Making Music and Learning Languages – Musicality and Grammar Aptitude

Daniel Malzer

Abstract Research on correlations between musicality and language aptitude have been predominantly investigating the phonetic aspect of language processing. The current state of research suggests a strong and stable link between musicality and receptive language abilities, such as recognition of sounds, intonation and stress patterns, as well as productive skills. Relatively fewer studies have explored relations of musicality and grammar aptitude, despite neurological studies highlighting similar brain regions involved in the processing of musical, especially rhythmic, as well as grammatical patterns. This paper thus aims to investigate if musical training and musicality does indeed relate to grammatical skills. It is hypothesised that extensive musical training does not only impact the musical ear but also the ability to de- and encode structures, as well as the capacity to recognise and retain complex sequences. These specific skills are widely recognised to be involved in the acquisition of novel grammar. Research was conducted by testing a sample of 25 participants, which was split into two groups, musicians and non-musicians. Musicality of all participants was assessed and a grammar achievement test was issued. The results suggest a strong correlation between musical training, musicality and grammatical aptitude.

1 Introduction

> What Plato says about all the fine arts as fostering learning can be applied to music in particular. He speaks of these arts as preparing the mind for understanding by providing a cultural formation. […] For Plato music directly touches the emotions and remotely prepares the intellect for learning, so that this end which refers to the intellectual life is consequent upon its effect in the moral order. (Schoen-Nazarro, 1978, p. 265)

Musical abilities, a good ear, and participating in social exchanges through music have been related to general intelligence and to superior education since the Greek

D. Malzer (✉)
Department of English and American Studies, University of Vienna, Vienna, Austria

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and Roman empires. Scholars were not only trained in disciplines such as grammar, rhetoric or mathematics but also, within the framework of the *artes liberales*, music.

In recent years, research has extensively explored connections of intelligence, musical aptitude and the talent to acquire new languages. These studies all share a common goal: to determine if, and to what degree, musicality is affecting, causing, or correlating with personal traits, such as the aforementioned talent to acquire new languages. The vast majority of studies investigating the connection of language aptitude and musicality have dealt almost exclusively with the auditory segment of language processing: pronunciation, differentiation of stress, sounds or intonation patterns. Generally, it can be concluded that musicality does indeed correlate strongly with phonetic processing of languages.

However, research into possible correlations between musicality and different fields of language acquisition has been relatively limited thus far. In a recent conference paper, Kalcheva and Fonseca-Mora underlined this apparent gap, pointing out that only a "few studies [have been] contributing to the relationship and influence of music (…) on grammar achievement" (2017, p. 391). The paper at hand attempts to add to this under-represented question: does musical aptitude correlate with grammatical pattern recognition and reproduction? Or, put in other words, do the observed correlations of language aptitude and musicality also apply to the processing of written words and sentences? Numerous studies suggest that similar brain regions are involved in the processing of musical as well as language syntax. Additionally, the long standing, but highly disputed, bootstrapping theory also suggests a strong link between the recognition of acoustic features and the development of syntactical awareness in first language acquisition of infants (see for example the critical analysis of Fernald & Mcroberts, 1996). Clearly, having received musical training does foster and develop a wide array of skills and abilities, especially in an interactional setting with other musicians. Adaptability, recognition and reproduction of rhythmic and melodic patterns and retention of complex sequences may all have an impact on the processing of grammatical structures of a language.

The conducted small scale study does indeed suggest that musicians with musical training and active participation in a musical setting do display superior grammatical aptitude. The study also indicates that sub-skills of musical aptitude including the processing of patterns such as melodic and rhythmic progressions, correlate more significantly with grammatical de- and encoding as opposed to phonetic processing of pitch and tempo.

The first section of the paper at hand aims to establish a common ground on the definitions of language aptitude, musicality and grammar aptitude, including a conclusive overview of the current state of research. Subsequently, the methodology and the results of the study will be presented, followed by the discussion section attempting to relate the results to the state of research.

1.1 Language Aptitude

Human beings differ greatly in the effort required to learn a second language. Dörnyei emphasises that these individual differences “refer to dimensions of enduring personal characteristics that are assumed to apply to everybody and on which people differ by degree “(2005, p. 4). These deviations from the average are regularly referred to as talent, trait, innate abilities or qualities.

The explanation of why individuals vary can be divided into internal and external factors (Jilka, 2009, p. 1). On the one hand, internal factors encompass biological and genetic factors such as intelligence, innate personality traits relating to motivation, or empathy and aptitude (Jilka, 2009, p. 1). External factors range from socio-economic circumstances and culture-specific environments to teaching and learning strategies and methods. Methodology and strategies for teaching and learning constitute the major focus of the last decades of research into second language acquisition (Dörnyei & Skehan, 2003, 593).

