languages

Article

The Contribution of Music Abilities and Phonetic Aptitude to L2 Accent Faking Ability

Marion Coumel [1], Christine Groß [2], Sabine Sommer-Lolei [3] and Markus Christiner [2,4,*]

[1] Department of Psychology, University of York, York YO10 5DD, UK
[2] Jazeps Vitols Latvian Academy of Music, K. Barona Street 1, LV-1050 Riga, Latvia
[3] Austrian Academy of Sciences, Dr. Ignaz Seipel-Platz 2, 1010 Vienna, Austria
[4] Centre for Systematic Musicology, University of Graz, Glacisstraße 27, 8010 Graz, Austria
* Correspondence: markus.christiner@uni-graz.at

Abstract: This study examined how second language (L2) speakers' individual differences in music perception abilities, singing abilities and phonetic aptitude relate to their L2 phonological awareness. To measure participants' L2 phonological awareness, we used an accent faking paradigm, where participants were asked to speak in their native language (German) while imitating a strong L2 accent (English). We measured their musical abilities with the AMMA test and their singing abilities with two singing tasks and a self-report questionnaire. Their phonetic aptitude was assessed with a combination of phonological short-term memory tasks (forward and backward digit span tasks), and language perception and production tasks, in which participants needed to process and imitate sounds from unfamiliar languages. A regression analysis revealed that singing abilities and phonetic aptitude could predict participants' English faking abilities. This suggests that being able to sing could help learners produce and memorise highly accurate L2 sounds, although their performance could also partly be explained by innate learning capacities such as phonetic aptitude. This study also proposes a new combination of tests to obtain a well-rounded assessment of individual differences in phonetic aptitude.

Keywords: accent faking; pronunciation; phonological awareness; second language learning; singing abilities; musical expertise; phonetic aptitude; short-term memory

check for updates

Citation: Coumel, Marion, Christine Groß, Sabine Sommer-Lolei, and Markus Christiner. 2023. The Contribution of Music Abilities and Phonetic Aptitude to L2 Accent Faking Ability. *Languages* 8: 68. https://doi.org/10.3390/languages8010068

Academic Editor: Jeanine Treffers-Daller

Received: 4 December 2022
Revised: 13 February 2023
Accepted: 20 February 2023
Published: 27 February 2023

1. Introduction

Being able to speak and communicate in a foreign language is more essential than ever as a consequence of a steadily growing multilingual world. While pronunciation is not the only factor that determines whether speech produced by second language (L2) speakers is comprehensible or not (Saito et al. 2016), L2 speakers can be perceived as less credible, less educated, less intelligent and less competent than native (L1) speakers due to their foreign-accented speech (Dewaele and McCloskey 2015; Fraser and Kelly 2012; Fuertes et al. 2012; Gluszek and Dovidio 2010; Lev-Ari and Keysar 2010). However, achieving high levels of L2 pronunciation skills is one of the most challenging tasks late L2 learners face during their language learning journey (cf. Granena and Long 2013). In order to build efficient educational strategies to teach L2 pronunciation, it is necessary to understand which factors lead to successful acquisition of L2 pronunciation and how such acquisition relates to language aptitude.

Previous research suggests that an individual's L2 phonological awareness, their knowledge of the L2 phonological system at the segmental and suprasegmental levels, and of the phonetic differences between the sounds of their first and their second language (Kivistö-de Souza 2015; Mora et al. 2014), relates to accuracy in production of L2 sounds (Baker and Trofimovich 2006; Mora et al. 2014) and to production of more comprehensible L2 speech (Venkatagiri and Levis 2007). Thus, in the present study, we decided to examine which factors could relate to learners' L2 phonological awareness. To measure L2 phonological awareness, we used an accent faking task where L1 German speakers were asked to fake an L2 English accent while reading L1 German sentences (Coumel et al. 2019; Kopečková et al. 2021; Kivistö-de Souza 2015; Mora et al. 2014). We then investigated the potential influence of individual differences in music perception abilities, singing abilities, and phonetic aptitude on learners' L2 accent faking abilities.

1.1. Music Perception and Singing Abilities

Previous research suggests that a wide variety of factors relate to L2 pronunciation skills such as individual differences in age of acquisition, amount of exposure to the target language, number of foreign language classes attended, and motivation (Flege et al. 1995; Muñoz 2014; Shoemaker 2014; see Suzukida 2021 for a review). In particular, a constantly growing number of studies have provided evidence that musical expertise may play a key role in supporting processing of pronunciation (Asaridou and McQueen 2013). This may be the case because both music and language are acoustic phenomena, both are hierarchically structured, both contain tonal and rhythmical features (Honing 2011; Jackendoff and Lerdahl 2006), and because tone transitions in melodies resemble the prosodic variations of spoken language (Oechslin et al. 2010). In fact, neurophysiological studies have shown that the acoustic signals of language resemble the spectral and temporal complexity of music (Ding et al. 2017; Groß et al. 2022; Schön et al. 2004). Further research suggests that overlapping cognitive resources could be responsible for the processing of both musical and linguistic stimuli (Besson et al. 2011; Peretz et al. 2015). This may explain why musical training has been found to improve neural processing of speech in neurophysiological investigations (Besson et al. 2011; Intartaglia et al. 2017; Parbery-Clark et al. 2012). At the behavioural level, musical training, higher musical abilities, or being able to play a music instrument seem to facilitate processing of linguistic input (Chobert et al. 2014; Delogu et al. 2010, 2006; François et al. 2013; Moreno 2009; Perrachione et al. 2013; Schön et al. 2004; Thompson et al. 2004).

Musical expertise also seems to relate to the processing and the learning of L2 pronunciation (Milovanov 2009; Pastuszek-Lipinska 2008). Performance on the AMMA test (Advanced Measures of Music Audiation; Gordon 1989), which measures participants' ability to detect differences in rhythm and tones between two musical statements, has been found to predict Japanese L1 speakers' perception of English phonology (Slevc and Miyake 2006). Another study has shown that Italian L1 speakers with high AMMA scores outperform participants with lower AMMA scores on a Mandarin lexical tone discrimination task (Delogu et al. 2010). Similarly, previous research has shown that musicians can be better at identifying and discriminating unfamiliar Mandarin tones than non-musicians (Gottfried and Riester 2000; Gottfried et al. 2004; Han et al. 2019). Finally, high musical abilities can lead to higher L2 productive phonological proficiency for pronouncing words or tones (Gottfried et al. 2004; Milovanov 2009; Milovanov and Tervaniemi 2011; Posedel et al. 2012; Slevc and Miyake 2006), while musicians have been found to outperform non-musicians on foreign language imitation tasks (Christiner and Reiterer 2013, 2018; Christiner et al. 2018).

Though this is less frequently investigated, there is evidence that singing abilities exert a stronger influence on foreign language pronunciation abilities than musical abilities assessed on the AMMA test (Christiner and Reiterer 2013, 2015, 2019). This could be because speaking and singing rely on similar mechanisms for emission, resonance and articulation, and for the control of body posture (García-López and Gavilán Bouzas 2010). Singing abilities may also help pronounce L2 sounds better. Singing seems to redefine how the individual components of the vocal organ, the respiratory system, the vocal folds, and the vocal tract which support vocalisation interact (Sundberg 1999). Singing training could thus in turn benefit the production of L2 sounds by allowing singers to produce them more accurately and by providing vocalists with an enhanced vocal flexibility (Christiner and Reiterer 2013, 2019).

Finally, being able to sing may help L2 speakers learn L2 sounds. The oromotor system, which is highly developed in singers, is thought to support the formation of memories (Schulze et al. 2012). As a result, it could help store accurate long-term phonetic representations of sounds (Ludke et al. 2014). Recent neurophysiological research has also provided evidence that sensory ability could explain the relationship between singing abilities and foreign language pronunciation learning skills (Christiner et al. 2022a). In line with this, several studies have shown that memorizing vocabulary is easier if words are sung (Apfelstadt 1984; Ludke et al. 2014; Thiessen and Saffran 2009), while singing to infants seems to positively influence vocabulary building (Franco et al. 2021). There is also evidence that singing activities can support L2 pronunciation learning (Baills et al. 2021; Good et al. 2015; Ludke 2016) and that individuals who sang more frequently during their childhood have better foreign language pronunciation skills (Christiner et al. 2022b).

