that they have experience. What would have been more accurate to see here, scientifically, is the authors/scientists including practice time on the individuals as well. Eight of the sixteen musicians participating were tonal-language speakers, namely Vietnamese and therefore categorized as "tonal musicians" by the authors (Ngo, Vu, & Strybel, 2016, p. 128). The rest of the musicians were, similarly, classified as nontonal musicians since they had no experience in speaking a tonal language. Furthermore, the rest of the 16 participants were evenly divided up between tonal non-musicians and lastly nontonal non-musicians (Ngo, Vu, & Strybel, 2016).

A noticeably recurring theme in these studies is the use of non-organic auditory stimuli, and this study is no exception. The stimuli were made in MatLab, a programming language that uses algorithms to create functions and portray signal processing (MathWorks, 2022). Stimuli was then played on a Visual Basic program, which allows the user to modify the input themselves, for example while the tests are underway (WhatIs.com, 2019).
Nevertheless, the frequencies of the tones were programmed to exactly replicate nineteen consecutive piano keys all the way from D4# to A5 (Ngo, Vu, & Strybel, 2016). The way in which the stimuli tests were executed is as follows: The standard tone was played for half a second followed by what the scientists refer to as an "interstimulus interval", meaning a break, for the same length. This was then followed up by the comparison tone that was played for half a second as well (Ngo, Vu, & Strybel, 2016, p. 128) Every single tone was presented 10 times in random orders totaling 190 trials (Ngo, Vu, & Strybel, 2016). How the tests worked is important to include as it provides a clearer picture of the study. Participants used noise cancelling headphones while testing, similarly to the study by Peretz et al on page 23 and were situated in front of a PC running Windows XP with the visual musical scales (Ngo, Vu, & Strybel, 2016, p. 129). Using the mouse, they participants were asked to pinpoint and click on the 19 positions indicated on the scales. Although, on the continuous scale, the interface was changed from a clicking movement, to a scrollbar where the participants could continuously move along the scale (Ngo, Vu, & Strybel, 2016).

At the end of each of the experiments, the participants were asked to take the MBEA index to make sure that the scientists could have a correct reading of their individual pitch processing ability (Ngo, Vu, & Strybel, 2016). The participants had to distinguish between 30 tones in the MBEA index. Both the rhythm subscale and the memory sequence consisted of the same number of tones. Thereby, the participants had to answer "yes" or "no" if they had heard the tones before in the previous session or if the tone/tones were unfamiliar to them (Ngo, Vu, & Strybel, 2016, p. 129). Experiments of the study were conducted on separate days. According to the scientist, it was of utmost importance that the experiments were not separated by too many days, thereby allowing the maximum time between sessions to be 3 days (Ngo, Vu, & Strybel, 2016). The participants first day consisted of a questionnaire that had to be filled out as well as a consent form. Only after these forms were completed could the experiments commence (Ngo, Vu, & Strybel, 2016). The participants were read the instructions and were given permission to ask questions during the "break" in between each experiment. The participants were also paid 30USD after the whole experiment was over (Ngo, Vu, & Strybel, 2016, p. 129).

The score from the MBEA index allowed the researchers to cross compare the results when converting the subscales to percentages (Ngo, Vu, & Strybel, 2016, p. 130). What this means is that the researchers could more easily read the performance of each of the participants as well as compare them to score from earlier studies as a backdrop (Ngo, Vu, & Strybel, 2016). Once again, musicians did outperform nonmusicians on the MBEA task and regularly scored about 10% higher than nonmusicians (Ngo, Vu, & Strybel, 2016, p. 130).

According to the illustration on page 130 of this article, the musicians in this study had overall higher score on all the subscales of the experiment, with varying degrees of deviation on each of the subscales (Ngo, Vu, & Strybel, 2016, p. 130). The same can be said for tonal language speakers, as they hugely outperformed the non-tonal speakers on the MBEA, again scoring higher than the non-tonal speakers, but "just" by 6% compared to the previously mentioned 10% (Ngo, Vu, & Strybel, 2016, p. 130).

However, it is important to note that overall, the interaction between musical training and tonal language experience was nonsignificant (Ngo, Vu, & Strybel, 2016, p. 130). Meaning there was no correlation or evidence of musical training or experience having been aided by tonal language fluency or experience, nor that tonal language fluency aided musical training. The CWS index [13] was then used to measure all the participants relative pitch processing abilities (Ngo, Vu, & Strybel, 2016). CWS is helpful in aiding the research personnel in reading the participants discrimination abilities as well as measuring the consistency at which they made their judgments in the previous exercises (Ngo, Vu, & Strybel, 2016, p. 130). From this index, the researchers could also determine whether the participants had high inconsistency in their choices, since high variance of choice meant that they were choosing inconsistently (Ngo, Vu, & Strybel, 2016). Final scores of the CWS index clearly showed that musicians scored five times higher than nonmusicians both on the discrete and the continuous musical experience scale. The scores for tonal language speakers, however, was lower than the non-tonal speakers by a quite a multitude of points (Ngo, Vu, & Strybel, 2016, p. 131). The writers of the article note that it is not significant, however it is still an interesting outcome that will be addressed later. Furthermore, the researchers note that the effect of the response scale was significantly higher for musicians when it came to the discrimination tests as well (p. 131) scoring higher than the nonmusicians on every single scale and test.