The main questions leading the field of research are if such an intrinsic talent for language aptitude can be measured, if it can predict learning success effectively, and how it relates to external factors such as context, methodology and sociological backgrounds (see Dörnyei & Skehan, 2003, p. 591). According to Carroll, language aptitude encompasses four components: the ability decode and encode unfamiliar sounds, the ability to identify grammatical functions in larger segments of language, the extraction of syntactic and morphological patterns and the application in new chunks of language and, finally, the generation of an associative memory, linking vocabulary between L1 and L2 (Carroll 1962, qtd. in Dörnyei & Skehan, 2003, p. 592). The Modern Language Aptitude Test, devised by Carroll consequently defines language aptitude through four complementary abilities: “phonetic coding ability, grammatical sensitivity, rote learning ability, inductive language learning ability” (Dörnyei, 2005, p. 39–40).

Apart from the Modern Language Aptitude Test, few other aptitude tests have gained as much influence on general research into aptitude. Noteworthy are the Pimsleur Language Aptitude Battery (Pimsleur, 1966) and, more recently, the CANAL-F (Cognitive Ability for Novelty in Acquisition of Language – foreign) battery devised by Grigorenko et al. (2000). While Pimsleur‘s test battery is “quite similar to Carroll‘s MLAT “(Dörnyei & Skehan, 2003, p. 594), the Canal-F test is based on the theory that the acquisition of a language is related to general knowledge acquisition (Grigorenko et al., 2000, p. 392). This approach emphasises the central ability to cope with novelty and ambiguity in the processing of new information of an unknown language (Grigorenko et al., 2000, p. 392). Finally, the LLAMA test battery (Meara, 2005) has seen considerable use in recent years. This aptitude test battery is “loosely based” (Meara, 2005, p. 2) on the MLAT by Carroll and Sapron, using mostly picture stimuli to negate the influencing factor of differing L1 and L2 backgrounds.

Despite the widespread use of aptitude tests, achieving reliable results is rather difficult. As Jilka points out, the difficulty lies within the differentiation between talent and external factors: "accordingly, individual test tasks should be defined and constructed in such a way that the targeted abilities are indeed investigated" (Jilka, 2009, p. 8). Jilka refers to the general concept of construct validity and reliability, a highly debated topic in teaching methodology in regard of testing and assessment (see for example Brown and Abeywickrama 2010, p. 30, or Hughes, 2003, p. 26). Jilka, furthermore, advocates for the control of as many of external factors as possible, to "get at the core of 'talent'" (Jilka, 2009, p. 9). Hence, in order to exclude experience, practice, and L1 proficiency (that can obviously vary greatly despite it being the native language) Jilka proposes the use of artificial or unknown languages and "a large homogeneous group of the same age and 'learning career'" (Jilka, 2009, p. 9).

Despite these inherent limitations and difficulties of testing aptitude, Dörnyei and Skehan highlight the importance of research, as, aside from age of onset, "language aptitude and motivation have generated the most consistent predictors of second language learning success"(2003, p. 589).

1.2 Musicality

Honing et al. define musicality as "as a natural, spontaneously developing trait based on and constrained by biology and cognition" (2015, p. 1). Thus, while it is unclear to which extent musicality is an innate talent or an acquired and trained skill there is no doubt that musicality encompasses "many different components, ranging from perceptual capacities for detecting pitch and rhythm, as well as motor capacities, to emotional/theory of mind capacities for anticipating an audience's reaction" (Marcus, 2012, p. 501). Moreover, despite possible biological predispositions, attaining musical proficiency is "significantly correlated with amount of practice" (Marcus, 2012, p. 503), or as Bermudez et al. emphasise: the "intensive training and practice involved in achieving high levels of musicianship place extraordinary demands on many of the mind's most critical faculties"(2009, p. 1583).

It is not only the de- and encoding of musical information in the reception and production that requires training and practice. Especially the interaction with other musicians involves pattern recognition and retention as well as improvisation as indicated by Koelsch (2005, p. 207). Volz emphasises the complex factors that intertwine when improvising and writing music (2005, p. 50). Kraus and Chandrasekaran support this notion in their experiments, ascertaining that

> [a]ctive engagement with music improves the ability to rapidly detect, sequence and encode sound patterns. Improved pattern detection enables the cortex to selectively enhance predictable features of the auditory signal at the level of the auditory brainstem (2010, p. 600).

In respect of anatomical characteristics, a multitude of studies observed structural differences within the brain of musicians in comparison to non-musicians.

Kraus and Chandrasekaran observed "increased neural activity (…) in the auditory cortex" of pianists while hearing piano music (2010, p. 599), while various voxel-based morphometries show increased grey matter density in the Broca's area of musicians (Sluming et al., 2002) as well as in the Herschl's gyrus and left inferior frontal gyrus (Gaser & Schlaug, 2003, James et al., 2014). Moreover, Maess et al. conducted a magnetoencephlaography, showing that "harmonically inappropriate chords activated Broca's area and its right-hemisphere homologue" (2001, p. 543, similarly Marques et al., 2007). Generally, it is agreed upon that musical training and expertise can be traced through differing brain structures. Strait and Kraus presume that these changes are caused by the extraordinary demands of processing music:

> [d]ue to its multisensory nature, attentional demands, complex sound structure, rhythmic organization and reliance on rapid audio-motor feedback, music is a powerful tool for shaping neuronal structure and function (Strait & Kraus, 2011, p. 141).

