No difference in vocal emotion perception between non-professional/amateur singers and instrumentalists

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**Word count:** aim 5000

# Abstract

Musicians outperform non-musicians in vocal emotion recognition, presumably due to predisposed differences in auditory sensitivity for melodic patterns that carry emotional meaning. However, the current literature is inconclusive regarding differential effects in subgroups of musicians. Therefore, we focused on two contrasts potentially relevant in the context of vocal emotions: singers (N= 45) vs. instrumentalists (N=43) and professional musicians (N = 40) vs. amateurs (N = 88) vs. non-musicians (N = 38). Importantly, due to consistent evidence against a causal role of musical training, we assumed that vocal emotion recognition would be unaffected by the type and amount of musical training. Using both frequentist and Bayesian inference, we found the predicted nulleffects for singer vs. instrumentalists, and for professionals vs. amateurs. The pattern for amateurs and non-musicians was inconclusive. In a subsequent correlational analysis, we replicated the consistent link between vocal emotion perception and auditory sensitivity, especially for melodies. Hence, the current work adds new evidence to the accumulating notion that the musicians’ advantage for vocal emotions is linked to differences in auditory sensitivity but not to the type of musical activities or the amount of formal training.

**Keywords:** vocal emotion perception, singers, instrumentalists, amateurs, parameter-specific voice morphing, musicality

# Public significance statement

* ToDo

# Introduction: associations between musicality and vocal emotion perception

The human voice is a prime carrier of emotional information. Therefore, adequate perception of vocal emotions is important for everyday social interaction (Laukka et al., 2016; Schirmer et al., 2025). On average, humans can infer emotion from voices well above chance (Banse & Scherer, 1996; Juslin & Laukka, 2003; Scherer, 2018), but this capacity is subject to great individual variability and seems to be linked to differences in **musicality**. It has been shown repeatedly that musicians outperform non-musician in vocal emotion recognition, although the overall effect size can be considered small to moderate (Martins et al., 2021; Nussbaum & Schweinberger, 2021). Several recent works sought to unravel the potential mechanisms underlying this advantage and emphasize the role of predisposed **acoustic sensitivity** rather than causal effects of musical training: Musicians have more fine-grained basic auditory perception compared to non-musicians, including … (Baldé et al., 2025; Kraus & Chandrasekaran, 2010). Correia et al. (2022) found that the link between music training and vocal emotion perception was fully mediated via these auditory perception skills. The association between auditory perception and vocal emotion recognition was even observed in the absence of any formal musical training (ToDo: Correia, Nussbaum 2024). While these insights are limited by their correlational nature, the presumably strongest evidence is provided by a recent randomized-controlled study in school children, which found no causal effects of musical training on vocal emotion perception performance (quelle). Thus, there is consensus in the literature that the observed performance difference of musicians and non-musicians is due to variations in acoustic sensitivity rather than the result of formal musical education.

In a previous study, we investigated how musicians’ auditory skills promote vocal emotion perception in more detail, by focusing on different auditory cues that transport emotional meaning (Nussbaum et al., 2024). We employed parameter-specific voice morphing to create vocal stimuli that expressed emotion only through fundamental frequency contour (F0), timbre or both. F0 is linked to dynamic pitch variation (also referred to as voice melody) and timbre is linked to perceived voice quality (i.e. whether it sounds harsh or gentle). Professional musicians outperformed a group of non-musicians when emotions were expressed by F0 and both cues, but not timbre alone. This group difference is complemented by an exploratory correlation between melody perception in music and vocal emotion recognition. Thus, musicians seem to be specifically proficient at exploiting melodic pitch patterns to infer vocal emotions.

While the available literature paints a fairly consistent picture regarding the link between musicality and vocal emotion perception, there is a key limitation inherent in most studies targeting group differences: they treat musicians as one uniform group, while they are, in fact, highly heterogeneous. On the one hand, there are quantitative differences regarding levels of expertise. On the other hand, there are qualitative differences, as musicians display a great variety of styles, genres, and forms of expression, within the scope of the Wester music system and beyond (Quellen). A particularly interesting distinction in the context of vocal emotions is the one between **singers and instrumentalists**, as singing is arguably the form of musical expression that is most closely related to vocal emotions. Another interesting debate evolves around differences between **professional musicians and amateurs**. Therefore, the present study targeted these subgroups to explore differential patterns in vocal emotion perception. In what follows, we review current insights and outstanding research gaps, cumulating in the rationale for the present study.