[13] Explained on page 27

Although this outcome was affected when the musicians were compared on the continuous and the discrete scale, scoring much lower on the latter (Ngo, Vu, & Strybel, 2016, p. 131). This difference was not noticed in the nonmusicians' scores, having minimal deviations in the readings between the tests. Unfortunately, the outcome of the final tests and the CWS index once again showed clear evidence of the effect of tonal language experience and musical training correlated with language experience having no significance based on these readings (Ngo, Vu, & Strybel, 2016, p. 131).

Although the further evidence from the studies showed slight beneficial edges for the tonal language users as well as the musicians, having less inconsistency across the board for the latter group and showing a higher discrimination value (Ngo, Vu, & Strybel, 2016, p. 132) with the former group. Conclusively, this paper is one of few which investigates the so-called "combined" effects meaning both musical training's effect on language learning and experience but also tonal language experience on musical ability and vice versa (Ngo, Vu, & Strybel, 2016, p. 132). What the researchers found is that as mentioned earlier [14] there seems to be no advantage for musicians who also happen to speak a tonal language in terms of pitch perception abilities. This is evidenced by the fact that neither the MBEA nor the CWS index test that followed could find a single correlation in the measurement of the pitch exercises presented to the participants. Therefore, according to Ngo et al, there seems to be no correlation at play relating the prerequisites of tonal language knowledge or musical training on pitch performance (Ngo, Vu, & Strybel, 2016). To summarize, the researchers mention again that the MBEA results showed only one of the prerequisite types of knowledge e.g., tonal language use or musical training produced better scores on the musical aptitude testing (Ngo, Vu, & Strybel, 2016, p. 132). Ngo et al also noted that individuals with musical training had even better results than those who had tonal language experience (Ngo, Vu, & Strybel, 2016).

Given the relatively small number of participants involved in the tests, the researchers hypothesize (Ngo, Vu, & Strybel, 2016, p. 133) that the lack of significance from tonal language experience on the relative pitch task may be related to that factor. This factor then contributed to the smaller output of data, than for example if they had more participants (Ngo, Vu, & Strybel, 2016). Whether or not this is significant is up for debate, since Ngo et al immediately distance themselves from this statement and concur with the fact that "low power", as in few participants, was not the reason behind the nonsignificant findings since non-tonal language speakers already performed better than the tonal language speakers on the relative pitch tasks (Ngo, Vu, & Strybel, 2016, p. 133). Therefore, they (Ngo, Vu, & Strybel,

[14] page 32

2016) surmise that tonal language knowledge is in fact mostly insignificant in pitch tasks when they resemble real music or musical scales (p. 133). Although they included this potentially extremely significant factor of the testing, they also mention that the results must be taken with caution since their samples were not matched on cognitive abilities, as these have been known to be linked to musicianship and tonal language (Ngo, Vu, & Strybel, 2016, p. 133).

Ngo, Vu and Strybel explain that one of the reasons they chose the CWS index as a means of testing, is the fact that it can be used to examine the real nature and effects of tonal language use and music experience (Ngo, Vu, & Strybel, 2016). Taking into consideration all the different backgrounds of the participants, the results showed that musicians aka those with musical experience performed better across the board than all other groups.

This includes the tests for consistency in reporting pitch variables, pitch discrimination, and sensitivity to pitch (Ngo, Vu, & Strybel, 2016). The reason being that musicians could understand the steps in the CWS scale tests since it resembled semitone distance between stimuli (Ngo, Vu, & Strybel, 2016, p. 133). Emphasizing again the role of tonal languages and their "marginal" significance, Ngo et al continue to explore the reasoning behind the results of the tests. They suggest that tonal language speakers were better at improving their discrimination tasks after practicing compared to the non-tonal group (Ngo, Vu, & Strybel, 2016, p. 133).

Regarding these findings, the researchers concluded that since tone language experience only had improved effect on that particular group's perceptional sensitivity to pitch change, and not their consistency [15] in pitch perception, that perhaps musical training is the required aid in maintaining higher consistency. To back up their claim, the researchers also reference other studies that had similar outcomes (Ngo, Vu, & Strybel, 2016, p. 133). Ngo, Vu and Strybel conclude their study writing about the results of their findings, which show that in contrast to earlier studies (Deutsch, Henthorn, & Dolson, 2004) in (Ngo, Vu, & Strybel, 2016) their tonal and non-tonal language participants did not have a great deal of difference in consistency [16] compared to the paper they mention. This may be due to several different factors. Since this was measured and experienced with the MBEA testing, they cannot rule out that they might have had a different outcome had they used the CWS index in addition to the MBEA in this regard as well (Ngo, Vu, & Strybel, 2016, p. 133).