1.3 Studies on Language Aptitude and Musicality

The main line of argument accompanying studies on language aptitude and musicality is the concept that musical practice trains the brain to be more perceptive. Hence, this increased auditory fitness is likely to affect not only the perception of sounds but also the production (see Kraus & Chandrasekaran, 2010, p. 599). Various studies have highlighted increased language aptitude of musicians compared to non-musicians in relation to receptive phonetic skills: increased pitch processing (Marques et al., 2007); better discrimination of tonal and segmental variations (Slevc & Miyake, 2006, p. 679; Marie et al., 2011); and increased phonetic awareness in distinguishing between phonemes and intonation (Fonseca-Mora, Toscano-Fuentes & Wermke, 2011, p. 105; Pastuszek-Lipinska, 2004, p. 68). Comparatively fewer studies also tested and observed increased productive abilities of musicians: improved pronunciation (Milovanova et al., 2008), or better performance on language imitation tasks (Christiner & Reiterer, 2015). Additionally, Christiner and Reiterer observed better results of vocalists compared to instrumentalists on a language imitation task of an unknown language (2015). These results are supported by a rather comprehensive study among 128 Chinese college students, again showing strong correlations between musical aptitude and suprasegmental production in a foreign language (Pei et al., 2016, p.19). In their extensive literature review, Chobert and Besson conclude:

> Taken together, these results show that musicianship facilitates the learning of non-native supra-segmental and segmental contrasts defined by acoustical features (e.g., pitch and duration) and improves categorical perception. It may be that musical expertise refines the auditory perceptive system (bottom-up facilitation), but it may also be that years of intensive musical practice exert top-down facilitatory influences on auditory processing. (2013, p. 928)

1.4 Grammar and Syntax Processing

Brown and Abeywickrama (2010, p. 294) define grammatical competence as knowledge of grammatical forms as structure of the language, as the meaning of these forms and, finally, as the pragmatic meaning in its corresponding context. Concerning the form, the authors emphasise that “form is both morphology, or how words are formed, and syntax, how words are strung together” (Brown & Abeywickrama, 2010, p. 294). These conceptual categories are based on the works of James Purpura who, in great detail, elaborated on the specific sub-categories of each area (Purpura, 2004, p. 91). Specifically for the sentential level, Purpura refers to the segmental and lexical forms, orthographic, syntactic and morphological features and irregularities, as well as word formation and morphosyntactic forms and affixes (Purpura, 2004, p. 91). However, Purpura additionally considers prosody and correspondence of sound and spelling as well as phonetic features as part of grammatical processing (2004, p. 91). Thus, following this paradigm, the process of de- and encoding of sounds and the transfer to the written word is all entrenched in the wider area of grammatical knowledge. Flöel et al. on the other hand, regard the extraction of rule-based information as the core and intrinsic requirement for the acquisition of grammar (2009, p. 1974). Hence, grammatical learning involves predominantly rule extraction to create and assess knowledge (Flöel et al., 2009, p. 1975). In a similar vein, Kepinska et al. emphasise the analytical ability as the dominant component while acquiring novel grammar (2016, p. 1).

Research into the field of syntax processing and aptitude generally observes great individual differences for the acquisition of syntactic knowledge (see for example Nauchi & Sakai, 2009; Hulstijn, 2005; Pakulak & Neville, 2010). Generally, ERP-[1] (see Pakulak & Neville, 2010; Tanner, Inoue & Osterhout, 2014) as well as FMRI-based studies (see Golestani et al., 2006; or Nauchi & Sakai, 2009) observed differences in the brain organisation between high and low proficiency groups tested through syntax processing tasks. The studies indicate activation in the left inferior frontal gyrus (Nauchi & Sakai 2009, p. 2626; Indefrey et al., 2004; Golestani et al., 2006, p. 1029), while some expressively emphasise the activation of the Broca‘s area situated in the inferior frontal gyrus (see for example Golestani et al., 2006, p. 1038; or Flöel et al., 2009, p. 1979). Some studies furthermore indicate a significant variability in white matter integrity around the Broca‘s between high and low proficiency groups in terms of grammatical aptitude (see Flöel et al., 2009, p. 1979). In essence, it is widely agreed upon that there is a significant correlation of syntactic ability and increased brain activity and differing brain structures.

[1] Event-related potential, which refers to the brain response as direct result of a stimulus. Regularly, EEGs are used to measure ERP.