## Singers vs. instrumentalists

Singing and playing an instrument are both fundamental forms of musical expression in humans, but they require very different motorical skills and usually a different amount of formal musical training (Quelle). Accordingly, structural differences have been observed in the brain, with singers showing increased volume and microstructural complexity in the arcuate fasciculus, a white matter tract connecting regions involved in sound perception and production (Halwani 2011). Further, singers outperformed instrumentalists in imitation of foreign speech (Christiner & Reiterer, 2015). However, there were no differences in pitch discrimination and pitch production overall (Nikjeh 2006, 2009). [ToDo: Check literature again]

With regard to vocal emotion perception, evidence is sparse and inconclusive. Intuitively, it may be assumed that singing fosters vocal emotion perception abilities to a larger degree than instrumental activities. In line with his idea, Correia 2022 and Nussbaum 2024 both found exploratory correlations between self-rated singing abilities and vocal emotion perception performance. This was complemented by a study of Greenspon (2023) showing that objectively measured singing ability also predicts vocal emotion recognition. On a neural level, however, Martins (2022) found no differences in electrophysiological response to XX stimuli between singers and instrumentalists, suggesting that… . Importantly, none of these studies provide evidence for a causal role of singing activity on vocal emotion. In fact, one of the first music intervention studies that targeted vocal emotion perception found that singing may even interfere (Tomposon 2004).

* musicality to be beneficial to vocal emotion perception irrespective of a specific expertise for an instrument or singing.

## Amateurs vs. professional musicians

* Most musicians start in childhood an then pick different paths: either become professionals or pursue another career
* Literature suggests that differences between amateurs and professionals are qualitatively different
* Vincenzi 2022: differences in general intelligence
* Rogenmoser 2018: brain aging
* Bonde (2018): general health
* To the best of our knowledge: no insight into differences between vocal emotion perception professional vs. non-professional musicians

## Rationale, outline etc.

Present work is a follow-up study of Nussbaum (2024) zooming into specific distinctions of musicians to explore how they may be linked to vocal emotion perception, which we report in three parts. For Part I, we recruited an original sample of non-professional instrumentalists and singers and assessed their vocal emotion recognition, their musical perception performance and self-rated musicality, following the same protocol as Nussbaum (2024). For Part II, we collapsed all participants recruited in part I into one group of amateur musicians and compared it to the professional musicians and non-musicians recruited by Nussbaum (2024). In Part III, we explored the correlational links between musicality and vocal emotion recognition.

* Literature suggest that the link is not causally driven by formal training
* So neither singing vs instrument nor amateus vs. professionals should make a difference
* If any: amateuts better (because they seem to outperform in some cognitive tasks which are linked to emotional sensitivity, like general intelligence)

The whole study and its hypothesis were preregistered.

# Part I: Comparison of non-professional singers and instrumentalists

## Hypotheses

**H1:** We expect NO difference between singers and instrumentalists in overall vocal emotion recognition performance.

**H2:** We expect NO difference between singers and instrumentalists in vocal emotion recognition performance based on timbre and F0 cues only.

## Method

Note that this is a follow-up to the study reported in Nussbaum et al. (2024). Thus, the stimulus material and the design are identical, but we recruited a new sample. The present study was preregistered (<https://doi.org/10.17605/OSF.IO/76PV5>).

### Participants

According to our preregistered plan, we aimed at a sample size of 40 singers (20 male, 20 female) and 40 instrumentalists (20 male, 20 female), because in our previous study, this sample size allowed us to reveal medium-sized group effects (d =0.81 for the Full and d = 0.56 for the F0 morphing condition) when we compared professional musicians and non-musicians.

Data were collected in a pseudonymized format from June 2023 to January 2024. All participants were aged between 18 and 54 years and fluent German speakers. Participants provided informed consent before completing the experiment and received compensation in form of 12.50 € or course credit upon completion. The experiment was in line with the ethical guidelines of the German Society of Psychology (DGPs) and approved by the local ethics committee of the Friedrich Schiller University Jena (Reg.-Nr. FSV 19/045).

In total, we collected data from 94 non-professional musicians (further also referred to as amateurs) that were divided into singers and instrumentalists. Recruitment criteria specified that participants had to be non-professional musicians (i.e., they held no music-related academic degree or worked professionally as a musician). Singers were required to be currently active in a choir or another singing group, but should not play an instrument actively and regularly (i.e., they must not currently be in an orchestra or a band). Instrumentalists, conversely, were required to be currently active in an orchestra or a band, but they should not engage in singing activities actively and regularly (i.e., they must not currently be in a choir or another singing group).

*Singers*

We recorded data from 48 singers, of which three were excluded (N = 2 had > 5 % trials of omission, N = 1 had technical issues during stimulus playback). Thus, data from 45 singers were analyzed (22 female, 22 male, aged 18 to 53 years [M = 27.02, SD = 8.2]). Mean onset age of musical training was 8 years (SD = 3.08, 5 - 20 years). Twenty-two participants had over 10 years of training, ten between 6-9 years, four between 4-5 years and three between 2-3 years. Six participants had less than one year of training (for more details see ToDo).