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More studies involving tonal languages possible effect on musical experience and pitch perception.

In addition to the perspectives from the studies that I have mentioned so far, there are more recent research that also address pitch perception and musical abilities. The two following studies follow a similar pattern to the latter papers, but the reason why I believe they are relevant includes two factors. Firstly, they concern themselves with musical pitch perception and musical abilities possible connection to genetic material. This is different from the other studies, but still relevant, as it may provide a different but equally clear picture of my research question. The second reason is that this is more recent research compared to the other studies, with the papers being published in 2018 and 2020 respectively. I wanted to include newer research to possibly usher a fresh perspective on the subject of tonal languages and music.

The first study that I will be visiting briefly (Creel, Weng, Fu, Heyman, & Lee, 2018) is an article titled "Speaking a tone language enhances musical pitch perception in 3–5-year-olds". The study wants to explore the development of pitch perception in young children, as the name suggests. Although previously analyzed studies have been concerning pitch processing in adults this study was the only one that I could find which had credible sources and a respected publisher while also concerning itself with the notion of musical pitch in children.

The researchers mention that the study is based upon earlier research conducted by a variety of scholars and scientists (Creel, Weng, Fu, Heyman, & Lee, 2018, p. 1). Similarly, the previous study by Ngo et al, the researchers of this study also used musical pitch perception tests, and a tonal language group versus a non-tonal language group. The two main hypotheses for this study were the *pitch specificity hypothesis* (p. 1) and the *pitch generalization hypothesis* which serve as the pretext to the the main question (Creel, Weng, Fu, Heyman, & Lee, 2018, p. 2). As explained by Creel et al., the first hypothesis states that "pitch is only specific to the context in which it is learned" (p. 1) while the second hypothesis states that the advantages of pitch processing are more general (as the name implies) and can serve to benefit areas beyond only a single matter (p. 2). The researchers presented evidence supporting both hypotheses, (Creel, Weng, Fu, Heyman, & Lee, 2018, p. 2) and both hypotheses were included in the tests involving the participating children. Results from the tests showed that although the younger children who spoke a tonal language, in this case Mandarin, were a bit less accurate at detecting pitch changes, overall results were in favor of the tonal speaking children, as they showed an advantage in pitch contour.

Pitch contour shows the rise and fall of the pitch. It can be compared to a singsong-y cadence like a rising and falling intonation in speech (Vocabulary.com, 2022). A great example of vocal pitch contour is the cadence of the Eastern Norwegian dialects. When compared to the non-tonal language speaking children (Creel, Weng, Fu, Heyman, & Lee, 2018, p. 5). The scientists' results were in favour of the second hypothesis, namely the pitch generalization hypothesis. since they provided evidence of tonal language speakers giving more attention to pitch in language processing than the non-tonal speakers (Creel, Weng, Fu, Heyman, & Lee, 2018, p. 5). Creel et al. also denote that since the children had not yet learned to read or write, their heightened accuracy in musical pitch processing **cannot** be attributed to scholarly learning. (p. 5). Creel and her colleagues go on to write that their results are vastly different from a slew of articles published earlier, since they (Creel et al.) were able to disprove or at least come to a different conclusion than any of the research papers that could not find a link between non-speech pitch processing and tonal language advantage (Creel, Weng, Fu, Heyman, & Lee, 2018, p. 5).

It is highly interesting to note, however, that the researchers mention that a possible genetic factor remains to be explained or researched, since they did not include that in this study, and it could not be ruled out according to them. (Creel, Weng, Fu, Heyman, & Lee, 2018, p. 5). They again give examples of other studies which concerned themselves around genetic implications in linguistic perception. (p. 5). All in all, the conclusion of this paper by Creel, Weng, Fu, Heyman and Lee cements itself in the fact that tonal language speaking children possess a greater cross-domain perception of pitch than adults who tonal language. While also showing that tonal language experience is connected to advanced musical pitch in young children (Creel, Weng, Fu, Heyman, & Lee, 2018, p. 6).

To continue the topic of a possible genetic advantage in pitch processing, I've decided to include another brief look at a study conducted recently. After a few google searches, I came across an article from 2020 written in Forbes magazine. (Amsen, 2020). The article called "Genes and Musical Ability Both Affect How People Hear Tonal Languages" summarizes a study conducted by Professor Patrick C.M. Wong, from the department of linguistics and modern language at The Chinese University of Hong Kong. (2022). The study (Wong, Kang, Wong, So, & Geng, 2020) encompasses language evolution and musical training by studying two gene variants found in tonal language speakers.