1.5 Studies on Musicality and Grammatical Aptitude

As aforementioned, studies examining the relation of musicality and grammatical aptitude are relatively scarce. Maess and Koelsch have conducted various studies and experiments attempting to establish correlations between the processing of musical and language syntax, including an MEG study in 2001, suggesting that complex-rule based information is likely to be processed in the "Broca's area and its right-hemisphere homologue" for language and music: "from a functional-neuroanatomical view [there is] a strong relationship between the processing of language and music" (Maess & Koelsch, 2001, p. 543). Further ERP studies observed similar activations in the Broca's area (Koelsch 2005, p. 209; and Koelsch et al., 2005) while a study from 2011 remained inconclusive on the relation of music and language in a simultaneous processing setting (Maidhof & Koelsch, 2011). Kunert et al. conducted an fMRI study further suggesting interaction of music and language processing in the Broca's area (2015, p. 11). The authors however point out that this may just be limited to the processing of violations (2015, p. 12). In contrast to these studies, Slevc and Miyake observed no correlation between language aptitude and syntactical nor lexical knowledge in their study (2006, p. 679). Most recently, Gordon, Jacobs, Schuele and McAuley (2015) as well as Kalcheva and Fonseca-Mora (2017) observed strong links between music and grammar in their studies. Kalcheva and Fonseca-Mora examined two groups (singers with professional training and non-musicians) of adult Spanish learners of English and conclude: "our study points to a beneficial influence of singing on grammar achievement as part of the foreign language learning process in adults" (2017, p. 391). These most recent experiments further support the importance of exploring possible correlations of grammatical aptitude and musical skills.

1.6 Hypothesis

As demonstrated in the literature review, research on brain structures and activation of certain brain regions while processing musical and grammatical input indicates numerous similarities. Moreover, additional similarities could be expected through the processes of de- and encoding of sequences in music and the processing of novel grammar.

The underlying rationale of this study aims to consider the abilities intrinsic to musicality which are fostered and enhanced through active participation in a musical setting such as an ensemble, orchestra or band music, which should strongly influence pattern detection, retention and application.

The general, overarching hypothesis enquires about the overall correlation of musicality and grammatical aptitude, thus H_1 constitutes itself as follows:

H_1: There is a significant positive correlation between musicality scores and the grammatical aptitude test.

H_2 on the other hand specifically aims to observe correlations of grammatical aptitude and musical expertise and training, hence:

H_2: Musicians achieve a significantly higher score on grammatical aptitude tests than non-musicians.

Finally, the study is interested in the specific sub-skills of musicality and which of these relate to grammatical aptitude. The musicality test encompasses 4 subcategories: tuning, melody, accent and tempo. Melody and accent requires the participant to process, and retain rhythmic and melodic patterns, which is hypothesised to be closely linked to the encoding and decoding of grammatical syntax. Thus, the final hypothesis aims to observe the following correlation:

H_3: The musicality subtests that test pattern recognition and retention (Melody and Accent) correlate stronger with the grammatical aptitude test than the phonetic recognition tests (Tuning and Tempo)

2 Methodology

2.1 Participants

The sample of the study consisted of 25 participants, 14 male (56%) and 11 female (44%). The questionnaire divided the group into 10 musicians (40%) and 15 non-musicians (60%) based on musical experience in terms of training and active participation in a musical setting. However, it has to be noted that despite considerable efforts, the musician group sees a skewed sample size in regard of gender distribution: of the 10 musicians, only 2 females (20%) could be recruited for the study. In terms of age, the group can be regarded as rather homogenous with a mean of 30 years ($SD = 4.3$), the youngest being 23 and the oldest 35 years old.

Regarding education, the sample group again displays a considerable level of homogeneity, as 9 of the 25 participants (36%) are currently enrolled in university programs, whereas 16 (64%) already obtained at least one university degree.

All participants reported to be German native speakers and, based on the self-assessment of the questionnaire, spoke English at least on B2-level.[2] All participants reported to be proficient at least at one more language, ranging from A2 to C2 level.

[2] The Common European Framework of Reference has been used as basis, for more details on the respective levels of proficiency see: Council of Europe 2011. The Common European Framework of Reference for Languages: Learning, Teaching, Assessment. Cambridge: CUP.

2.2 Instruments

To investigate the hypotheses, two tests were administered to assess musicality and grammatical aptitude. First of all, the Mini-Proms test (available online[3]) devised by Strauß et al. (2015) was used to determine overall musical abilities of the participants. The test assesses overall musicality through four subtests: *melody*, *accent*, *tuning* and *tempo*. Each section differed on maximum points achievable, *melody* and *accent* ranging from 0 to a maximum of 10 points, *tuning* and *tempo* from 0 to 8 points, resulting in a total of 36 points overall.

The *melody* section asks the test taker to compare harmonic sequences and patterns. The following section, *tuning*, requires the participant to determine if consecutive tones are the same or different in regard to pitch. Thirdly, *tempo* similarly requires the test taker to compare the relative tempo of two sound sequences with a monotone rhythm without any accents. And, finally, the *accent* section requires the retention and detection of rhythmic patterns over a sequence of 5–12 beats. According to Strauß et al., the test shows strong reliability and consistency throughout the entire procedure, being able to reliably predict musical experience and training (see Strauß et al., 2015).