*Instrumentalists*

Data from 46 instrumentalists were collected, of which three were excluded. One had technical issues during stimulus playback, one was also active in a choir, one held a Master’s degree in music science and was therefore relocated into the group of professional musicians (see Part II). Thus, data from 43 instrumentalists entered analysis (24 female, 18 male, aged 18 to 54 years [M = 28.51, SD = 10.64]). Mean onset of musical training was 7 years (SD = 2.27, 4 - 14 years). Thirty-five participants had studied their instrument for over 10 years, one between 6-9 years and three between 1-2 years. Four participants had less than one year of training (for more details see ToDo).

### Stimulus material

As stimulus material, we used parameter-specific voice morphs that express the emotional information either through the fundamental frequency contour only (F0), through timbre only (Tbr) or through a combination of both (Full).

For voice morphing, we selected original audio recordings from a database of vocal actor portrayals, comprised of pseudowords (/molen/, /loman/, /belam/) uttered by eight speakers (four male, four female) with expressions of happiness, pleasure, fear, and sadness. To synthesize the parameter-specific emotional voice morphs, we created morphing trajectories between each emotion and an emotional average of the same speaker and pseudoword, using the Tandem-STRAIGHT software (Kawahara et al., 2013; Kawahara et al., 2008). The averages had been created previously by blending all emotions together and were thus assumed to be uninformative and unbiased with respect to the four emotions of interest. After substantial preprocessing (e.g. manual mapping of time- and frequency anchors in each stimulus), Tandem-STRAIGHT enables voice morphing via weighted interpolation of five independent parameters: (1) F0-contour, (2) timing, (3) spectrum-level, (4) aperiodicity, and (5) spectral frequency; the latter three are summarized as timbre.

We created three types of morphed stimuli (see **Figure 1**). **Full-Morphs** were stimuli with all parameters taken from the emotional version (corresponding to 100% from the emotion and 0% from average), except for the timing parameter, which was taken from the average (corresponding to 0% emotion and 100% average). **F0-Morphs** were stimuli with the F0-contour taken from the emotion, but timbre and timing taken from the average. **Timbre-Morphs** were stimuli with all timbre parameters taken from the emotion, but F0 and timing from the average. Note that the timing was kept constant across all conditions to allow a pure comparison of F0 vs. timbre. Furthermore, we kept all average stimuli as a further ambiguous reference category. In total, this resulted in 8 (speakers) x 3 (pseudowords) x 4 (emotions) x 3 (morphing conditions) + 24 average (8 speakers x 3 pseudowords) = 312 stimuli (duration M = 780 ms, range 620 to 967 ms, SD = 98 ms). Using PRAAT (Boersma, 2018), we normalized all stimuli to a root-mean-square of 70 dB SPL.

For a more detailed description of the stimulus creation, see Nussbaum et al. (2024). For general information about voice morphing, refer to Kawahara and Skuk (2019).

**Figure 1**

*Morphing matrix for stimuli with averaged voices as reference*



*Note. Figure reprinted from Nussbaum et al. (2024)*

### Design

Data were collected online via PsyToolkit (Stoet, 2010, 2017), but after completion of the study all participants met with the experimenter for a short personal debriefing. This was done to increase commitment and conscientiousness for the experiment.

Participants were required to ensure a quiet environment for the duration of the study and use a computer with a physical keyboard and headphones. As browser, we recommended Google Chrome, and excluded Safari for technical reasons. Prior to the listening tasks, participants could adjust their sound settings to a comfortable sound pressure level

First, participants entered demographic information, including age, sex, native language, profession, and potential hearing impairments such as tinnitus. They then completed an emotion classification experiment, a test on music perception (the Profile of Music Perception Skills) and several questionnaires on musicality, personality and socioeconomic background. Mean duration of the whole online study was about 75 minutes.

Emotion classification experiment

In the experiment, participants classified vocal emotions as happiness, pleasure, fear, or sadness. Each trial started with a green fixation cross presented for 500 ms. Then the sound was played while a loudspeaker symbol was shown on the screen. Subsequently, a response screen showed the emotion labels and participants could enter their response within a 5000 ms time window starting from voice offset. Responses were entered with the left and right index and middle fingers, with random mapping of response keys to emotion categories for each participant, out of four possible key mappings (see Tables on OSF ToDo). In case of a response omission, the final trial slide (500 ms) prompted participants to respond faster; otherwise, the screen turned back. Then the next trial started.

Preceding the experiment, participants completed eight practice trials with stimuli not used during the actual task. Subsequently, all 312 experimental stimuli were presented once in randomized order across six blocks of 52 trials each. Between blocks, participants could take self-paced breaks. The total duration of the experiment was about 25 minutes.

Profile of Music Perception Skills (PROMS)

To measure music perception skills, we used a modular version of the Profile of Music Perception Skills (Law & Zentner, 2012; Zentner & Strauss, 2017), comprised of the four subtests „Melody“, „Pitch“, „Timbre”, and „Rhythm“. Participants completed 18 items per subtest, always preceded by one practice trial. Each trial, participants heard a reference stimulus twice followed by a target stimulus. Then, they indicated whether reference and target were the same or different via a 5-point Likert scale with the labels “definitely same”, “maybe same”, “don’t know”, “maybe different”, and “definitely different”. Duration of the PROMS was about 20 minutes.