Back in 2007, Patrick Wong wanted to examine musical training to identify its effect in aiding individuals to learn a tonal language (Wong & Perrachione, Leaning pitch patterns in lexical identification by native English-speaking adults, 2007). The theory of that paper was that musical training would help individuals learning a tone language in identifying subtle pitch changes in lexical tones (Amsen, 2020). The current 2020 study by Wong et al included over four hundred participants who all spoke Cantonese natively. Cantonese is another Chinese language closely related to Mandarin (Wong, Kang, Wong, So, & Geng, 2020, p. 2). The Cantonese speaking participants were compared to an earlier study by Wong and others, wherein Norwegians and ethnic Chinese were compared in cranial volume and pitch perception (Wong, Chandrasekaran, & Zheng, 2012) in (Wong, Kang, Wong, So, & Geng, 2020, p. 3). Han Chinese participants of the study had showed evidence of a gene called ASPM (Abnormal Spindle Microtubule Assembly). It is a gene which initializes production of a protein in cell division. Although unrelated to this thesis, it is also present in several different types of cancers occurring in the human body and the reason why is unclear (MedlinePlus, 2011). Under the current circumstances of research, the ASPM was found to aid individuals in processing lexical tones. The gene is used as a component that is present in both native tonal language speakers and non-tonal speakers.

Wong was however not convinced about the correlation between these two groups and therefore decided to conduct the study to identify the effects of ASPM in individuals (Amsen, 2020). Participants were volunteers who were asked to identify lexical tone differences, musical pitch differences, and rhythm differences in a series of tests. Quite interestingly, DNA samples were taken of these subjects to see if their genetic code could tell us anything about why some did well on the tests and others not so much. The ASPM gene showed a significantly different location in people who were adept at discriminating between lexical tones and people who were not (Wong, Kang, Wong, So, & Geng, 2020, p. 4).

Here is where the effect of musical training comes into play. Even though Wong's research group included people with the gene variation, which made them more adept at distinguishing lexical tones, it was only perceived as a « small effect» (Wong, Kang, Wong, So, & Geng, 2020, p. 4). The reason being that the participants with the gene variant which hindered lexical tone pitch processing had the same results as the participants with the opposite gene variant when musical training was included as a background. Conclusively, this evidence shows that musical experience nullified the effect of the variant genes (Wong, Kang, Wong, So, & Geng, 2020). This may mean that language evolution may have occurred alongside genetic evolution. It suggests that populations where the most common genetic variant is the one that makes these linguistic pitch changes easier to hear, would be those populations where tonal languages were more likely to be used. While one version of the ASPM gene could give an individual the advantage required to master a tonal language, the evidence also shows that musical training, and thereby musical experience, acquired through practice is the key to success.

Further discussion of findings in research on music and tonal languages

In the main part of the thesis, I have looked at studies concerning music and tonal languages. Additionally, I decided to include two more studies which were subjectively important to the thesis as well as informative on areas of study closely related to the main studies. Thereby possibly giving the reader a clearer picture of the relationship between musical and linguistic processing. The first two of these studies use the ERP-method as their measuring tool. They also conclude with fairly similar results. The first two studies have different factors (Besson 1995 having musicians vs non-musicians and Giuliano 2011 having tonal vs non-tonal speakers) but still lead to results that support each other. The results show that both studies had some interesting findings in the negative component between 200-400ms. Besson & Faïta found evidence that shows a component of the ERP called N400 which is present in the results of the tests surrounding the irregular endings of words. This component was only present in the musician's ERPs. Giuliano et al., also found an N200-400 component where native speakers of tonal languages peaked in the processing of pitch intervals. Besson & Faïta talk about how musical training leads to an advantage in how an individual perceives both linguistic and musical input. Giuliano and his colleagues then further develop this potential relationship since they share the same conclusion as Besson & Faïta in that both tonal language experience and musical experience can lead to general enhancements in pitch processing that are not specific to linguistic input. Meaning that both groups may have an easier time learning each other's areas of expertise. Besson & Faïta conclude their study by mentioning that musicians have a prerequisite enhanced ability to process small pitch changes in language as well as music, while Giuliano et al., argue that native tonal language speaker's brains are more adapted to pitch processing linguistic as well as non-linguistic (tone) input. This means that the two studies are interconnected in their conclusion. Does that mean that musicians and tonal language speakers have an advantage in learning languages? It may seem that way solely based off these two studies.

The next study that I will be discussing is the one by Peretz et al. (2011). This particular paper is highly important to the thesis since it is the only one of the studies that I have chosen to include as research, that had a drastically different outcome than the rest of the research papers. Even though Peretz, Nguyen & Cummings had a similar pretext as both Giuliano et al. and Besson & Faïta's papers, their results were, as mentioned, quite differing. Like Giuliano's paper, Peretz and her colleagues used only native tonal language speakers and non-tonal language speakers as the focus groups in the tests. Even more similarly, the groups were asked to perform the same tasks as in both previous papers, namely, to detect small pitch changes which occurred in the tests. The tonal language group's mother tongue was Mandarin Chinese, exactly the same language that Giuliano's research group used in their paper. Peretz and her research associates' reasoning behind this paper was their interest in re-examining previous works that claimed factitiously that tone language speakers possessed a prerequisite enhanced musicality when comparing pitch patterns in both music and language. Not quoting other papers by title or publishing researchers, one can assume they mean Giuliano's paper since it was published just some months earlier and has a similar structure to the current study.