Secondly, to assess grammatical aptitude, this study included section B of the Oxford Classics Language Aptitude Test (2013), a subtest of the Oxford University Classics Admissions Test. This specific sub-section features an artificial language, *Fub*, and requires the participants to detect, recognise and retain grammatical patterns and subsequently apply these rules in translation tasks ranging from short phrases to longer sentences featuring compound clauses. As the sample group had a diverse language background aside the shared L1 and English (including Hungarian, Spanish, Turkish, Croatian, Chinese, Dutch, French, or Italian) the artificial language allowed to eliminate any bias in relation to the language background. Moreover, the English skill level used in the prompt and the tasks themselves did not exceed B2 at any point, thus eliminating any further advantage based on the respective skill levels of English of the participants. Finally, the tasks closely follow the aforementioned construct of Purpura (2004, 91) eliciting grammatical knowledge pertaining to syntactical and morphological form. It has to be noted that scoring was done by the author of the study, attempting to eliminate any intra-rater bias through concealing the names of the test-takers and evaluating every test twice.[4] The test section provided the scores for each item independently, the maximum score

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[3] Universität Innsbruck 2017. "Mini-Proms". https://www.uibk.ac.at/psychologie/fachbereiche/pdd/personality_assessment/proms/take-the-test/mini-proms/. (25 Jul. 2017).

[4] It has to be noted however, that the Oxford Classics Language Aptitude Test is not validated and generally not used for language aptitude testing. Moreover, while a solution sheet was provided, the scoring of the tests is still subject of personal assessment and consideration. Thus, intra- and inter-rater reliability may be considered average. Despite these reliability issues, construct and content validity and the relative authenticity of the language processing situations do outweigh, in the opinion of the author, the downsides of the scoring.

possible amounted to 50 points. Each item consisted of translation tasks, either requiring the participant to translate the artificial language into English or vice versa. The following example aims to illustrate the task:

huufls hohub red	The teachers taught the pupils.
hiip pik hohub	A teacher provided homework.
rored pik daawl	The pupils had homework.
rored pik liikl	The pupils liked the homework.
tok daaw rored	A pupil had a dog.
totok liiks red	The dog liked the pupils.
tok rored huuf	The pupil taught the dog.
paat pik totok	The dog ate the homework.

Give the meaning of:
liikl hohub tok
[3] (Oxford Classics Language Aptitude Test, 2013, Section B(a)).

Thus, each section commenced with a set of examples providing enough information to deduce morphological and syntactical patterns and to apply them in the consecutive translation tasks. The maximum points per task is given in the squared bracket, with each separate word (‘liikl‘, ‘hohub‘, and ‘tok‘) amounting to 1 point, half for correct vocabulary, and half for correct form (‘tok‘in the example representing the vocabulary ‘dog‘and the grammatical function of object of the sentence).

2.3 Procedure

A preliminary basic questionnaire was compiled aiming to assess the musical background of the participants. Aside from general questions determining age, gender, nationality, language background and language proficiency, the main corpus of the questionnaire elicited the amount and duration of musical training, as well as the participation in organised musical environments, such as band practice, orchestra or ensembles. In line with the proposed hypothesis, to be qualified as a musician, the participants had to attend a minimum amount of musical training (2 years in the last 5 years, or 5 years overall) in addition to regular participation in an orchestra or similar musical activity (again 2 years in the last 5, or 5 overall). Due to the small sample size of musicians, no distinction was made between instrumentalists, multi-instrumentalists, or vocalists.

Subsequently, the participants received an online link to test for musicality (details below in the test section) and, finally, an email with an editable pdf file including the grammar aptitude test. The participants were asked to send a screenshot of the final results page of the musicality test (including the detailed sub-scores) together with the filled-in grammar test back for assessment. The overall length of the two tests combined amounted to roughly 1 h and 15 min.

3 Results

A One-Sample Kolmogorov-Smirnov Test was conducted to test for a normal distribution of the musicality and grammar test. Results suggest a normal distribution for both tests (p = 0.20 for the Musicality Test and p = 0.55 for the Grammar Test), which was confirmed visually with QQ-plots and histograms.

To test for H_1, the correlation of musicality and grammatical aptitude, a Pearson-Correlation Test was conducted. Results show a strong, significant correlation ($r = 0.688$, $p < 0.001$) between the results of the musicality test scores and the grammatical test scores. This finding is supported visually by a scatterplot depicting the correlation between the musicality test scores and the grammar test ($r^2 = 0.474$, see Fig. 1). Hence, the H1 can be accepted.

To test for H2, T-Tests for independent samples for musicians and non-musicians was conducted with respect to both the musicality and grammar tests. Considering the musicality test, musicians scored on average 25.95 points ($SD = 5.1$) while non-musicians reached an average of 19.73 points (SD = 2.4) on a 36 points scale. Levene‘s Test for Equality of Variances between musicians and non-musicians for the musicality test shows that equal variances between the two groups can be assumed ($p = 0.57$). The T-test for equality of means showed a significant difference between the two groups ($t(23) = -3.58$; $p = 0.002$,).