1.2. Phonetic Aptitude

Another potential predictor of successful acquisition of L2 pronunciation is learners' phonetic aptitude, i.e., their untaught, inherent ability to acquire knowledge of (foreign) language sounds. Some studies indeed suggest that individual differences in how well individuals are able to learn a foreign language partly lie outside training and learning effects (Golestani and Pallier 2007; Golestani et al. 2011). Phonetic aptitude has typically been defined as a subcomponent of language aptitude. For instance, in his pioneering work, Carroll (1981) included phonemic coding ability as part of language aptitude, i.e., how well an individual can identify new speech sounds and retain them in long-term memory.

While overall language aptitude has gained increasing interest in the past decade, how it relates to learning and achievement in an L2 remains unclear (Wen et al. 2017). One of the reasons for this might be that defining and measuring language aptitude is challenging. Researchers consider that it is a complex rather than a unitary trait (Delvaux et al. 2014; Dörnyei 2005; Skehan 2019) and that it consists of multiple general cognitive and verbal abilities (Linck et al. 2013). We argue here that, in order to obtain a well-rounded assessment of phonetic aptitude, a wide battery of tests should be used (see below) to measure a learner's ability to process, produce, and memorise (unfamiliar) speech sounds.

Acoustic memory, the capacity to process novel sounds and, more specifically, to store non-linguistic acoustic information temporarily before it is phonologically encoded, may contribute to phonetic aptitude. Acoustic memory is measured, for instance, by asking participants to assess if a target unfamiliar speech sound was heard in a preceding sequence of sounds (e.g., Kogan 2020). Some research has shown that acoustic memory supports processing of foreign sounds (Kogan 2020; Safronova 2016).

Importantly, most phonetic aptitude tests included in language aptitude tests so far have assessed perception, but not production. For instance, the PLAB (Pimsleur Language Aptitude Battery; Pimsleur 1966) consists of a subsection where students listen three times to almost identically sounding words in Ewe, a language unknown to them, and are asked to remember and discriminate them in a follow-up session. Likewise, the LLAMA test (Language Learning and Meaning Acquisition; Meara 2005) only includes a sound recognition task in which participants memorise short stretches of spoken utterances in a British Columbian Indian language.

However, measuring the phonetic aptitude with both perception and production tasks seems necessary given that studies in the field of music and language have reported dissociations between perception and production processes. Some studies have shown that individuals who perceive languages more accurately do not necessarily generate them better (Christiner 2020; Golestani and Pallier 2007), while participants who accurately perceive different pitches do not necessarily sing them accurately (Berkowska and Dalla Bella 2009; Hutchins and Moreno 2013; Loui et al. 2009; Pfordresher and Mantell 2014; Tremblay-Champoux et al. 2010). Such results suggest that perception and production skills may be partially dissociated. Thus, one may need to assess aptitude both in terms of perception and production to obtain a well-rounded assessment of phonetic aptitude (but see Flege and Bohn (2021) for a model describing the possibility that perception and production co-evolve). In line with this, Jilka (2009) proposed to assess phonetic abilities with a variety of tasks including not only perception but also production of L1, L2, and unfamiliar languages (see Reiterer et al. (2011) for a use of imitation tasks to assess phonetic aptitude in production). More recently, Delvaux et al. (2014) have hypothesised that phonetic compliance, the intrinsic ability to produce unfamiliar speech sounds, also determines how well learners can acquire the phonetics and phonology of an L2.

Finally, phonological STM, the subcomponent of working memory that supports processing of verbal material (Baddeley et al. 1998) may also contribute to phonetic aptitude. Phonological STM includes the phonological store and the phonological loop (cf. Baddeley and Hitch 1974): the phonological store temporarily holds verbal information, while the phonological loop refreshes the information stored in the phonological store via articulatory rehearsal processes. The phonological STM span can be measured via serial recall of number or words. Phonological STM measures have been found not to correlate with acoustic memory measures (see e.g., Ghaffarvand Mokari and Werner 2019; Kogan 2020), which suggests that phonological STM and acoustic memory rely on distinct processes and resources.

Phonological STM may support language learning by allowing L2 learners to remember and repeat acoustically sentences they have never been exposed to (Christiner and Reiterer 2013). In line with this, previous research has shown that STM can be a strong predictor of language abilities (Baddeley et al. 1998; Wen and Skehan 2011), while STM is sometimes considered a language acquisition device (Biedroń and Pawlak 2016). Clinical studies have also provided evidence that patients with phonological loop impairments may have poor abilities to learn foreign languages and new unfamiliar phonological forms of utterances (Baddeley et al. 1998; Baddeley 2010). By contrast, high L2 performers such as polyglots seem to possess an elaborate phonological STM (Papagno and Vallar 1995), and performances on tasks targeting the phonological loop have been found to predict L2 pronunciation learning (Papagno et al. 1991). More recently, the ability to imitate new words or phrases has always yielded strong correlations to participants' performance on STM tasks in adults (Christiner and Reiterer 2013, 2019) and children (Christiner et al. 2018; Christiner and Reiterer 2018). Phonological STM has also been found to influence how learners perceive L2 speech (MacKay et al. 2001; Cerviño-Povedano and Mora 2011, 2015).

1.3. Faking Accents

Multiple methods exist to assess achievement in L2 pronunciation such as reading tasks and (quasi-) spontaneous speech tasks (Jilka 2009), or verbal shadowing of foreign languages (Pastuszek-Lipinska 2008). Fewer studies have, however, used accent faking methods, also called the delayed mimicry paradigm (Flege and Hammond 1982). In accent faking tasks, participants mimic a foreign language's pronunciation while talking in their mother tongue. These tasks allow the measurement of learners' phonological awareness of their L2 (Kopečková et al. 2021; Mora et al. 2014), i.e., their knowledge of the L2 phonological system, and how it differs phonetically from their first language (Kivistö-de Souza 2015; Mora et al. 2014). Accent faking tasks require participants to retrieve previously stored phonetic knowledge of the foreign language and, as such, target long-term memory representations of sounds (Coumel et al. 2019; Flege and Hammond 1982; Mora et al. 2014).

Importantly, learners may have explicit and implicit phonological awareness and accent faking tasks allow the measurement of both. Explicit phonological awareness refers to knowledge learners could be able to verbalise (e.g., that "r" sounds differ between German and English), whereas implicit phonological awareness refers to phonological aspects learners could perceive or produce but could not explain (e.g., differing stress patterns between German and English; cf. Kivistö-de Souza 2015; Moore 1997; Mora et al. 2014). The few studies investigating learners' L2 phonological awareness so far have rather focused on explicit phonological awareness and used stimulated recalls or language learning journals to ask participants to comment on their own L2 pronunciation or L2 learning processes (Kennedy et al. 2014; Kennedy and Trofimovich 2010; Wrembel 2015; see Kivistö-de Souza 2015 for an overview). L2 phonological awareness may however also consist of implicit knowledge: L2 teachers rarely provide explicit phonology instruction (see Gilbert 2010), and high levels of phonological awareness may result from high quantity of exposure to authentic L2 linguistic input without instructions. Thus, as they measure both explicit and implicit phonological awareness, accent faking tasks seem an ideal way to obtain a well-rounded portrait of learners' L2 phonological awareness. A final advantage of accent faking tasks is that they give the opportunity to target phonetic abilities specifically (Coumel et al. 2019). Unlike in reading and (quasi-)spontaneous speech tasks, participants read in their mother tongue in accent faking tasks. Thus, they do not need to worry about semantics and syntax.

Amongst the few studies using the accent faking paradigm (Flege and Hammond 1982; Kivistö-de Souza 2015; Kopečková et al. 2021; Mora et al. 2014), only two to our knowledge have examined the predictors of performance on this task (Coumel et al. 2019; Reiterer et al. 2013). These studies reported significant relationships between accent faking skills and participants' music perception abilities, singing abilities, and performances on language imitation tasks, but not on working memory tasks. However, the authors of these studies measured singing abilities with self-reports only. Having professional singers rate the performances of participants on singing tasks should be a more accurate way to measure singing abilities. Moreover, none of these studies used an exhaustive measure of phonetic aptitude targeting all the aspects described in Section 1.2. Therefore, in the present study, we aimed to improve the measurements of singing abilities and phonetic aptitude (with respect to these studies, see below) in order to better assess the relationship between these factors and participants' L2 phonological awareness as measured on the accent faking task.

1.4. Present Study

The present study asked the following research question:

Do individual differences in music perception abilities, in singing abilities and in phonetic aptitude explain variance in L2 accent faking abilities?