Questionnaires

After the PROMS, participants completed several questionnaires: the German Version of the Autism Quotient Questionnaire, AQ, (Baron-Cohen et al., 2001; Freitag et al., 2007), a 30-item Personality Inventory measuring the Big-Five domains (Rammstedt et al., 2018), the Goldsmiths Musical Sophistication Index, Gold-MSI, (Müllensiefen et al., 2014) to assess the participants’ degree of self-reported musical skills, additional questions concerning music experience and musical engagement, their socioeconomic background, and the 20-item version of the Positive-Affect-Negative-Affect-Scale, PANAS (Breyer & Bluemke, 2016; Watson et al., 1988).

### Data analysis

In line with our preregistered plan, we collapsed data across speakers and pseudowords for analysis. Further, data on emotional averaged were excluded because they were not relevant for our hypotheses. Response omissions (~1%) were treated as errors and participants with more than 5% of such omissions excluded from data analysis. Analyses of Variance (ANOVAs) and correlational analyses were performed using R Version 4.3.2 (R Core Team, 2020). Post-hoc tests were Benjamini-Hochberg corrected where appropriate (Benjamini & Hochberg, 1995).

We complemented these classical frequentist analyses with a Bayesian approach, which – in contrast to null hypothesis significance testing - allows a quantification of evidence for null findings (Rosenfeld & Olson, 2021). These analyses were conducted in JASP Version 0.19.3 (Quelle) using default priors. We report the Bayes factor (BF10) as an indicator for the likelihood of the null and alternative hypothesis given the observed data. BF10 > 1 indicate larger evidence for the alternative hypothesis, BF10 < 1 larger evidence for the null hypothesis. For example, a BF10 = 3 means that the alternative hypothesis is three times more likely than the null hypothesis, whereas the reciprocal BF = .33 means that the null hypothesis is three times more likely than the alternative. Following the guidelines by Jarosz and Wiley (2014) we consider values of BF10 = 1-3 (.1-.33) as anecdotal, BF10 = 3-10 (.33-.10) as moderate, BF10 = 10-30 (.10-.03) as strong, BF10 = 30-100 (.03-.01) as very strong and BF10 > 100 (< .01) as decisive evidence for the alternative hypothesis and the reciprocal values in parenthesis as respective evidence for the null hypothesis.

In alignment with the approach by Nussbaum et al. (2024), we recoded responses in the PROMS from 0 to 1 in 0.25 steps starting with the “definitely” correct option down two the “definitely” incorrect option (thus, “don’t know” was always coded with 0.5) and subtracted 0.5 from the final measure. Thus, a positive score indicates that participants were more correct/confident, whereas a negative score indicates more incorrect/uncertain ratings. For statistical analyses, we used the averaged performance across trials for each subtest.

## Transparency and openness

We specified how we determined our sample size, all data exclusions, all manipulations, and all measures in the associated preregistration (<https://doi.org/10.17605/OSF.IO/76PV5>). Preprocessed data, analysis scripts and supplemental materials can be found in the associated OSF repository (ToDo). For stimulus examples, refer by Nussbaum et al. (2024).

## Results

### Demography, musicality, and personality of participants

Singers and instrumentalists did not differ significantly in the socioeconomic status assessed via educational level, X2(2, N = 88) = 1.06, p = .588; highest academic degree, X2(7, N = 88) = 9.06, p = .249, and household income, X2(4, N = 88) = 5.23, p = .264 (for more details see Table ToDo). Further, the groups did not differ in age or positive and negative affect (assessed with the PANAS) and were comparable regarding Big Five personality traits and autistic traits. In the Gold-MSI, singers and instrumentalists scored comparatively on the general musicality score, but there were differences on two subfactors: instrumentalists scored higher on the subfactor Formal Education, while singers scored higher on Singing. In the PROMS, both groups performed comparably in all four subtests. Participant characteristics assessed via self-report and music performance in the PROMS are summarized in **Table 1**.