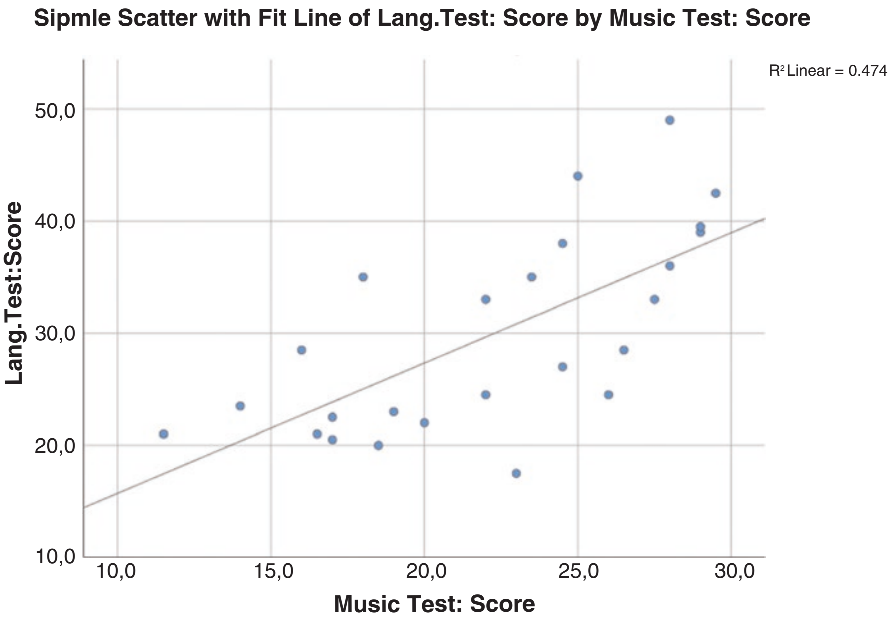

Fig. 1 Scatterplot of musicality test and grammar test

Similarly, the results of the grammatical aptitude test differed significantly between musicians (M = 36.6, SD = 6.76) and non-musicians (*M* = 25.47, *SD* = 6.76). Levene's Test revealed homogeneity of variance ($p = 0.976$) with the T-Test again showing a significant difference between musicians and non-musicians ($t(23) = -3.939$; $p = 0.001$). Hence, the results display a significant difference between the results on the musicality test as well as on the grammar test between the two groups of participants. Thus, H2 can be accepted.

Finally, H3 aimed to examine correlations between the subtests *melody* and *accent* of the musicality test in contrast with *tuning* and *tempo* and the grammar test. Pearson-Correlations of each sub-skill and the grammar test results display the expected divergences between the pattern detection and retention subsets of *accent* and *melody* compared to the phonetic perception tests, *tuning* and *tempo*. The subtest *accent* displayed the strongest, significant correlation ($r = 0.696$, $p < 0.001$) with the grammar test results, followed by *melody* ($r = 0.623$, $p = 0.001$), *tempo* ($r = 0.502$, $p = 0.01$) and *tuning* ($r = 0.476$, $p = 0.016$). Hence, while all four subskills correlate positively with the grammar test results, *melody* and *accent* clearly show a significantly stronger overall correlation. Hence, H3 can be accepted.

In order to evaluate possible factors interfering with the results, more tests were conducted. An independent samples T-Test comparing the results of males and females on the musicality and grammar test showed insignificant results regarding the musicality test ($t(23) = 1.124$; $p = 0.273$; male $M = 23.25$, $SD = 5.6$; female $M = 20.91$, $SD = 4.5$). In contrast, the results of the grammar test show significant differences between gender groups ($t(23) = 2.209$; $p = 0.037$; male $M = 33.11$, $SD = 9.4$; female $M = 25.86$, $SD = 6.2$). However, as elaborated on above, the sample group did not consist of matching numbers of females and males, especially concerning the musician group, which is most likely the reason for the differing results.

Regarding age and the musicality test, the Pearson test showed a significant positive correlation ($r = 0.416$, $p = 0.039$) while the relation of age and the language test was not significant ($r = 0.297$, $p = 0.149$). As Fig. 2 demonstrates however, generally musicians in the sample size were older than their non-musician counterparts, which again is very likely the reason for the observed differences.

Finally, in terms of education, an independent samples t-test demonstrated that there is no difference between the two groups present (university degree and Matura (i.e. Austrian A-levels)) for both the musicality test ($t(23) = -0.247$; $p = 787$) and language test ($t(23) = -0.316$; $p = 0.755$).

Overall, the results strongly indicate correlations between musical expertise and grammatical aptitude. Additionally, H3 suggests that musical abilities that are related to pattern analysis, retention and application also correlate more strongly with the results of the grammatical aptitude test in comparison to the detection of phonetic characteristics in terms of pitch and tempo. Naturally, the observed results only indicate correlations and cannot attest for any causality.