We used the AMMA test (Gordon 1989) to assess L2 learners' music perception abilities, as well as a large battery of tests to measure their individual differences in singing abilities and phonetic aptitude. Importantly, while Coumel et al. (2019) only measured the singing capacities of their participants with self-reports, we here measured the individual differences in singing abilities with real singing tasks rated by professional singers. To measure phonetic aptitude, we included both an L0 (used in this article to refer to languages unknown to the participants) perception task and an L0 production task, and forward and backward digit span tasks.

Based on previous research, we hypothesised that music perception abilities and singing abilities would predict variance in L2 accent faking performances (Coumel et al. 2019). How phonetic aptitude would relate to accent faking abilities was less clear. Previous research has indeed shown that performance on direct language imitation task relates to accent faking abilities (Reiterer et al. 2013), but not to measures of STM (Coumel et al. 2019).

2. Materials and Methods

2.1. Participants

A total of 97 German native speakers (56 women, mean age $M = 28.32$ years old) were included in the study. The study was advertised on social media and on notice boards. Our recruitment criteria were that participants should be German native speakers and unable to comprehend or speak the languages included in the L0 production task and in the L0 perception task. Based on these recruitment criteria, though we had originally invited 108 participants to take part, 11 participants were excluded from the study: three of them were early bilinguals and eight of them were familiar with at least one of the languages included in the L0 production and perception tasks. The participants provided informed consent before the test session and took part voluntarily. The study was approved by the Rīga Stradiņš University (RSU) Research Ethics Committee (2-PEK-4/3/2022).

To collect data about the participants' language and musical background and check whether they met the recruitment criteria, the participants were invited to complete a self-report questionnaire and were interviewed (the goal of the interview was to double-check participants' responses on the questionnaire). The participants' answers on the questionnaire and on the interview showed that they were all German native speakers raised in a primarily monolingual environment, who besides English could speak other foreign languages such as French, Italian, Spanish, or Dutch. All participants had learnt English as a second language in school, had at least a B2 level in English, and had received at least four years of English instruction (*Years of Formal English Instruction*). A total of 37 participants were musicians who regularly played a musical instrument or sang in a choir at the time of testing, while 25 reported that they sang or played a musical instrument occasionally. A total of 35 participants reported that they did not sing in a choir or at home and that they had never played or learnt a musical instrument besides the recorder in primary school lessons.

2.2. Materials and Scoring

2.2.1. Accent Faking Task

In this task, participants were presented with written German sentences (see Supplementary Section S1) on a screen with PowerPoint slides and instructed to read them aloud with a strong English accent. Each participant saw six sentences which contained nine or eleven syllables. These sentences were created to resemble the sentences included in the L0 perception and production tasks in terms of length. Participants wore headphones with an integrated microphone. We recorded their language production in a music studio with the software Steinberg Cubase 11.

The recordings were rated by five simultaneous English/German bilinguals (3 female) who were between 28 and 43 years old. They all had an academic background in the fields of linguistics or language studies. The raters were instructed to evaluate the recordings based on how well the participants pretended to be English native speakers who spoke German. The raters provided each recording a score on a scale between zero (lowest possible score) and ten (highest possible score). They were asked to ignore which regional accent the participant used (e.g., American or British accent). Each rater was exposed to each recorded file once and the files were presented to them in a random order on the online platform https://quest.christiner.at/login.php (accessed on 23 February 2023). The participants' *English Accent Faking* score corresponded to the average of their ratings across all sentences. We computed intraclass correlation coefficients which showed that the ratings of the native speakers were highly reliable (see Supplementary Section S2, Tables S1–S7).

2.2.2. Musical and Singing Tasks

Music Perception Abilities

We used the AMMA test (Advanced Measures of Music Audiation, Gordon 1989) to assess participants' music perception abilities. In this test, participants were presented with two musical statements and asked to determine whether these were identical or differed rhythmically or tonally. Differences in rhythm consisted of variations in tempo, metre or duration across musical statements. For differences in tones, a few notes differed between the two musical statements. The test contained 33 items: participants first completed three practice trials before completing the task with the remaining 30 experimental trials. Among the 30 trials, 10 pairs of statements were identical, 10 differed rhythmically and 10 differed tonally. The trials were presented to the participants in a random order. We computed and used participants' raw scores on the task which could vary between 0 and 40 for each of the two conditions. Thus, each participant received two scores: *AMMA T* for the trials targeting tonal differences and *AMMA R* for the trials targeting rhythmic differences.

Singing Abilities

We assessed the singing abilities of the participants both with singing tasks and with a self-report questionnaire. Participants first completed a familiar song task and a song learning task. In the familiar song task, we asked participants to sing the familiar song “Happy Birthday”. This task is typically used to examine singing in non-professional singers (Dalla Bella et al. 2007; Dalla Bella and Berkowska 2009; Christiner 2020; Christiner and Reiterer 2013, 2019; Christiner et al. 2018). In the song learning task, participants were presented with two short sequences taken from an unfamiliar song and asked to imitate them (Christiner 2020; Christiner et al. 2021). In both tasks, participants were instructed to sing as accurately and as beautifully as possible, and they were free to sing in a key they found pleasurable and suitable for their singing voice. Participants were also told that their performance would not be evaluated based on the accuracy of the lyrics and, in the song learning task, they were instructed to use different words if they had forgotten the lyrics. Participants were recorded with the Steinberg Cubase 11 software and beyerdynamic headphones (DT 290) with an integrated microphone.

The recordings were subsequently uploaded on the online platform https://quest.christiner.at/login.php (accessed on 23 February 2023) where the two singing tasks were rated by eight professional singing teachers. These raters were instructed to rate the participants performances on zero (lowest score) to ten (highest score) scales to evaluate participants’ *Melodic Singing Ability* (i.e., how accurately participants reproduced the melody of the original song), *Rhythmic Singing Ability* (i.e., how accurately participants reproduced the rhythm of the original song), *Voice Quality* (i.e., based on the resonance, the warmth and the colour of the participant’s voice), *Clarity/Focus* (i.e., referring to sensations of vocal vibrations of clear, well-produced tones), *Vocal Range* (i.e., how large participants’ vocal range was), and *Volume* (i.e., how appropriate the volume participants used was for their singing voice). To reduce the duration of the rating task for individual raters, four of the raters scored the recordings based on the first three criteria, while the other four raters scored the recordings based on the remaining three criteria. All raters scored all participants and the recordings were presented to them in a random order. Intraclass correlation coefficients demonstrated that the ratings of the professional singers were highly reliable (see Supplementary Section S2, Tables S13–S18).

The self-report questionnaire measured the singing habits of the participants. Participants were asked to estimate how many hours per week they had been singing over the last five years (*Singing Hours per Week)*. They were told that they should consider any form of singing (e.g., in the car, in the bathroom and the like). In addition, they had to indicate whether they believed they could sing “very well”, “well”, “average”, “poor”, or “very poor” (*Singing Self-Estimation*). Finally, we measured the participants’ singing behaviour during their childhood (*Singing Childhood*). To do so, we used an already established multi-item scale concept (Christiner et al. 2022b) consisting of eight questions asking the participants to indicate how frequently they sang on certain occasions as a child on a scale between one and six. To test the reliability of the multi-item scale concept, we computed Cronbach’s α which showed that the reliability was high, with all Cronbach’s α = 0.81 (see Supplementary Section S2, Table S19).

2.2.3. Phonetic Aptitude Tasks

The current study included a comprehensive battery of tests designed to measure individual differences in multiple aspects of phonetic aptitude. Specifically, we gathered a series of tasks which together would assess how well learners can process, produce, and memorise (unfamiliar) speech sounds.

First, we used a foreign sounds recognition task (L0 perception task) in which participants were exposed to a series of sounds from languages they were unfamiliar with and subsequently asked to recognise them. This task measured participants’ acoustic memory as it targeted languages unknown to the participants for which they had no pre-established phonological categories (see Kogan 2020; see also Cerviño-Povedano and Mora 2011 and Saito et al. 2016 for the use of a similar tasks with nonwords).

Second, our assessment of phonetic aptitude included a direct language imitation task (L0 production task), where participants were exposed to sentences in foreign languages they did not know and asked to repeat these sentences as accurately as possible. It is important to stress that this direct language imitation task targeted a different set of abilities from the ones targeted in the accent faking task, as it involved unfamiliar languages and thus did not require participants to retrieve phonetic representations from long-term memory. The L0 production task helped assessing how participants processed novel sounds, i.e., their acoustic memory (see Kogan 2020) as well as their phonetic compliance (Delvaux et al. 2014), i.e., how well they could produce unfamiliar speech sounds (see also Jilka 2009; Reiterer et al. 2011). Direct imitation tasks show high ecological validity (Christiner 2020) and seem particularly well-suited to assess learning of a foreign language's pronunciation: they resemble the way children learn their first language, i.e., by mimicking the new words or phrases they are exposed to (Gathercole 2006). Importantly, the L0 production and L0 perception tasks contained a wide variety of foreign languages in order to increase the reliability of the measurement.