**Table 1**

*Characteristics of participants - Demography, personality, and musicality*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Singers** | **Instrumentalists** |  |  |  |  |  |
|  | M (SD) | M (SD) | t | dfa | p | Cohens d |  |
| Age | 27.02 (8.2) | 28.51 (10.6) | -0.73 | 78.93 | .465 | -0.17 [-0.61, 0.28] |  |
|  |  |  |  |  |  |  |  |
| *PANAS* |  |  |  |  |  |  |  |
| positive Affect | 3.00 (0.68) | 3.11 (0.57) | -0.77 | 84.78 | .446 | -0.17 [-0.59, 0.26] |  |
| negative Affect | 1.53 (0.47) | 1.40 (0.35) | 1.49 | 80.61 | .141 | 0.33 [-0.11, 0.77] |  |
|  |  |  |  |  |  |  |  |
| *Big Five* |  |  |  |  |  |  |  |
| Openness | 4.04 (0.55) | 3.99 (0.51) | 0.46 | 85.96 | .647 | 0.10 [-0.32, 0.52] |  |
| Conscientiousness | 3.47 (0.69) | 3.76 (0.70) | -1.91 | 85.62 | .060 | -0.41 [-0.84, 0.02] |  |
| Extraversion | 3.21 (0.70) | 3.00 (0.73) | 1.44 | 85.3 | .155 | 0.31 [-0.12, 0.74] |  |
| Agreeableness | 3.81 (0.57) | 4.01 (0.60) | -1.61 | 85.29 | .112 | -0.35 [-0.77, 0.08] |  |
| Neuroticism | 2.74 (0.77) | 2.61 (0.78) | 0.80 | 85.75 | .426 | 0.17 [-0.25, 0.60] |  |
|  |  |  |  |  |  |  |  |
| *AQ* |  |  |  |  |  |  |  |
| Total | 18.2 (6.15) | 19.28 (8.55) | -0.68 | 76.04 | .500 | -0.16 [-0.60, 0.30] |  |
| Attention to Detail | 5.4 (2.33) | 5.63 (2.53) | -0.44 | 84.64 | .662 | -0.10 [-0.52, 0.33] |  |
| Social | 12.8 (5.37) | 13.65 (7.53) | -0.61 | 75.65 | .545 | -0.14 [-0.59, 0.31] |  |
| Social Skills | 2.4 (1.94) | 3.09 (2.95) | -1.30 | 72.01 | .200 | -0.31 [-0.77, 0.16] |  |
| Communication | 2.53 (1.94) | 2.44 (2.3) | 0.20 | 82.02 | .842 | 0.04 [-0.39, 0.48] |  |
| Imagination | 2.51 (1.75) | 2.81 (1.88) | -0.78 | 84.86 | .437 | -0.17 [-0.60, 0.26] |  |
| Attention Switching | 5.36 (1.91) | 5.30 (2.23) | 0.12 | 82.69 | .904 | 0.03 [-0.40, 0.46] |  |
|  |  |  |  |  |  |  |  |
| *Gold-MSI* |  |  |  |  |  |  |  |
| General ME | 4.78 (0.85) | 4.75 (0.80) | 0.19 | 85.99 | .866 | 0.04 [-0.39, 0.46] |  |
| Active Engagement | 3.83 (0.82) | 4.21 (1.13) | -1.79 | 76.79 | .078 | -0.41 [-0.86, 0.05] |  |
| Formal Education | **4.39 (1.14)** | **4.95 (0.62)** | -2.85 | 68.31 | .006 | -0.69 [-1.18, -0.20] | \*\* |
| Emotion | 5.50 (0.81) | 5.60 (0.76) | -0.60 | 85.99 | .549 | -0.13 [-0.55, 0.29] |  |
| Singing | **4.98 (0.97)** | **4.19 (1.27)** | 3.25 | 78.56 | .002 | 0.73 [0.27, 1.19] | \*\* |
| Perception | 5.73 (0.82) | 5.77 (1.03) | -0.22 | 80.11 | .825 | -0.05 [-0.49, 0.39] |  |
|  |  |  |  |  |  |  |  |
| *PROMS* |  |  |  |  |  |  |  |
| Pitch | 0.23 (0.08) | 0.24 (0.06) | -0.30 | 82.92 | .766 | -0.07 [-0.50, 0.37] |  |
| Melody | 0.17 (0.10) | 0.14 (0.10) | 1.29 | 85.08 | .199 | 0.28 [-0.15, 0.71] |  |
| Timbre | 0.29 (0.08) | 0.3 (0.09) | -0.59 | 86.00 | .556 | -0.13 [-0.55, 0.30] |  |
| Rhythm | 0.31 (0.09) | 0.30 (0.08) | -0.56 | 85.13 | .577 | -0.12 [-0.55, 0.30] |  |

*Note. Descriptive values show mean ratings for the PANAS (Breyer & Bluemke, 2016), the Big-Five Domains (Rammstedt et al., 2018), and the Gold-MSI (Müllensiefen et al., 2014). AQ score were calculated based on Hoekstra et al. (2008) and Baron-Cohen et al. (2001).*

*a Note that original degrees of freedom were 86 but were corrected due to unequal variance.*

### Emotion classification performance

The mean proportion of correct responses was submitted to an ANOVA with Emotion (Happiness, Pleasure, Fear, and Sadness) and Morph Type (Full, F0, and Timbre) as repeated measures factors and Group (singers and instrumentalists) as a between subject factor (see **Table 2**).