Peretz et al. mention a 2006 study by Robert Slevc and Akira Miyake (Individual Differences in Second-Language Proficiency: Does Musical Ability Matter?) that showed evidence of native Japanese speakers who had musical training and aptitude demonstrating a more precise pronunciation of spoken English. However, by including the study, another problem arises. Peretz et al.'s claim that tonal language speakers possess enhanced musicality based on Slevc and Miyake's study is incorrect. The reason being that Japanese is **not** a tonal language (ALTA Language Services, 2018). It is considered a pitch language, which means that some syllables and words require a specific pitch accent, either upwards or downwards, to make the speaker seem more authentic in their pronunciation (Kanshudo, 2022). This does not interfere with the meaning of said word if the speaker cannot correctly pronounce the pitch, such as in Mandarin[17].

A potentially significant factor in the outcome Peretz et al.'s study may have occurred due to them not going straight for the Event-Related Potentials to measure the pitch processing capabilities of the participants. Instead, they first used the Montreal Battery for the Evaluation of Amusia (MBEA) to check if any of the participants were potentially affected. The MBEA is, as mentioned earlier, developed by Isabelle Peretz herself.

[17] Explained on page 13

The pre-testing trials concerning the MBEA revealed to the researchers that one of the tonal language speakers indeed had amusia. This may be construed as a small hint at tonal language experience not having a higher correlation to musical experience. As one would often think that since a person is fluent in a tonal language, they must also then be musically inclined due to the basis of a tonal language is being able to correctly pronounce tones. This can be likened to singing, or even playing an instrument like the violin, where tones must be played in a certain way for it to sound correct. Peretz et al. then denote that this person's was excluded from the final trials. However, I would argue that it would have been interesting to include them to see how it could affect the final results. Another factor that already this early in the paper supports Peretz' findings have to do with the tonal language speakers impaired ability to discriminate between the scales in the melodic contour testing part of the MBEA trials.

Unlike Giuliano et al., Peretz et al. do not mention genetics as playing a role in the outcome of the study, solely basing their findings upon their own evidence as well as studies that they mention which leads Peretz et al. to conclude that their evidence is not an isolated finding. They base the core of their evidence on the tonal language speakers pitch-change impairment in the downward pitch stimuli. These stimuli were played so that each one was played right after the other. Testing the participants individually assumedly so that they could get a clearer outcome of each trial. Nevertheless, since the pitch-change impairment only occurred on the downward moving pitch and not the upward moving pitch, the researchers conclude that the outcome is irrelevant to musical experience. Their reason being that the Mandarin languages tones interfere with the downward pitch. This is both due to Mandarin having a more diverse pitch range in falling tones [18] and since none of the participants (tonal or non-tonal speakers) had trouble discriminating between the rising pitch changes. Thereby, Peretz' group assumed that the tonal language speakers were using solely language-based pitch processing as opposed to tonal pitch processing and therefore finding no evidence of tonal language knowledge or experience enhancing pitch perception in music. Rather, they conclude with the exact opposite notion, that tonal language experience negatively affects linguistic pitch perception.

[18] Page 13

Even though the researchers noted that their outcome was not connected to musical experience, this may nevertheless seem like somewhat regretful evidence to the hypothesis that tonal language experience can *aid* in musical experience. But Peretz et al. never mention anything about tonal languages affecting musical experience negatively at all. Only mentioning that the tonal language speakers used linguistic processing instead of tonal processing, and them not including musicians in the tests, further investigation must be carried out. This is where the next main research paper comes in.

The paper by Ngo, Vu and Strybel (Effects of Music and Tonal Language Experience on Relative Pitch Performance., 2016) is the most detailed of the research papers that I have analyzed for this thesis. This is evident both in terms of content and how the testing was summarized by the researchers. In this study, the publishing scientists did not only include tonal and non-tonal language speakers to test pitch performance, but also musicians as well as non-musicians were included. Possibly to get a clearer picture in the event of the tests, as well as the final result. Their outcome reflects both the findings of Besson & Faïta and Giuliano et al. as well as providing a clear-cut connection between all the previous research papers. Ngo et al. wanted to prove that pitch perception is correlated directly to the appreciation of music (p. 125). Drawing similarities to the previous paper, the researchers also used the Montreal Battery of the Evaluation of Amusia (MBEA) since they noted that it would give more concise determination of both the magnitude as well as the direction of where the pitch changes would occur later in the study. Their result did not detect amusia in the subjects belonging to any of the groups.