Finally, our measure of phonetic aptitude included forward and backward digit span tasks to measure participants' phonological STM. This task allowed the assessment of their capacity to temporarily hold verbal information (as it included numbers and not unfamiliar speech sounds as in the other tasks) and to rely on articulatory rehearsal to remember the words.

L0 Perception Task

Participants completed an online L0 perception task which we adapted from Christiner et al. (2022a). On a given trial, participants first heard a series of eight, ten or twelve model language constituents (Stimline) always coming from one of five possible languages (Slovak, Tagalog, Mandarin, Farsi, Japanese). Two seconds after listening to the Stimline, the participant listened to either one, two or three target language constituents (Stimcompare) which either had or had not appeared in the Stimline. Participants were asked to indicate whether they had heard the target constituent(s) in the Stimline or not. The task first included a practice task with one trial which participants could complete as many times as they wished. The main part of the task contained 25 trials. The participants' *Language Perception* score corresponded to the proportion of correct answers they gave on the task in decimal numbers (zero means that none of the trials were correctly answered, while 1 indicates that all trials were correctly answered).

L0 Production Task

Participants completed a language imitation task targeting the same languages as the L0 perception task. They were exposed to 10 nine and 10 eleven-syllable long sentences spoken by native speakers of the target languages (i.e., there were four sentences per language) and asked to repeat them with the best accent possible. Each model sentence was automatically played three times, with intervals of 50 ms. The main experimental task was preceded by a practice phase in which participants heard and repeated four trials presenting Polish sentences. The participants' responses were recorded with the Steinberg Cubase 11 software and beyerdynamic headphones (DT 290) with integrated microphone.

The recordings were then uploaded onto the online platform https://quest.christiner.at/login.php (accessed on 23 February 2023) to be rated by native speakers of the respective languages (five raters for Slovak, four raters for Tagalog, five raters for Mandarin, four raters for Farsi, and six raters for Japanese). The raters were instructed to evaluate how native-like the participants sounded to them, by focusing on participants' overall performance. They provided their ratings on a scale between zero (lowest possible score) and ten (highest possible score). The participants' *Language Production* score corresponded to their average ratings across all languages and trials. Intraclass correlation coefficients showed that the ratings of the native speakers were highly reliable (see Supplementary Section S2, Tables S8–S12).

Digit Span Tasks

The participants' phonological STM was assessed with forward and backward Wechsler digit span tasks (Tewes 1994). Participants were asked to repeat a length-increasing sequence of numbers presented auditorily in forward or backward orders. The forward span version included three to nine items, while the backwards span version included from two to eight numbers. Participants received two scores, one for the forward task (*STM F*) and one for the backward task (*STM B*). The score corresponded to the number of items they were able to correctly repeat, the maximum being 14.

2.2.4. Procedure

To keep testing time as short as possible, participants completed the tasks in the lab in three separate sessions of approximately 45 min each (see Table 1). The order of the sessions was the same for all participants. In the first session, participants completed all background (music and language) questionnaires and performed the L0 perception task. They were also interviewed about their foreign language knowledge to find out whether they met the criteria to be included in the study (see Section 2.1). In the second session, participants completed the L0 production task followed by the singing tasks and finally, the digit span tasks. In the final session, they completed the AMMA test and the accent faking task.

Table 1. Overview of the procedure.

	Session 1	Session 2	Session 3
Participant background	-Language and musical background self-report questionnaire -Interview	-	-
Phonological awareness	-	-	Accent faking task
Musical and singing abilities	-	Singing tasks	AMMA test
Phonetic aptitude	L0 perception task	-L0 production task -Digit span tasks	-

3. Results

3.1. Overview of the Analysis

Given the complexity of our dataset, we split the analysis into two parts. First, we performed a correlational analysis to understand the relationships between the measured variables (see Supplementary Section S3, Table S20). Since many variables significantly correlated to each other, we then performed a principal component analysis (PCA) to reduce the number of predictors. We then coined unit-weighted composite scores based on the PCA output for the singing and phonetic aptitude measures. Second, we built a regression model to identify the predictors of participants' performance on the accent faking task. We used IBM SPSS Statistics (Version 28.0; IBM Corp, Armonk, NY, USA) to perform the statistical analyses.

3.1.1. Descriptive Statistics

Table 2 below reports the descriptive statistics of the main variables under consideration.

Table 2. Descriptive statistics of the variables. English AoA (age of acquisition) represents the age at which participants started learning English; years of formal English instruction represents the number of years for which the participants had received English formal instruction; singing total corresponds to participants average scores across the variables melodic singing ability, rhythmic singing ability, voice quality, clarity/focus, vocal range, and volume[1].

Variables	Mean (M)	Standard Deviation (SD)
English Accent Faking	4.36	1.33
Years of Formal English Instruction	8.95	2.71
English AoA	6.51	1.06
AMMA T	25.86	4.92
AMMA R	28.81	4.08
Singing Childhood	29.13	8.93
Singing Self-Estimation	2.89	1.08
Singing Hours per Week	1.47	2.10
Singing Total	6.09	1.30
L0 Perception	0.63	0.12
L0 Production	3.06	0.92
STM F	7.49	1.83
STM B	7.60	2.02

3.1.2. PCA on All the Variables

Since the language and musical variables were highly inter-correlated (Supplementary Section S3), we performed a PCA analysis. This aimed at combining individual music perception, singing and language variables including STM measures into broader dimensions. All these variables were included in the PCA analysis, and we used orthogonal rotation (varimax). Factor loads below 0.4 were suppressed. The Kaiser–Meyer–Olkin measure for sampling adequacy for the analysis showed that KMO = 0.71 and all KMO variables were >0.57, which was therefore above the accepted limit of 0.5. A Bartlett's test of sphericity, $\chi^2(78) = 484.49$, $p < 0.001$, indicated that the correlations between items were sufficiently large for the PCA analysis. We ran a first analysis to obtain eigenvalues for each component in the data. Four components had eigenvalues over 1 and, in combination, they explained 67.96% of the variance (Table 3).

Table 3. Summary of the PCA analysis (N = 97).

Variables	Singing Complex	Phonetic Aptitude Complex	Music Perception
Singing Hours per Week	0.789		
Singing Childhood	0.785		
Singing Self-Estimation	0.747		
Singing Total	0.568		
STM F		0.840	
L0 Production		0.676	
STM B		0.598	
L0 Perception		0.571	
AMMA R			0.908
AMMA T			0.908
EIGENVALUES	2.19	1.60	1.03
Percentage of variance explained	18.16	15.83	15.11

Based on the results of this PCA analysis, we created the new following variables: *Singing Complex* which corresponded to participants' average for the variables Singing Total, Singing Hours per Week, Singing Self-Estimation and Singing Childhood; *Phonetic Aptitude Complex* which we calculated as participants' average of STM F, STM B, L0 Perception and L0 Production scores; *AMMA Total* which reflected participants' score on the two subsections of the AMMA test. We coin unit-weighted the composite scores of the variables of the Singing Complex and of the Phonetic Aptitude Complex, and transformed them into z-scores before combining the variables into single scores.

3.1.3. Correlational and Regression Analysis

In this part of the analysis, we first ran a correlational analysis to examine the relationship between participants' performance on the accent faking task and the other variables and determine which predictors should be entered in the regression analysis. Table 4 reports the results of this correlational analysis. It indicates that, while Singing Complex, Phonetic Aptitude Complex, English AoA and Years of Formal English Instruction all significantly correlated with participants' accent faking performance (but note that these correlations were weak to moderate), the AMMA Total did not. Therefore, we did not include the AMMA Total in the regression analysis. We did not include English AoA and Years of Formal English Instruction either as they would have conflated the regression model.

Table 4. Results of the correlational analysis.

	AMMA Total	Singing Complex	Phonetic Aptitude Complex	Years of English Instructions	English AoA
English Accent Faking	0.168	0.382 **	0.459 **	0.605 **	−0.645 **
AMMA total		0.170	0.381 **	0.104	−0.065
Singing complex			0.130	0.324 **	−0.250 **
Phonetic aptitude complex				0.327 **	−0.249 **
Years of English instructions					−0.23 **

Note: ** means significant at the 0.01 level (2-tailed).