The results revealed main effects of **Emotion** and **Morph Type**, which were qualified by an interaction. Crucially, however, we found no main effects or interactions involving **Group** (see **Figure 3**). Planned Bayesian analysis revealed moderate evidence for the null effect of group for overall performance (p = .542, BF10 = 0.265), as well as for Full (p = .392, BF10 = 0.31), F0 (p = .935, BF10 = 0.226), and Timbre morphs (p = .555, BF10 = 0.262) separately. Thus, we found evidence consistent with our hypotheses H1 and H2.

**Table 2**

*Results of the 4 × 3 × 2 mixed-effects ANOVA on the mean proportion of correct responses*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **df1** | **df2** | **F** | **p** | **Ωp2 [95%-CI]** | ***ε*HF** |
| Group | 1 | 86 | 0.38 | .542 | .00 [.00 .01] |  |
| Emotion | 3 | 258 | 72.43 | <.001 | .45 [.36 .53] |  |
| Morph Type | 2 | 172 | 768.93 | <.001 | .90 [.87 .93] | .741 |
| Group x Emotion | 3 | 258 | 2.14 | .095 | .01 [.00 .04] |  |
| Group x Morph Type | 2 | 172 | 0.36 | .635 | .00 [.00 .01] |  |
| Emotion x Morph Type | 6 | 516 | 22.78 | <.001 | .20 [.14 .25] | 827 |
| Group x Emotion x Morph Type | 6 | 516 | 1.33 | .249 | .00 [.00 .01] |  |

**Figure 3**

Mean proportion of correct responses per Morph Type separately for singers and instrumentalists



Note. Whiskers represent 95% confidence intervals. Violin plots represent variation of individual participants. The dotted line represents guessing rate at .25.

Follow-up analysis of the Morph Type effect revealed that performance was best in the Full condition (*M* = 0.75 ± 0.02 SEM), followed by the F0 (*M* = 0.62 ± 0.02) and then the Timbre condition (*M* = 0.41 ± 0.01); Full vs. F0: |*t*(87)| = 23.28, *p* < .001, *d* = 2.50 [2.07, 2.92], F0 vs Timbre: |*t*(87)| = 21.44, *p* < .001, *d* = 2.30 [1.90, 2.70], Full vs Timbre: |*t*(87)| = 33.94, *p* < .001, *d* = 3.64 [3.06, 4.21]). This Morph Type main effect was also found for all emotions separately (all *F*s(2, 174) > 102.44, *p* < .001), although it differed slightly between emotions, as suggested by the interaction (see **Figure 3,** for all post-hoc tests, refer to OSF).

To address our specific interest in the relative importance of F0 and Timbre for the different emotions, we calculated the performance differenceF0-Tbr for each emotion separately. Performance difference was largest for Happiness (M = 0.34 ± 0.02 SEM), followed by Fear (M = 0.21 ± 0.02), Sadness (M = 0.18 ± 0.02), and Pleasure (M = 0.10 ± 0.02; all pairwise comparisons |*t*s(77)| ≥ 2.57, pscorrected ≤ .012, ds ≥ 0.28 [0.06 0.49], except for Fear vs. Sadness (|t(87)| = 1.13, pcorrected = .261).

These effects of Morph Type and Emotion therefore present a full replication of the patterns reported in Nussbaum et al. (2024).

**Figure 3**

Mean proportion of correct responses per Emotion and Morph Type



Note. Whiskers represent 95%-confidence intervals. Grey dots represent individual participants’ data. The dotted line represents guessing rate at .25.

ToDo: additional analyses like confusion data or classification of averages on OSF

# Part II: Comparison of professionals, amateurs and non-musicians

ToDo

## Hypotheses

**H3:** Amateur musicians outperform non-musicians in vocal emotion perception, in the Full and in the F0 condition.

**H4:** Amateurs perform equal or better to professional musicians in the Full and the F0 condition.

## Method

For this analysis, we collapsed all participants from Part I into the group of amateur musicians and compared it to the groups of professional musicians and non-musicians reported in Nussbaum et al. (2024). Note that we added one participant to the professional group, because he held a master’s degree in music (see Part I), so numbers slightly diverge from the original publication. All professional musicians reported to have a music-related academic degree or a non-academic music qualification. Non-musicians were required not to play an instrument or engage in any other musical activities. For a more detailed description, please refer to Nussbaum et al. (2024).

In total, we analyzed data from 40 professional musicians (20 male, 20 female, aged 20 to 42 years [*M* = 29.6; *SD* = 5.58]), 38 non-musicians (18 male, 20 female, aged 19 to 48 years [*M* = 30.5; *SD* = 6.54]) and 88 amateurs (40 male, 46 female, 2 diverse, aged 18 to 54 years [*M* = 27.75; *SD* = 9.44].

The stimulus material, design and data analysis were identical to Part I. We focused our analysis on the comparison of amateurs with the other two groups, because the comparison of professional musicians and non-musicians is reported in Nussbaum et al. (2024).