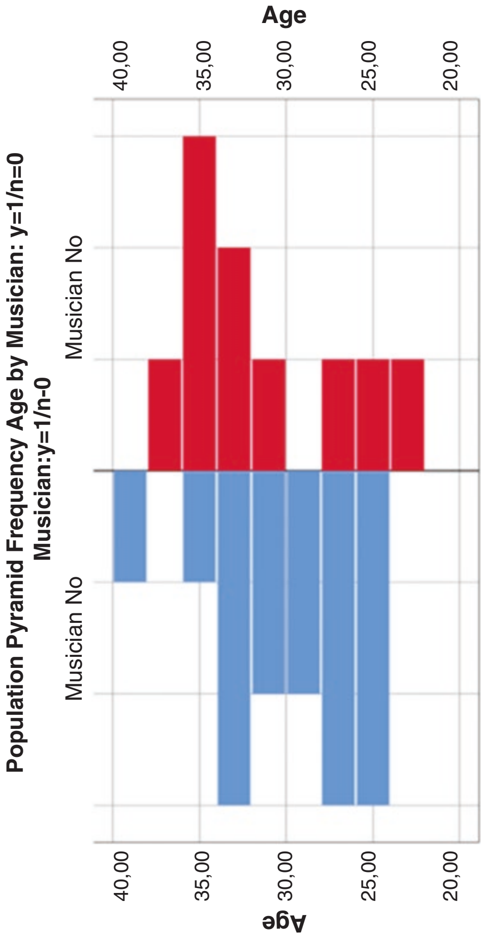

Fig. 2 Population pyramid highlighting age distribution among musicians and non-musicians

4 Discussion

The previously listed research offers a plethora of explanations for these observed correlations. As discussed above, studies on grammatical aptitude and musicality regularly highlight similar brain regions involved in the processing of music and language. Maess et al., having observed activations in the Broca‘s area while processing musical chords, indicate that

> complex rule-based information is processed in these areas with considerably less domain-specificity than previously believed. This might suggest that these areas process syntax, that is, complex rule-based information, in a domain other than language (2001, p. 543)

Similarly, numerous studies emphasise similarities in the nature of processing music and syntax information in language through the shared requirement of pattern detection. Kunert et al. ascertain that “[i]nstrumental music and language are both syntactic systems, employing complex, hierarchically-structured sequences built using implicit structural norms” (2015, p. 1), while Brown et al. regard music and speech both as combinatorial systems “in which larger structures are generated hierarchically from a pool of smaller, more unitary components” (2006, p. 2791). Also Flöel et al. emphasise these factors, indicating that the acquisition of grammar implies the “extraction of rule-based information” (2009, p. 1974). This again can be related to the processing of music, as Kraus and Chandrasekaran point out:

> Active engagement with music improves the ability to rapidly detect, sequence and encode sound patterns. Improved pattern detection enables the cortex to selectively enhance predictable features of the auditory signal at the level of the auditory brainstem (2010, p. 600)

These observations generally highlight that musicality is not limited to the processing of sounds alone. Aside from the auditory skills involved, active musical engagement naturally also relates to motor skills, but also to the processing of rules and patterns (see Kalcheva & Fonseca-Mora, 2017, p. 391). This may also explain the underlying rationale behind H_3, the assumed positive correlation of the pattern-based musicality sub-tests, melody and rhythm. These two sub-skills are obviously core characteristics of musical interaction. Hence, the results of the present study indicating a relation between musical expertise through practice and training in an interactional setting and grammatical aptitude could in fact be based on similar processes of pattern detection and extraction and application of deduced rules.

Furthermore, Fonseca-Mora, Toscano-Fuentes and Wermke emphasise that, after all, “language acquisition depends on interaction” (2011, 101). It can be assumed that increased interaction and focus through practice may increase the success of language acquisition. Similarly, this study defined the prerequisite to be qualified as musician as having participated in an organised musical setting which naturally involves interaction as well. The interactional nature and the processes involved in musical interaction per se are lacking conclusive research, thus any relation based on similar interactional settings can only be hypothesised. However, to add to the interactional nature of language and music, simple personal experience can attest for the complex process of interacting with others through music. Clearly, musical communication predominantly requires the processing of auditory cues and input, but it also stresses rhythmic and melodic pattern detection to anticipate and comprehend structures to enable the musicians to interact successfully. From this point of view, the processing of language and music can be regarded as a similar process of inferencing, de- and encoding of information followed by the application of these complex rule-based in the generation of another sentence or the next part of a sequence of sounds and rhythmic patterns. Chobert and Besson support this notion by emphasising that "musical practice requires sustained attention control and memory" (2013, p. 931) which in turn may positively affect language processing as well. Finally, the aforementioned bootstrapping theory may yet add another line of reasoning for the correlation of musicality and grammatical aptitude. Soderstrom et al. indicate that infants may deduce syntactic boundaries of strings of language "even before lexical knowledge is available" through a natural sensitivity to prosodic markers of "syntactic units smaller than the clause" (2003, p. 249). Mazuka (2007)support these findings in their own experiments, adding that the rhythmic organisation of a language "provides the child learner with a means of segmenting the speech stream into linguistically significant units (2007, p. 1). However, it has to be noted that the bootstrapping theory is highly disputed. Fernald and McRoberts criticise the absence of direct evidence and the problematic inconsistency of acoustic cues (1996, p. 365).