We entered Phonetic Aptitude Complex and Singing complex as independent variables and English Accent Faking as the dependent variable into a multiple linear regression model. We used a stepwise model following purely mathematical decisions, while the criterion when entering independent variables was a probability of F-change < 0.05. Table 5 presents the outcome of this regression analysis. The regression analysis revealed that the Phonetic Aptitude Complex and the Singing Complex could account for around 30% of the variance in Accent Faking abilities.

Table 5. Outcome of the regression analysis.

Multiple Regression Models Explaining the Variance in Accent Faking		
Predictor	**Partial Correlation (pr)**	***p*-Value**
Dependent variable: English Accent Faking		
Model 1: Adjusted R = 0.20, $F(1, 95) = 25.38$, $p < 0.001$		
Phonetic aptitude complex	0.46	<0.001
Model 2: Adjusted R = 0.30 $F(1, 94) = 14.58$, $p < 0.001$		
Phonetic aptitude complex	0.45	<0.001
Singing complex	0.37	<0.001

4. Discussion

In this study, we aimed to identify which factors are related to L2 English phonological awareness in German native speakers. To do so, we measured the participants' L2 phonological awareness with an accent faking task (cf. Coumel et al. 2019; Kopečková et al. 2021; Kivistö-de Souza 2015; Mora et al. 2014), and assessed how individual differences in music perception abilities, singing abilities and phonetic aptitude are related to accent faking performances. The regression model revealed that 30% of the variance in accent faking abilities could be explained by singing abilities and phonetic aptitude. Music perception abilities alone as measured by the AMMA test did not correlate with accent faking abilities.

Below we discuss the relationship between singing abilities, phonetic aptitude and accent faking abilities, as well as what the results suggest regarding L2 pronunciation learning.

4.1. Music Perception and Singing Abilities

The regression analysis demonstrated that the singing complex was one of the significant predictors of performance on the accent faking task. This result corroborates previous observations with accent faking tasks (Coumel et al. 2019). Notably, in the present study, rather than using self-reports (as in Coumel et al. 2019), the singing complex we built relied on a larger battery of tests and participants completed real singing tasks that were rated by professional singers. This approach allowed us to assess the singing skills and singing behaviour of the participants more directly and more accurately.

Although further research is needed to determine the direction of the influence, our results could suggest that singing abilities help language learners develop accurate L2 phonological awareness. Previous research has shown that more proficient singers may benefit from higher vocal and motor flexibility, or from a more developed oro-motor system that could enable them to produce L2 sounds more accurately (Christiner 2020; Christiner and Reiterer 2013, 2019). Some theoretical frameworks also suggest that individuals with higher vocal flexibility and accuracy could benefit from better perceptual abilities. For instance, in the motor theory of speech (Liberman and Mattingly 1985), individuals perceive "intended gestures" when exposed to speech. Similarly, Best (1995) proposes that language production and perception rely on shared representations of articulatory gestures. It could thus be that individuals with better singing abilities perceive speech better and store more accurate phonetic representations. Finally, being able to sing could provide participants with better language learning abilities. Given that faking an accent requires participants to retrieve sound representations from long-term memory, our results could indicate that high singing abilities allow L2 speakers to memorise better more accurate long-term phonetic representations (Coumel et al. 2019; Schulze et al. 2012). Together, these capacities could allow better singers to possess more detailed phonetic representations and a higher awareness of how to reproduce the typical accent of foreign-sounding speech.

The correlational analysis (see Table 4) however suggested that music perception abilities alone as measured on the AMMA test did not relate to accent faking abilities. This finding stands in contradiction with previous research reporting significant relationships between music perception abilities and foreign language pronunciation (Milovanov 2009; Milovanov and Tervaniemi 2011), direct foreign language imitation, and foreign language perception skills (Christiner et al. 2018; Christiner 2020; Christiner et al. 2021; Christiner and Reiterer 2019). Given that singers likely have good music perception abilities (see e.g., Best 1995; Liberman and Mattingly 1985), this absence of a significant correlation simply implies that having high music perception abilities alone do not lead to better accent faking abilities.

Singing abilities may relate to accent faking abilities more than music perception abilities alone because singing is more similar to speaking than listening to music (García-López and Gavilán Bouzas 2010). Brain imaging studies have also revealed that trained vocalists display structural adaptations in the arcuate fasciculus which instrumentalists do not (Halwani et al. 2011). Crucially, the left arcuate fasciculus is a fibre tract which seems to be involved both in musical functions and in language processing (Ocklenburg and Güntürkün 2018). Research has also shown that singing skills are more likely to foster better foreign language imitation abilities than being able to play a music instrument or than having high music perception abilities (Christiner and Reiterer 2019).

This result could also reflect the dissociation sometimes observed between perception and production (but see Flege and Bohn 2021). For instance, being better at perceiving foreign language input does not necessarily foster better production capacities (Golestani and Pallier 2007). In line with this, Halwani et al. (2011) argued that vocalists differ from instrumentalists in the sense that they enjoy an increased awareness of the sound production process on top of their enhanced music perception abilities.

To sum up, our results suggest that having high music perception abilities alone is not sufficient to account for variance in accent faking abilities, while singing abilities are more strongly related to accent faking performance and L2 phonological awareness.

4.2. Phonetic Aptitude and Accent Faking Abilities

The results show that the phonetic aptitude complex, measured here as a combination of the ability to process and produce unfamiliar languages and phonological STM skills also relate to accent faking abilities. This suggests that having high phonetic aptitude could help L2 speakers acquire better sound representations of the L2 foreign sounds, which they can later retrieve to produce foreign-accented speech. Our results thus indicate that higher phonetic aptitude may contribute to better L2 phonological awareness.

Accent faking tasks also enable researchers to assess achievement in L2 pronunciation as they require participants to retrieve previously stored phonetic knowledge of the foreign language and, as such, target long-term memory representations of sounds (Coumel et al. 2019; Flege and Hammond 1982; Mora et al. 2014). In line with our results, brain imaging studies have provided evidence that language aptitude is related to later achievement in language. For instance, an increasing number of studies suggests that there are individual differences in brain structures responsible for higher aptitude in foreign speech perception and production, with white matter density being higher in the inferior parietal cortices bilaterally and in the left insular cortex in fast learners of new speech sounds (e.g., Golestani and Pallier 2007). Other research with phoneticians has provided evidence not only for experience-dependent plasticity, but also for gross morphological differences in the auditory cortex with respect to non-phoneticians which cannot be explained by training effects (Golestani et al. 2011). These findings imply that aptitude is relatively stable and can inform about the potential to achieve a certain level of expertise (Wen et al. 2017).

Importantly, the tasks included in our general measures of phonetic aptitude in the present study targeted multiple potential aspects of phonetic aptitude, such as the capacity to both process and produce unfamiliar speech sounds (cf. Delvaux et al. 2014), acoustic memory (see Kogan 2020), and phonological STM. Future research is needed to better understand which of these variables more specifically support acquisition of L2 phonological awareness.

5. Conclusions

This study showed that singing abilities and phonetic aptitude are significantly related to L2 accent faking abilities. Music perception abilities alone however did not relate to performance on the accent faking task. These results could suggest that being able to sing and high phonetic aptitude foster higher phonological awareness, which in turn could lead to better L2 pronunciations skills. We note, however, that singing abilities and phonetic aptitude only accounted for 30% of variance in accent faking abilities. Future studies are needed to identify whether other factors such as elementary auditory skills (i.e., the ability to discriminate pitch changes, loudness, tone onset, . . .) may also predict L2 phonological awareness.

This study proposes a new, comprehensive battery of tests to assess individual differences in phonetic aptitude. Our findings also have pedagogical implications as they plead in favour of including singing tasks in the teaching of L2 pronunciation. For example, teachers could encourage their students to sing in the target language. Doing so has been found to support L2 pronunciation learning (e.g., Good et al. 2015) and could help learners store more accurate long-term L2 phonetic representations (Coumel et al. 2019; Schulze et al. 2012) and rely on (auditory) sensory experience to support their L2 pronunciation learning (Christiner et al. 2022a).

We also note that it might be particularly relevant for language educators to examine in the future for which aspects of L2 pronunciation singing abilities are the most relevant. In that regard, as described by Kivistö-de Souza (2015), we acknowledge that a limitation of accent faking tasks is that they partly depend on participants' articulation abilities. In other words, lower performance on the task could for example reflect problems in articulation rather than deficits in L2 phonological awareness. An objective for future research could be to disentangle the relative contribution of articulation capacities and pure L2 phonological awareness to accent faking abilities.