They also decided that they would not use Event-Related Potentials to process pitch, but rather the Cochran Weiss Shanteau index [19] (CWS) since it provides a more in-depth view in determining which of the participants had better discrimination in the pitch changes of the stimuli. The CWS showed them that musicians were better than non-musicians in recognizing the differences in both musical and linguistic pitch and were also more consistent in their answers than their counterparts (p. 125). Ngo et al used both Chinese and Vietnamese speakers as their tonal language group. Even though they do not specify what kind of Chinese language the participants spoke, if they either spoke Mandarin or Cantonese as these are the most wide-spread languages of the Chinese family, both are still tonal languages. The only major difference (aside from pronunciation of words and them not being mutually intelligible) is that Cantonese has 6 tones while Mandarin has 4. However, in addition to them including Vietnamese which also has 6 tones, this may have greatly influenced their findings.

[19] Explained on page 32

Although Ngo et al. never mention that as being the case, one can assume that it may have had a significant role given the additional number of prerequisite processing which comes with speaking a tonal language that has more tones than the languages included in the previous studies. Nevertheless, speaking both of these tonal languages was shown to require high levels of relative pitch perception [20] in the individual to comprehend the prosody in the language (p. 125). Their reasoning behind this is that it would be nearly impossible for tonal language speakers to somehow fail at pitch perception since the basis of tonal language knowledge requires such a high level of pitch perception to be able to produce the tones in their language. Not only the production, but also the understanding of other languages should be much higher in tonal language speakers due to these factors (p. 126). Ngo et al. then bases this theory on the fact that there are generally more individuals with absolute pitch who are not only also tonal language speakers, but also musicians. They correlate these occurrences with having an early exposure in life to both a tonal language and music learning (p. 126).

It is a common conception in musician circles that Chinese and Vietnamese students have a much higher occurrence of absolute pitch than European students. This is for example, also mentioned in the book "*Musikk og Hjernen" (Music and the Brain)* (Brean & Skeie, 2019). The writers mention that usually only 1 in 10.000 individuals have absolute pitch, but that it is much more common in Asian individuals (Musikk og Hjernen, p. 48). The fact that absolute pitch was more present in Chinese students than American students was already presented by Giuliano et al. The researchers also mentioned that tonal language speakers were more numerous in absolute pitch individuals, although only when considering fluent speakers of a tonal language. Non-fluent or semi fluent individuals did not possess this advantage (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011). Going back to Brean & Skeie, as well as acknowledging the high prevalence of absolute pitch in Asian individuals, they also mention very briefly that the high frequency in absolute pitch individuals is due to there being a genetic factor at play (Brean & Skeie, 2019, p. 48).

[20] Explained on page 32 (cont. p. 33)

Mentioning other studies, Ngo, Vu & Strybel point to multiple papers as evidence suggesting the cross domanial influence of music and language, in both directions (Ngo, Vu, & Strybel, 2016, p. 126). An interesting notion in the findings of both Giualiano et al. and Ngo et al. is that both papers point to evidence suggesting that musicians have a more accurate discrimination in Chinese tones, regardless of their knowledge of the language beforehand. The evidence is included from (Wong P. S., 2007) in (Giuliano, Pfordresher, Stanley, Narayana, & Wicha, 2011) and from (Lee & Hung, 2008) in (Ngo, Vu, & Strybel, 2016).

This is directly correlated to and proofs a hypothesis which emerges throughout Besson and Faïta's 1995 paper (An event-related potential (ERP) Study of Musical Expectancy: Comparison of Musicians with Nonmusicians) which is that musicians have an advantage in language learning (pp. 1290-1293). Highly interestingly, even though a lot of the theories and testing show that language and music processing do have a lot in common, the study by Ngo et al. also correlates somewhat with Peretz et al.'s 2011 study (Tone Language Fluency Impairs Pitch Discrimination). There are multiple similarities that can be drawn here as well. The first one being that as mentioned earlier, the interaction between musical training and tonal language experience was nonsignificant (Ngo, Vu, & Strybel, 2016, p. 130). Effectively, there was no evidence of tonal language experience aiding musical experience nor that musical experience had aided in the pitch processing of tonal languages. This again may be compared due to Peretz' findings that showed impairment in mandarin speakers as well as the use of linguistic pitch instead of musical pitch like mentioned earlier. [21] Another fact is that while musicians scored five times higher than nonmusicians on the musical experience scale, the scores for the tonal language speakers was lower than the non-tonal speakers (Ngo, Vu, & Strybel, 2016, p. 131).

The tonal speaking musicians also got approximately the same results as the non-tonal speaking musicians, which shows that tonal language experience does not aid musical pitch processing by itself. This directly correlates the notion by Peretz et al. (2011) that they could not find any evidence of tonal language speakers musical pitch perception being enhanced by their exposure to said type of language. That is why it is important to note that overall, the interaction between musical training and tonal language experience was less significant than what they had hypothesized, according to Ngo et al. (Effects of Music and Tonal Language Experience on Relative Pitch Performance., 2016).