Naturally, numerous other factors can be considered to have caused the observed results and correlations. First of all the present study does contain certain incalculable factors due to administrative difficulties. Primarily, the small sample size may negatively impact the overall validity. Especially considering that the participants took the tests in an uncontrolled environment, the study cannot attest for factors such as external help, extension of the time limits or participant-related reliability factors such as fatigue.

Furthermore, as elaborated on above, the test itself displays certain issues concerning rater-reliability. Additionally, the Oxford language aptitude test did not undergo a validation process, thus construct and content validity cannot be accounted for. However, it has to be noted that the test is used in this form as admissions test since a considerable amount of time and the tasks themselves strongly suggest indicate construct validity in relation to the framework suggested by Purpura (2004, p. 91).

Secondly, as Strait and Kraus quite poignantly observe, the general problem with comparative studies is the problem of other interfering factors that can hardly ever be attested for, such as general intelligence, socio-economic background or learning methods and strategies (2011, p. 133). Thus, it is entirely possible that the groups examined in the present study may also differ significantly on any these factors, as they are all regularly linked to aptitude and language processing as well. The design of the study made it impossible to exclude these possible intervening factors, however, larger scale studies could include intelligence, working memory and further additional tests to better control these factors. Despite these limitations, the sample group at least showed general homogeneity in respect of educational background, and common L1, similar levels of L2.

Especially the relation of working memory and language aptitude demands further mentioning. While research investigating this relationship is still limited, quite a few studies show indeed a positive correlation (see for example Yalçın, Sevdeğer & Erçetin, 2016). Yalçın, Sevdeğer and Erçetin furthermore observed a strong correlation between working memory and grammatical inferencing (2016, p. 144). Moreover, a comprehensive meta-analysis of 79 studies in 2013 strongly supports a positive relationship between working memory and L2 proficiency (see Link et al. 2014). The grammatical aptitude test does represent itself as a rather fitting example for working memory and aptitude relations due to the process of the test involving retention of phrases under time constraints.

Furthermore, another factor that may have influenced the results on the grammar test could be the motivational aspect of the study. The structure of the testing sequence allowed the participants to see their results on the musicality test (together with a short summary evaluating their scores) before taking the grammar test. Dörnyei and Skehan specifically emphasise that motivational aspects are a very strong predictor of learning success (2003: 589). Thus, the experience and the results of the musicality test may have influenced motivation and performance on the following task.

Finally, another factor possibly influencing results, is reading ability, which may in fact be related to musicality as a growing number of studies suggest. Overy et al. observed correlations between the detection of musical timing and tempo perception and dyslexia, concluding that reading impairment may be remedied through musical training (2003, p. 34). Similarly, Strait, Hornickel and Kraus support the relation of musical aptitude and general reading ability, concluding that their data acquired through a small scale empirical study among school children indicate "common brain mechanisms underlying reading and music abilities that relate to how the nervous system responds to regularities in auditory input" (2011, p. 1). Another recent small scale study adds to these observed correlations: Bekius, Cope and Grube conclude that their findings confirm the "relevance of auditory regularity processing in reading skill" (2016, p. 8). As emphasised above, every grammar or vocabulary task has to be embedded in a skill such as reading, speaking, listening or writing. Thus, while it seems impossible or impractical to attempt to eliminate this factor, a reading ability test could be administered to control for this factor as well.

The relatively long list of limitations and various other factors possibly influencing test results only highlights the complexity of language aptitude and the concept of musicality. Despite all these aforementioned factors, especially working memory, motivation and reading which may have contributed to the overall test results, the overall strong correlations of the presumed hypotheses relating musicality and grammatical syntax can not be disregarded.

5 Conclusion

The present study highlights the possible relation of musical expertise and grammatical aptitude. Despite various factors that could not be accounted for, the results definitely warrant further research on these correlations. The review of previous studies also highlights that the concepts of musicality, grammar, and aptitude in general require considerable research to better grasp and define these terms. The results of the study can be based on presumed similarities of language and music processing in regard of pattern de- and encoding. Clearly, musicality and active musical engagement encompass more than the processing of sounds. Especially the focus on patterns transmitted through rhythm, accentuation, and harmonic progression indicate the complex nature of musicality. Thus, the present study strongly suggests further research into these rather unrepresented aspects of musical ability and language processing. Naturally, the present study can only add a small indication of these possible relationships, especially considering the inherent limitations. Eventually, consecutive studies certainly have to account for the, frankly, numerous factors that may influence language aptitude while testing for correlations between musicality and language processing.

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