Supplementary Materials: Supplementary Sections S1–S4 can be downloaded at: https://www.mdpi.com/article/10.3390/languages8010068/s1.

Author Contributions: Conceptualisation, M.C. (Markus Christiner) and M.C. (Marion Coumel); methodology, M.C. (Markus Christiner) and M.C. (Marion Coumel); formal analysis, M.C. (Markus Christiner), C.G., S.S.-L.; investigation, M.C. (Markus Christiner); resources, M.C. (Markus Christiner); data curation, M.C. (Markus Christiner); writing—original draft preparation, M.C. (Marion Coumel); writing—review and editing, M.C. (Markus Christiner) and M.C. (Marion Coumel); project administration, M.C. (Markus Christiner), S.S.-L., C.G.; funding acquisition, M.C. (Markus Christiner). All authors have read and agreed to the published version of the manuscript.

Funding: Open Access Funding by The University of Graz. M.C. (Markus Christiner) is a recipient of an APART-GSK Fellowship of the Austrian Academy of Sciences at the Centre of Systematic Musicology of the University of Graz. Sabine Sommer-Lolei is a recipient of a DOC-team fellowship of the Austrian Academy of Sciences.

Institutional Review Board Statement: The study was approved by the Rīga Stradiņš University (RSU) Research Ethics Committee (2-PEK-4/3/2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on reasonable request from the corresponding author. The data are not publicly available due to privacy restrictions.

Conflicts of Interest: The authors declare no conflict of interest.

Note

[1] We ran a PCA analysis with the nine singing scores of the participants (see Singing Abilities). It showed that the six scores of the two singing tasks could be combined into one *Singing Total* score (see Supplementary Section S4).

References

Apfelstadt, Hilary. 1984. Effects of melodic perception instruction on pitch discrimination and vocal accuracy of kindergarten children. *Journal of Research in Music Education* 32: 15–24. [CrossRef]

Asaridou, Salomi S., and James M. McQueen. 2013. Speech and music shape the listening brain: Evidence for shared domain-general mechanisms. *Frontiers in Psychology* 4: 321. [CrossRef] [PubMed]

Baddeley, Alan D. 2010. Working memory. *Current Biology* 20: R136–R140. [CrossRef]

Baddeley, Alan D., and Graham Hitch. 1974. Working Memory. In *Psychology of Learning and Motivation: V.8. Psychology of Learning and Motivation. Advances in Research and Theory*. Edited by Gordon H. Bower. Burlington: Elsevier, pp. 47–89.

Baddeley, Alan D., Susan Gathercole, and Costanza Papagno. 1998. The phonological loop as a language learning device. *Psychological Review* 105: 158–73. [CrossRef]

Baills, Florence, Yuan Zhang, Yuhui Cheng, Yuran Bu, and Pilar Prieto. 2021. Listening to songs and singing benefitted initial stages of second language pronunciation but not recall of word meaning. *Language Learning* 71: 369–413. [CrossRef]

Baker, Wendy, and Pavel Trofimovich. 2006. Perceptual paths to accurate production of L2 vowels: The role of individual differences. *International Review of Applied Linguistics in Language Teaching* 44: 165–81. [CrossRef]

Berkowska, Magdalena, and Simone Dalla Bella. 2009. Acquired and congenital disorders of sung performance: A review. *Advances in Cognitive Psychology* 5: 69–83. [CrossRef]

Besson, Mireille, Julie Chobert, and Céline Marie. 2011. Transfer of training between music and speech: Common processing, attention, and memory. *Frontiers in Psychology* 2: 94. [CrossRef]

Best, Catherine. 1995. A direct realist perspective on cross-language speech perception. In *Speech Perception and Linguistic Experience: Theoretical and Methodological Issues in Cross-Language Speech Research*. Edited by W. Strange. Baltimore: Timonium, pp. 167–200.

Biedroń, Adriana, and Mirosław Pawlak. 2016. New conceptualizations of linguistic giftedness. *Language Teaching* 49: 151–85. [CrossRef]

Carroll, John B. 1981. Twenty-five years of research on foreign language aptitude. In *Individual Differences and Universals in Language Learning Aptitude*. Edited by Karl C. Diller. Rowley: Newbury House, pp. 83–118.

Cerviño-Povedano, Eva, and Joan C. Mora. 2011. Investigating Catalan learners of English overreliance on duration: Vowel cue weighting and phonological short-term memory. In *Achievements and Perspectives in the Acquisition of Second Language Speech: New Sounds 2010*. Edited by Katarzyna Dziubalska-Kołaczyk, Magdalena Wrembel and Malgorzata Kul. Bern: Peter Lang, pp. 53–64.

Cerviño-Povedano, Eva, and Joan C. Mora. 2015. Spanish EFL learners' categorization of /i:-I/ and phonological short-term memory. *Procedia—Social and Behavioral Sciences* 173: 18–23. [CrossRef]

Chobert, Julie, Clément François, Jean-Luc Velay, and Mireille Besson. 2014. Twelve months of active musical training in 8- to 10-year-old children enhances the preattentive processing of syllabic duration and voice onset time. *Cerebral Cortex* 24: 956–67. [CrossRef] [PubMed]

Christiner, Markus. 2020. Musicality and Second Language Acquisition: Singing and Phonetic Language Aptitude Phonetic Language Aptitude. Ph.D. thesis, University of Vienna, Vienna, Austria.

Christiner, Markus, and Susanne Maria Reiterer. 2013. Song and speech: Examining the link between singing talent and speech imitation ability. *Frontiers in Psychology* 4: 874. [CrossRef]

Christiner, Markus, and Susanne Maria Reiterer. 2015. A Mozart is not a Pavarotti: Singers outperform instrumentalists on foreign accent imitation. *Frontiers in Human Neuroscience* 9: 482. [CrossRef] [PubMed]

Christiner, Markus, and Susanne Maria Reiterer. 2018. Early influence of musical abilities and working memory on speech imitation abilities: Study with pre-school children. *Brain Sciences* 8: 169. [CrossRef] [PubMed]

Christiner, Markus, and Susanne Maria Reiterer. 2019. Music, song and speech. In *Bilingual Processing and Acquisition: Vol. 8. The Internal Context of Bilingual Processing*. Edited by John Truscott and Michael Sharwood Smith. Amsterdam: John Benjamins, pp. 131–56.

Christiner, Markus, Bettina L. Serrallach, Jan Benner, Valdis Bernhofs, Peter Schneider, Julia Renner, Sabine Sommer-Lolei, and Christine Groß. 2022a. Examining individual differences in singing, musical and tone language ability in adolescents and young adults with dyslexia. *Brain Sciences* 12: 744. [CrossRef] [PubMed]

Christiner, Markus, Christine Gross, Annemarie Seither-Preisler, and Peter Schneider. 2021. The melody of speech: What the melodic perception of speech reveals about language performance and musical abilities. *Languages* 6: 132. [CrossRef]

Christiner, Markus, Stefanie Rüdegger, and Susanne Maria Reiterer. 2018. Sing Chinese and tap Tagalog? Predicting individual differences in musical and phonetic aptitude using language families differing by sound-typology. *International Journal of Multilingualism* 15: 455–71. [CrossRef]

Christiner, Markus, Valdis Bernhofs, and Christine Groß. 2022b. Individual differences in singing behavior during childhood predicts language performance during adulthood. *Languages* 7: 72. [CrossRef]

Coumel, Marion, Markus Christiner, and Susanne Maria Reiterer. 2019. Second language accent faking ability depends on musical abilities, not on working memory. *Frontiers in Psychology* 10: 257. [CrossRef]

Dalla Bella, Simone, and Magdalena Berkowska. 2009. Singing proficiency in the majority: Normality and "phenotypes" of poor singing. *Annals of the New York Academy of Sciences* 1169: 99–107. [CrossRef]

Dalla Bella, Simone, Jean-François Giguère, and Isabelle Peretz. 2007. Singing proficiency in the general population. *Journal of the Acoustical Society of America* 121: 1182–89. [CrossRef]

Delogu, Franco, Giulia Lampis, and Marta Olivetti Belardinelli. 2006. Music-to-language transfer effect: May melodic ability improve learning of tonal languages by native nontonal speakers? *Cognitive Processing* 7: 203–207. [CrossRef]

Delogu, Franco, Giulia Lampis, and Marta Olivetti Belardinelli. 2010. From melody to lexical tone: Musical ability enhances specific aspects of foreign language perception. *European Journal of Cognitive Psychology* 22: 46–61. [CrossRef]

Delvaux, Véronique, Kathy Huet, Myriam Piccaluga, and Bernard Harmegnies. 2014. Phonetic compliance: A proof-of-concept Study. *Frontiers in Psychology* 5: 1375. [CrossRef] [PubMed]

Dewaele, Jean-Marc, and James McCloskey. 2015. Attitudes towards foreign accents among adult multilingual language users. *Journal of Multilingual and Multicultural Development* 36: 221–38. [CrossRef]

Ding, Nai, Aniruddh D. Patel, Lin Chen, Henry Butler, Cheng Luo, and David Poeppel. 2017. Temporal modulations in speech and music. *Neuroscience and Biobehavioral Reviews* 81, Pt B: 181–87. [CrossRef] [PubMed]

Dörnyei, Zoltán. 2005. *The Psychology of the Language Learner: Individual Differences in Second Language Acquisition. Second Language Acquisition Research*. Mahwah: L. Erlbaum.