[21] Page 27 and 46

All in all, their conclusion and findings of the study subjectively only revealed major enhancements in both linguistic and musical processing for musicians, while tonal language speakers had relatively similar or sometimes impaired processing compared to both musicians and of course non-tonal language speakers. Once again, the study at hand (Ngo, Vu, & Strybel, 2016) while demonstrating clear similarities to both papers which favor linguistic and musical correlation, also shows a relatively insignificant interconnection of the hypothesis that tonal language experience may aid musical experience. Nevertheless, by comparing it to the papers by Besson & Faïta and Giuliano et al., it has shown some factors which may be construed as contributing to the notion that musical experience could aid in language learning, albeit less significantly than what I had initially hypothesized would be the case.

Continuing the discussion with the two shorter studies that remain to be "dissected" we will take a look at the study by Creel, Weng, Fu, Heyman & Lee titled *"Speaking a Tone Language Enhances Musical Pitch Perception in 3-5-year-olds"* (2018). The main difference between this study, and the previously analyzed papers is the fact that the scientists only included children and had no adults participating in the study. Creel et al. clarify early on (p. 1) that their research is based on numerous studies that suggest both cross domanial influences in language to music transfer, but that an individual who is skilled in one of these domains may have benefits in the other domain as well. They also mention that said cross domanial influence may potentially have negative effects (p. 1). The study can be likened to Giuliano, Peretz and Ngo's papers since it also tests pitch perception, and very much alike the two former papers since it only uses tonal versus non-tonal language speakers as the participants in the study. As mentioned in the main part of the thesis, the study bears two hypotheses which center around pitch. The first one being the pitch specificity hypothesis and the second hypothesis being centered around pitch generalization. The backgrounds of both hypotheses are explained by Creel et al. (Speaking a tone language enhances musical pitch perception in 3–5-year-olds, 2018, pp. 1-2) as well as earlier in the current thesis.[22] Even though the researchers supported both hypotheses to begin with, the latter one (pitch generalization) seemed to have been favored by the scientists upon their later findings (p. 5). It became clear to the scientists that the younger children, even though being less accurate at detecting pitch change, were much better at pitch contour. [23]

[22] Page 40
[23] Explained on page 41

This outcome could not be connected to scholarly learning, according to Creel et al., since the children were obviously too young to have been in school (3-5 years of age). Nevertheless, they present vastly interesting results. Compared to the rest of the research papers, they point to direct evidence of early tonal language experience leading to a better pitch processing in musical settings.

They also mention that this may have an (as of 2018) untested genetic implication as well, based on other studies, which they mention on page 5 (Creel, Weng, Fu, Heyman, & Lee, 2018). The currently analyzed paper's conclusion can be seen as proof in the fact that young children, who are tonal language speakers do in fact possess greater cross-domain perception of pitch than adults who speak tonal languages. While also showing that tonal language experience is connected to advanced musical pitch in young children (Creel, Weng, Fu, Heyman, & Lee, 2018, p. 6). Thereby proving their initial hypothesis correct. This outcome can be again connected to Besson and Faïta's 95 study and Giuliano et al. 2011. The reason being that there was already a mention of musicians having an easier time learning languages in both papers, and the current paper presented evidence of that hypotheses' counterpart, proving additionally that these domains are interconnected on a deeper level than what could be proven by earlier studies.

Since both Giuliano's study and Creel's paper mentions possible genetic factors in pitch processing and musical experience, the next paper (Wong, Kang, Wong, So, & Geng, 2020) is important to include in this discussion. The study is centered around the lexical processing of tones, with ethnic Chinese Cantonese speakers as the tonal language group. As mentioned earlier [24], Cantonese is a language with 6 tones which makes it also one of the most advanced tonal languages, according to Wong et al. (ASPM-lexical tone association in speakers of a tone language: Direct evidence for the genetic-biasing hypothesis of language evolution, 2020, p. 2). They wanted to see if there was any correlation between language education and musical training. They tested 400 cantonese speakers wherein they could detect a gene variant called ASPM [25]. Referring to earlier studies (Wong, Chandrasekaran, & Zheng, 2012) they also noted that the ASPM gene was only present in ethnic Chinese participants in that study, therefore it is assumed that they did not include ethnic Europeans in the current study (Wong, Kang, Wong, So, & Geng, 2020) since they were not found to possess this gene variant. However, this variant was found to aid in lexical tone processing in ethnic Chinese persons.

[24] Page 42
[25] Explained on page 42

Therefore, they hypothesized that this ASPM gene was the key to a better lexical processing, at least in Cantonese speakers. However, it was quickly disproven as the only proof or evidence of enhanced processing, since it was only described as a having a small effect compared to musical training. Additionally, it also nullified any effect, whether it be positive or negative, of the ASPM gene in relation to lexical processing.

Thereby, the conclusion of the article leads the reader to believe that musical experience is the strongest contender when it comes to aiding pitch processing. Further evidence of this will be presented below.