## Results

### Demography, musicality, and personality of participants

Professionals, amateurs and non-musicians did not differ in the socioeconomic status assessed via educational level (χ²(6, N = 166) = 11.11, p = .085) and highest academic degree (χ²(16, N = 166) = 24.04, p = .089). However, there were differences regarding household income (χ²(8, N = 166) = 20.19, p = .01, ϕ = .25), with amateurs reporting higher household income than professionals and non-musicians (for more details see OSF).

The groups were comparable in age as well as in positive and negative affect (assessed with the PANAS). For the Big Five, analyses of variance revealed group differences for extraversion, with slightly higher levels in professionals than in amateurs (|t(82.15)|= 2.91, p = .005, d = 0.64 [0.20, 1.08]; see OSF for a detailed summary). Regarding autistic traits, the three groups did not differ in their overall score, but there were differences on the several subscales. For the detailed pattern and all post-hoc tests, please refer to OSF.

In the Gold-MSI, professional musicians scored significantly higher than amateurs (all subscales |*t*s| ≥ 4.08, *p*s < .001), except Emotion (|*t*(80.76)|= 2.29, *p* = .025), which in turn scored higher than non-musicians (all subscales |*t*s| ≥ 2.59 , *p*s < .013). This is a pattern (professionals > amateurs > non-musicians) one would expect for self-rated musicality.

In the PROMS, professionals outperformed amateurs in the Pitch and Melody subtest (Pitch: |t(97.32)| = 2.57, p = .012, d = 0.55 [0.12, 0.98]; Melody: |t(95.24)| = 4.42, p < .001, d = 0.91 [0.48, 1.33]), whereas there were no differences in the Timbre and Rhythm subtests (*p*s ≥ .09). Amateurs performed better than non-musicians in the Pitch, Melody and Rhythm subtest (Pitch: |t(81.21)| = 4.39, p < .001, d = 0.97 [0.51, 1.43]; Melody: |t(91.34)| = 5.65, p < .001, d = 1.18 [0.74, 1.62]; Rhythm: |t(80.84)| = 3.16, p = .002, d = 0.7 [0.25, 1.15]), but not in the Timbre subtest (p = .064). Thus, a clear pattern of professionals > amateurs > non-musicians was only found for melody and pitch. Participant characteristics are summarized in **Table 3.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Professionals** |  | **Amateurs** |  | **Non-Musicians** |
|  | M (SD) |  | M (SD) |  | M (SD) |
| *PANAS* |  |  |  |  |  |
| positive Affect | 3.32 (0.65) |  | 3.05 (0.63) |  | 3.1 (0.67) |
| negative Affect | 1.69 (0.48) |  | 1.47 (0.42) |  | 1.49 (0.69) |
|  |  |  |  |  |  |
| *Big Five* |  |  |  |  |  |
| Openness | 4.12 (0.50) |  | 4.02 [0.53) |  | 3.81 (0.80) |
| Conscientiousness | 3.49 (0.71) |  | 3.61 (0.70) |  | 3.76 (0.72) |
| Extraversion | **3.48 (0.66)** | > | **3.11 (0.72)** |  | 3.38 (0.79) |
| Agreeableness | 3.92 (0.57) |  | 3.91 (0.59) |  | 3.75 (0.66) |
| Neuroticism | 2.95 (0.65) |  | 2.69 (0.77) |  | 2.58 (0.82) |
|  |  |  |  |  |  |
| *AQ* |  |  |  |  |  |
| Total | 15.7 (4.98) |  | 18.73 (7.40) |  | 17.58 (6.41) |
| Attention to Detail | 5.43 (2.04) |  | **5.51 (2.42)** | > | **4.32 (2.01)** |
| Social | **10.28 (4.70)** | < | **13.22 (6.49)** |  | 13.26 (6.51) |
| Social Skills | **1.48 (1.68)** | < | **2.74 (2.49)** |  | 2.61 (2.63) |
| Communication | 1.85 (1.61) |  | 2.49 (2.12) |  | 2.39 (1.73) |
| Imagination | 2.18 (1.52) |  | 2.66 (1.8) |  | 2.87 (1.95) |
| Attention Switching | 4.78 (1.91) |  | 5.33 (2.06) |  | 5.39 (1.92) |
|  |  |  |  |  |  |
| *Gold-MSI* |  |  |  |  |  |
| General ME | **5.68 (0.50)** | > | **4.76 (0.82)** | > | **2.74 (1.07)** |
| Active Engagement | **4.94 (0.81)** | > | **4.02 (1.00)** | > | **2.95 (1.19)** |
| Formal Education | **5.95 (0.56)** | **>** | **4.66 (0.96)** | > | **1.71 (0.68)** |
| Emotion | 5.88 (0.73) |  | **5.55 (0.78)** | > | **4.95 (1.32)** |
| Singing | **5.34 (0.83)** | **>** | **4.59 (1.19)** | > | **2.84 (1.26)** |
| Perception | **6.31 (0.51)** | > | **5.75 (0.92)** | > | **4.22 (1.49)** |
|  |  |  |  |  |  |
| *PROMS* |  |  |  |  |  |
| Pitch | **0.27 (0.06)** | > | **0.24 (0.07)** | > | **0.18 (0.06)** |
| Melody | **0.23 (0.08)** | > | **0.16 (0.10)** | > | **0.07 (0.08)** |
| Timbre | 0.32 (0.08) |  | 0.29 (0.08) |  | 0.26 (0.09) |
| Rhythm | 0.33 (0.08) |  | **0.32 (0.09)** | > | **0.27 (0.08)** |