Flege, James Emil, and Ocke-Schwen Bohn. 2021. The Revised Speech Learning Model (SLM-R). In *Second Language Speech Learning: Theoretical and Empirical Progress*. Edited by Ratree Wayland. Cambridge: Cambridge University Press, pp. 3–83.

Flege, Jame Emil, and Robert M. Hammond. 1982. Mimicry of non-distinctive phonetic differences between language varieties. *Studies in Second Language Acquisition* 5: 1–17. [CrossRef]

Flege, James Emil, Murray J. Munro, and Ian R. A. MacKay. 1995. Effects of age of second-language learning on the production of English consonants. *Speech Communication* 16: 1–26. [CrossRef]

Franco, Fabia, Chiara Suttora, Maria Spinelli, Iryna Kozar, and Mirco Fasolo. 2021. Singing to infants matters: Early singing interactions affect musical preferences and facilitate vocabulary building. *Journal of Child Language* 49: 552–77. [CrossRef] [PubMed]

François, Clément, Julie Chobert, Mireille Besson, and Daniele Schön. 2013. Music training for the development of speech segmentation. *Cerebral Cortex* 23: 2038–43. [CrossRef] [PubMed]
Fraser, Catriona, and Barbara F. Kelly. 2012. Listening between the lines. *Australian Review of Applied Linguistics* 35: 74–93. [CrossRef]
Fuertes, Jairo N., William H. Gottdiener, Helena Martin, Tracey C. Gilbert, and Howard Giles. 2012. A meta-analysis of the effects of speakers' accents on interpersonal evaluations. *European Journal of Social Psychology* 42: 120–33. [CrossRef]
García-López, Isabel, and Javier Gavilán Bouzas. 2010. La voz cantada [The singing voice]. *Acta otorrinolaringologica Espanola* 61: 441–51.
Gathercole, Susan. 2006. Nonword repetition and word learning: The nature of the relationship. *Applied Psycholinguistics* 27: 513–43. [CrossRef]
Ghaffarvand Mokari, Payam, and Stefan Werner. 2019. On the role of cognitive abilities in second language vowel learning. *Language and Speech* 62: 260–80. [CrossRef]
Gilbert, Judy B. 2010. Pronunciation as orphan: What can be done? *TESOL SPLIS* 7: 1–5.
Gluszek, Agata, and John F. Dovidio. 2010. The way they speak: A social psychological perspective on the stigma of nonnative accents in communication. *Personality and Social Psychology Review* 14: 214–37. [CrossRef]
Golestani, Narly, and Christophe Pallier. 2007. Anatomical correlates of foreign speech sound production. *Cerebral Cortex* 17: 929–34. [CrossRef]
Golestani, Narly, Cathy J. Price, and Sophie K. Scott. 2011. Born with an ear for dialects? Structural plasticity in the expert phonetician brain. *Journal of Neuroscience* 31: 4213–20. [CrossRef] [PubMed]
Good, Arla J., Frank A. Russo, and Jennifer Sullivan. 2015. The efficacy of singing in foreign-language learning. *Psychology of Music* 43: 627–40. [CrossRef]
Gordon, Edwin. 1989. *Advanced Measures of Music Audiation*. Chicago: GIA.
Gottfried, Terry L., and Devon Riester. 2000. Relation of pitch glide perception and Mandarin tone identification. *Journal of the Acoustical Society of America* 108: 2604. [CrossRef]
Gottfried, Terry L., Ann M. Staby, and Christine J. Ziemer. 2004. Musical experience and Mandarin tone discrimination and imitation. *The Journal of the Acoustical Society of America* 115: 2545. [CrossRef]
Granena, Gisela, and Michael H. Long. 2013. Age of onset, length of residence, language aptitude, and ultimate L2 attainment in three linguistic domains. *Second Language Research* 29: 311–43. [CrossRef]
Groß, Christine, Bettina L. Serrallach, Eva Möhler, Jachin E. Pousson, Peter Schneider, Markus Christiner, and Valdis Bernhofs. 2022. Musical performance in adolescents with ADHD, ADD and Dyslexia—Behavioral and neurophysiological aspects. *Brain Sciences* 12: 127. [CrossRef]
Halwani, Gus F., Psyche Loui, Theodor Rüber, and Gottfried Schlaug. 2011. Effects of practice and experience on the arcuate fasciculus: Comparing singers, instrumentalists, and non-musicians. *Frontiers in Psychology* 2: 156. [CrossRef]
Han, Yueqiao, Martijn Goudbeek, Maria Mos, and Marc Swerts. 2019. Mandarin tone identification by tone-naïve musicians and non-musicians in auditory-visual and auditory-only conditions. *Frontiers in Communication* 4: 70. [CrossRef]
Honing, Henkjan. 2011. *Musical Cognition: A Science of Listening*, 1st ed. Somerset: Taylor and Francis.
Hutchins, Sean, and Sylvain Moreno. 2013. The linked dual representation model of vocal perception and production. *Frontiers in Psychology* 4: 825. [CrossRef]
Intartaglia, Bastien, Travis White-Schwoch, Nina Kraus, and Daniele Schön. 2017. Music training enhances the automatic neural processing of foreign speech sounds. *Scientific Reports* 7: 12631. [CrossRef]
Jackendoff, Ray, and Fred Lerdahl. 2006. The capacity for music: What is it, and what's special about it? *Cognition* 100: 33–72. [CrossRef]
Jilka, Matthias. 2009. Assessment of phonetic ability. In *Language Talent and Brain Activity*. Edited by Grzegorz Dogil and Susanne Maria Reiterer. Berlin and Boston: De Gruyter Mouton, p. 1766.
Kennedy, Sara, and Pavel Trofimovich. 2010. Language awareness and second language pronunciation: A classroom study. *Language Awareness* 19: 171–85. [CrossRef]
Kennedy, Sara, Josée H. Blanchet, and Pavel Trofimovich. 2014. Learner pronunciation, awareness, and instruction in French as a second language. *Foreign Language Annals* 47: 79–96. [CrossRef]
Kivistö-de Souza, Hanna. 2015. Phonological Awareness and Pronunciation in a Second Language. Ph.D. dissertation, Universitat de Barcelona, Barcelona, Spain.
Kogan, Vita. 2020. The Effect of First Language Perception on the Discrimination of a Non-Native Vowel Contrast: Investigating Individual Differences. Ph.D. thesis, University of Barcelona, Barcelona, Spain.
Kopečková, Romana, Magdalena Wrembel, Ulrike Gut, and Anna Balas. 2021. Differences in phonological awareness of young L3 learners: An accent mimicry study. *International Journal of Multilingualism*, 1–17. [CrossRef]
Lev-Ari, Shiri, and Boaz Keysar. 2010. Why don't we believe non-native speakers? The influence of accent on credibility. *Journal of Experimental Social Psychology* 46: 1093–96. [CrossRef]
Liberman, Alvin M., and Ignatius G. Mattingly. 1985. The motor theory of speech perception revised. *Cognition* 21: 1–36. [CrossRef] [PubMed]
Linck, Jared A., Meredith M. Hughes, Susan G. Campbell, Noah H. Silbert, Medha Tare, Scott R. Jackson, Benjamin K. Smith, Michael F. Bunting, and Catherine J. Doughty. 2013. Hi-LAB: A new measure of aptitude for high-level language proficiency. *Language Learning* 63: 530–66. [CrossRef]