Conclusion

During the course of my investigations presented in this dissertation, it has become clear that evidence suggesting the influence of tonal or non-tonal language competency on musical competency is far from clear-cut. My initial hypothesis that individuals with tonal language backgrounds had a higher understanding of music and enhanced musical experience is evidently not entirely correct. This outcome is based on the findings in the six studies that provide the key findings for my analyses. It would seem that while fluency or even experience in one or more tonal languages does affect musical experience to a degree, musical experience has an even greater impact on an individual's ability to process pitch in language. Starting with the fact that Besson & Faïta (An event-related potential (ERP) Study of Musical Expectancy: Comparison of Musicians with Nonmusicians, 1995) mention that the participants with musical training were far more adept at and had greater knowledge in not only the musical processing, which was already expected and somewhat logical, but also the verbal (linguistic) processing. Their study is the first one in these series that points to clear and direct evidence to back up the fact that musical training and experience is the key factor in language processing and knowledge.

This is further backed up as evidence by Giuliano et al.'s paper wherein they reference another paper (Wong P. S., 2007) with findings that show musical training was again correlated to pitch information, even though no musicians were included in Giuliano et al.'s study. The Slevc and Miyake paper (Individual Differences in Second-Language Proficiency: Does Musical Ability Matter?, 2006) is also mentioned by Peretz et al. as showing evidence to the fact that musically trained individuals who spoke Japanese were much better at pronouncing spoken English words even thought they had little or no knowledge of the language. Ngo et al.'s paper is possible the highest supporter of musical training as the main factor in both linguistic and musical pitch processing, as they present evidence from their MBEA trials that showed individuals with musical training having better results than tonal language speakers. Additionally, musical training was mentioned by the researchers as the supposed required aid in maintaining higher consistency in pitch processing tasks. Even though this thought process is evident in all studies, there is one exception. The study by Creel et al. (Speaking a tone language enhances musical pitch perception in 3–5-year-olds, 2018) shows findings that prove that language experience does in fact lead to better pitch processing in music, however, the participants in the study were only very young children. Adding to that, they also mention genetics as a possible connection.

The whole notion that genetics plays a major role in pitch processing was largely disproven by the paper by Wong et al. (2020) since it clearly pointed to musical experience essentially “deleting” any effect of the so called ASPM gene that lead to better lexical tone processing in ethnic Chinese individuals.

In conclusion, while a tonal language background does in fact aid musical experience, it does so only to a certain degree. However, it appears that tonal language background gives a significant advantage in pitch processing for young children. In adults the studies did not find significant differences between people with tonal language backgrounds compared with non-tonal language users. However, when they compared musicians with non-musicians the musicians performed better at pitch processing both in language and music. These are the same findings Besson and Faita presented back in 1995. Genetics evidently contributes to this conclusion, albeit much less significantly than musical training. This means that all in all, each paper that was published and presented in my study published following Besson & Faïta (1995) was able to indirectly support Besson & Faïta’s hypothesis, albeit to varying degrees.
Besson & Faïta also corroborate my own experiences growing up, which suggests that my musical training to a large degree, influenced not only my interest in languages and language learning, but also my ability to learn languages and become fluent in five languages.
I do not imagine that I would have learned to speak this many languages had I not been playing, and maybe most importantly, regularly practicing an instrument for many years.

The reason for the differences between tonal language speaking children and adults are unclear and remain to be explored further. Even though the differences are presented to us in these papers, we do not have a clear understanding of how or why this is the case. This is something that may be interesting to research in the future. Another topic that was not within the scope of this dissertation, was the fact that culture could possibly play a role in how individuals perceive musical and linguistic input. My focus in this dissertation has been on cognitive understanding of how tonal and non tonal language competence affect our understanding of music. According to Brean & Skeie (Musikk og Hjernen, 2019) the cultural impact of how we experience sound based illusions is very prescient. They mention that the tritone paradox is an interesting way to look at how differently people perceive linguistic and musical prosody which is a sound-based illusion wherein a pair of tones are spaced one tritone apart (also defined as three whole tones). The reason it is called a paradox is because some people may hear ascending tones while others may hear descending ones (Teachey, 2022). The tritone paradox is again according to Brean & Skeie similar to a Shepard tone (p. 51). The Shepard tone is another sound-based illusion. It is comprised of two pure tones wherein both are played simultaneously. One is played in a descending manner while the other is played in an ascending manner. This then gives the illusion of the tones being forever descending or ascending, even though it always goes back to the beginning (Brean & Skeie, 2019, p. 51). Brean & Skeie also mention that this illusion is connected to how our brains perceive pitch. Further on, they included a short mention of a study, wherein tritone paradoxes were played to individuals from different countries around the world (Brean & Skeie, 2019, p. 53). The people who spoke the same language, with a different variety (dialect) or accent perceived the pairs of tones differently (Musikk og Hjernen, p. 53). This may potentially mean that pitch processing is also affected not only by language, but also culture. Although this is not directly stated by the book, further research regarding this theory would be interesting to conduct on a larger scale in the future.

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