**Table 3**

*Characteristics of participants - Demography, personality, and musicality*

*Note. Descriptive values show mean ratings for the PANAS (Breyer & Bluemke, 2016), the Big-Five Domains (Rammstedt et al., 2018), and the Gold-MSI (Müllensiefen et al., 2014). AQ score were calculated based on Hoekstra et al. (2008) and Baron-Cohen et al. (2001). Comparison signs (“>” or “<”) indicate significant differences. For a full report of statistical details, please refer to OSF.*

### Emotion classification performance

The mean proportion of correct responses was submitted to an ANOVA with Emotion (Happiness, Pleasure, Fear, and Sadness) and Morph Type (Full, F0, and Timbre) as repeated measures factors and Group (professionals, amateurs, and non-musicians) as a between subject factor (see **Table 4**).

The results revealed the main effects of **Emotion** and **Morph Type**, which were qualified by interaction. Crucially, however, we found no main effect involving **Group** and only a trend for an interaction with **Morph Type**.

**Table 4**

*Results of the 4 × 3 × 3 mixed-effects ANOVA on the mean proportion of correct responses*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **df1** | **df2** | **F** | **p** | **Ωp2 [95%-CI]** | ***ε*HF** |
| Group | 2 | 163 | 1.96 | .144 | .01 [.00 .06] |  |
| Emotion | 3 | 489 | 130.24 | <.001 | .44 [.38 .49] |  |
| Morph Type | 2 | 326 | 1357.80 | <.001 | .89 [.87 .91] | .829 |
| Group x Emotion | 6 | 489 | 1.17 | .322 | .00 [.00 .00] |  |
| Group x Morph Type | 4 | 326 | 2.14 | .089 | .01 [.00 .04] | .829 |
| Emotion x Morph Type | 6 | 978 | 40.95 | <.001 | .20 [.15 .24] | .875 |
| Group x Emotion x Morph Type | 12 | 978 | 0.74 | .688 | .00 [.00 .00] | .865 |

Planned comparisons between **professionals and amateurs** revealed moderate evidence for the null effect for overall performance (p = .473, BF10 = 0.238), as well as for Full (p = .322, BF10 = 0.286), F0 (p = .435, BF10 = 245), and Timbre morphs (p = .840, BF10 = 0.205) separately. Planned comparisons between **amateurs and non-musicians** revealed inconclusive evidence for overall performance (p = .107, BF10 = 0.546), as well as for Full (p = .044, BF10 = 1.009), and F0 (p = .105, BF10 = 0.576) separately. For Timbre morphs, there was moderate evidence for the null effect (p = .975, BF10 = 0.205). Thus, we found evidence consistent with our hypotheses H4, but inconclusive evidence regarding H3. 

# Part III: Correlational analyses

## Hypotheses

*Correlations with the PROMS*

**H5:** Averaged vocal emotion recognition (VER) performance is correlated with averaged music perception performance.

**H6:** Full-VER and F0-VER are correlated with melody perception in music

*Correlations with the GOLD-MSI:*

**H7:** Averaged-VER and Full-VER are correlated with the General-ME.

**H8:** Averaged-VER and Full-VER are correlated with the Perception Subscale

**H9:** Averaged-VER and Full-VER are correlated with self-rated singing abilities.

## Method

ToDo, Wichtig: nur auf Basis der neuen Daten aus Part I, da die Daten, die in Part II dazugekommen sind ja diese Hypothesen motiviert haben. Die jetzt in die Analyse einzuschließen wäre also unzulässig.

Aus preregistration: - all correlations are controlled for formal musical education

## Results

ToDo

We found evidence for our hypotheses H5 and H6, but not for the hypotheses H7 – H9.

# Discussion

ToDo

## Singers vs. instrumentalists

ToDo

## Professional musicians vs. amateurs

ToDo

## Constraints on generality and future directions

ToDo

# Summary and Conclusion

ToDo

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The authors declare no conflicts of interests.

# Credit Author Statement

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# Supplementary material

Supplemental figures and tables, analysis scripts, and raw data can be found on the associated OSF repository (ToDo).

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