Loui, Psyche, David Alsop, and Gottfried Schlaug. 2009. Tone deafness: A new disconnection syndrome? *Journal of Neuroscience* 29: 10215–20. [CrossRef]
Ludke, Karen M. 2016. Singing and arts activities in support of foreign language learning: An exploratory study. *Innovation in Language Learning and Teaching* 12: 371–86. [CrossRef]
Ludke, Karen M., Fernanda Ferreira, and Katie Overy. 2014. Singing can facilitate foreign language learning. *Memory and Cognition* 42: 41–52. [CrossRef]
MacKay, Ian R., Diane Meador, and James Emil Flege. 2001. The identification of English consonants by native speakers of Italian. *Phonetica* 58: 103–25. [CrossRef] [PubMed]
Meara, Paul. 2005. *LLAMA Language Aptitude Tests*. Swansea: Lognostics.
Milovanov, Riia. 2009. Musical aptitude and foreign language learning skills: Neural and behavioural evidence about their connections. Paper presented at 7th Triennial Conference of European Society for the Cognitive Sciences of Music (ESCOM 2009), Jyväskylä, Finland, August 12–16; pp. 338–42.
Milovanov, Riia, and Mari Tervaniemi. 2011. The interplay between musical and linguistic aptitudes: A review. *Frontiers in Psychology* 2: 321. [CrossRef] [PubMed]
Moore, Harumi. 1997. Learning pronunciation and intonation of Japanese through drama by beginning language students: A case for reflective journals. *Japanese Association of Language Teachers Journal* 19: 235–69.
Mora, Joan C., Youssef Rochdi, and Hanna Kivistö-de Souza. 2014. Mimicking accented speech as L2 phonological awareness. *Language Awareness* 23: 57–75. [CrossRef]
Moreno, Sylvain. 2009. Can music influence language and cognition? *Contemporary Music Review* 28: 329–45. [CrossRef]
Muñoz, Carmen. 2014. Contrasting effects of starting age and input on the oral performance of foreign language learners. *Applied Linguistics* 35: 463–82. [CrossRef]
Ocklenburg, Sebastian, and Onur Güntürkün, eds. 2018. *The Lateralized Brain: The Neuroscience and Evolution of Hemispheric Asymmetries*. London: Elsevier Academic Press.
Oechslin, Mathias S., Martin Meyer, and Lutz Jäncke. 2010. Absolute pitch-functional evidence of speech-relevant auditory acuity. *Cerebral Cortex* 20: 447–55. [CrossRef]
Papagno, Costanza, and Giuseppe Vallar. 1995. Verbal short-term memory and vocabulary learning in polyglots. *Quarterly Journal of Experimental Psychology Section A* 48: 98–107. [CrossRef] [PubMed]
Papagno, Costanza, Tim Valentine, and Alan D. Baddeley. 1991. Phonological short-term memory and foreign-language vocabulary learning. *Journal of Memory and Language* 30: 331–47. [CrossRef]
Parbery-Clark, Alexandra, Adam Tierney, Dana L. Strait, and Nina Kraus. 2012. Musicians have fine-tuned neural distinction of speech syllables. *Neuroscience* 219: 111–19. [CrossRef]
Pastuszek-Lipinska, Barbara. 2008. Influence of music education on second language acquisition. *Proceedings of Acoustics*, 5125–30. [CrossRef]
Peretz, Isabelle, Dominique Vuvan, Marie-Élaine Lagrois, and Jorge L. Armony. 2015. Neural overlap in processing music and speech. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 370: 20140090. [CrossRef]
Perrachione, Tyler K., Evelina G. Fedorenko, Louis Vinke, Edward Gibson, and Laura C. Dilley. 2013. Evidence for shared cognitive processing of pitch in music and language. *PLoS ONE* 8: e73372. [CrossRef] [PubMed]
Pfordresher, Peter Q., and James T. Mantell. 2014. Singing with yourself: Evidence for an inverse modeling account of poor-pitch singing. *Cognitive Psychology* 70: 31–57. [CrossRef] [PubMed]
Pimsleur, Paul. 1966. *Pimsleur Language Aptitude Battery*. New York: Harcourt Brace Javanovich.
Posedel, James, Lisa Emery, Benjamin Souza, and Catherine Fountain. 2012. Pitch perception, working memory, and second-language phonological production. *Psychology of Music* 40: 508–17. [CrossRef]
Reiterer, Susanne Maria, Xiaochen Hu, Michael Erb, Giuseppina Rota, Davide Nardo, Wolfgang Grodd, Susanne Winkler, and Hermann Ackermann. 2011. Individual differences in audio-vocal speech imitation aptitude in late bilinguals: Functional neuro-imaging and brain morphology. *Frontiers in Psychology* 2: 271. [CrossRef] [PubMed]
Reiterer, Susanne Maria, Xiaochen Hu, T. A. Sumathi, and Nandini C. Singh. 2013. Are you a good mimic? Neuro-acoustic signatures for speech imitation ability. *Frontiers in Psychology* 4: 782. [CrossRef]
Safronova, Elena. 2016. The Role of Cognitive Ability in the Acquisition of Second Language Perceptual Phonological Competence. Ph.D. thesis, University of Barcelona, Barcelona, Spain.
Saito, Kazuya, Pavel Trofimovich, and Talia Isaacs. 2016. Second language speech production: Investigating linguistic correlates of comprehensibility and accentedness for learners at different ability levels. *Applied Psycholinguistics* 37: 217–40. [CrossRef]
Schön, Daniele, Cyrille Magne, and Mireille Besson. 2004. The music of speech: Music training facilitates pitch processing in both music and language. *Psychophysiology* 41: 341–49. [CrossRef]
Schulze, Katrin, Faraneh Vargha-Khadem, and Mortimer Mishkin. 2012. Test of a motor theory of long-term auditory memory. *Proceedings of the National Academy of Sciences* 109: 7121–25. [CrossRef]
Shoemaker, Ellenor. 2014. The exploitation of subphonemic acoustic detail in L2 speech segmentation. *Studies in Second Language Acquisition* 36: 709–31. [CrossRef]
Skehan, Peter. 2019. Theorising and updating aptitude. In *Language Learning and Language Teaching: Vol. 52. Doing SLA Research with Implications for the Classroom*. Edited by Robert M. DeKeyser and Goretti Prieto Botana. Amsterdam: John Benjamins, pp. 69–93.

Slevc, L. Robert, and Akira Miyake. 2006. Individual differences in second-language proficiency: Does musical ability matter? *Psychological Science* 17: 675–81. [CrossRef]

Sundberg, Johan. 1999. The perception of singing. In *Academic Press Series in Cognition and Perception. The Psychology of Music*, 2nd ed. Edited by Diana Deutsch. San Diego: Acad. Press, pp. 171–212.

Suzukida, Yui. 2021. The contribution of individual differences to L2 pronunciation learning: Insights from research and pedagogical implications. *RELC Journal* 52: 48–61. [CrossRef]

Tewes, U. 1994. *Hamburg-Wechsler-Intelligenztest für Erwachsene-Revision 1991 (HAWIE-R)*. Bern: Huber.

Thiessen, Erik D., and Jenny R. Saffran. 2009. How the melody facilitates the message and vice versa in infant learning and memory. *Annals of the New York Academy of Sciences* 1169: 225–33. [CrossRef] [PubMed]

Thompson, William Forde, E. Glenn Schellenberg, and Gabriela Husain. 2004. Decoding speech prosody: Do music lessons help? *Emotion* 4: 46–64. [CrossRef]

Tremblay-Champoux, Alexandre, Simone Dalla Bella, Jessica Phillips-Silver, Marie-Andrée Lebrun, and Isabelle Peretz. 2010. Singing proficiency in congenital amusia: Imitation helps. *Cognitive Neuropsychology* 27: 463–76. [CrossRef] [PubMed]

Venkatagiri, Horobail S., and John M. Levis. 2007. Phonological awareness and speech comprehensibility: An exploratory study. *Language Awareness* 16: 263–77. [CrossRef]

Wen, Zhisheng, Adriana Biedroń, and Peter Skehan. 2017. Foreign language aptitude theory: Yesterday, today and tomorrow. *Language Teaching* 50: 1–31. [CrossRef]

Wen, Zhisheng, and Peter Skehan. 2011. A new perspective on foreign language aptitude research: Building and supporting a case for “working memory as language aptitude”. *Ilha do Desterro* 60: 15–44.

Wrembel, Magdalena. 2015. Metaphonological awareness in multilinguals: A case of L3 Polish. *Language Awareness* 24: 60–83. [CrossRef]