Singing Proficiency in the Majority

Normality and "Phenotypes" of Poor Singing

Simone Dalla Bella[a,b] and Magdalena Berkowska[a]

[a]*Department of Cognitive Psychology, University of Finance and Management in Warsaw, Warsaw, Poland*

[b]*International Laboratory for Brain, Music, and Sound Research (BRAMS), Montreal, Canada*

Recent evidence indicates that the majority of occasional singers can carry a tune. For example, when asked to sing a well-known song (e.g., "Happy Birthday"), nonmusicians performing at a slow tempo are as proficient as professional singers. Yet, some occasional singers are poor singers, mostly in the pitch domain, and sometimes despite not having impoverished perception. Poor singing is not a monolithic deficit, but is likely to be characterized by a diversity of singing "phenotypes." Here we systematically examined singing proficiency in a group of occasional singers, with the goal of characterizing the different patterns of poor singing. Participants sang three well-known melodies (e.g., "Jingle Bells") at a natural tempo and at a slow tempo, as indicated by a metronome. For each rendition, we computed objective measures of pitch and time accuracy with an acoustical method. The results confirmed previous observations that the majority of occasional singers can sing in tune and in time. Moreover, singing at a slow tempo after the target melody to be imitated was presented with a metronome improved pitch and time accuracy. In general, poor singers were mostly impaired on the pitch dimension, although various patterns of impairment emerged. Pitch accuracy or time accuracy could be selectively impaired; moreover, absolute measures of singing proficiency (pitch or tempo transposition) dissociated from relative measures of proficiency (pitch intervals, relative duration). These patterns of dissociations point to a multicomponent system underlying proficient singing that fractionates as a result of a developmental anomaly.

Key words: **musical disorders; tone deafness; poor singing; congenital amusia; singing proficiency; vocal performance; music performance**

Introduction

Most believe that people who did not receive vocal training (i.e., occasional singers) are unable to carry a tune. This belief is confirmed by occasional singers' judgments of their own sung renditions. For example, almost 60% of 1000 university students reported that they cannot imitate melodies.[1] Moreover, self-declared tone-deaf individuals (around 17% of the student population) believe that they cannot sing proficiently.[2] However, this scenario is too defeatist. The actual prevalence of deficits affecting singing proficiency (e.g., poor-pitch singing[3]) is lower, probably confined to 10–15% of the population.[1,4] The majority of the general population is able to sing a familiar melody in tune and in time, provided that the melody is performed at a slow tempo.[4] In addition, occasional singers are typically very consistent in their renditions both within,[4–6] and across subjects[7,8] when considering both starting pitch and tempo. In sum, singing appears quite natural for the large majority of humans.

Some individuals (herein referred to as "poor singers") are unable to carry a tune, though. These poor singers are commonly called "tone

Address for correspondence: Simone Dalla Bella, Department of Cognitive Psychology, University of Finance and Management in Warsaw, Ul. Pawia 55, 01-030 Warsaw, Poland. Fax: +48 22 536-5364. sdallabella@vizja.pl

The Neurosciences and Music III—Disorders and Plasticity: Ann. N.Y. Acad. Sci. 1169: 99–107 (2009).
doi: 10.1111/j.1749-6632.2009.04558.x

deaf" and suffer from a lifelong difficulty in processing music despite normal intellectual, memory, and language skills.[9,10] Poor singers, mostly impaired on the pitch dimension, exhibit inaccurate production of pitch intervals[1,3,4] or pitch transposition.[1] Poor-pitch singing is often the result of impoverished perception.[11] Nevertheless, inaccurate production of pitch intervals can occur in the absence of perceptual disorders.[4,12,13] A similar condition was observed as a consequence of brain damage.[14,15] More recently, evidence of the opposite dissociation (i.e., impaired perception with spared production) has been also found in tone-deaf individuals,[16] thus pointing toward separate perception and action mechanisms.[17]

In sum, there is increasing evidence that lack of singing proficiency may stem from various sources, leading to differentiable patterns of impairment. In the present study we aimed to systematically examine patterns of impairments in poor singers in terms of both pitch and time accuracy using acoustical measures of singing proficiency.[4] Occasional singers were first asked to sing three well-known melodies from memory at a spontaneous tempo. In a second task, occasional singers imitated the same melodies after they were presented at a slow tempo together with a metronome. On the basis of previous results, we expected this second task to provide optimal conditions for proficient singing.

Method

Participants

Thirty-nine occasional singers (29 females and 10 males), aged between 19 and 39 years (M = 25.9 years), mostly university students (M = 12.3 years of education) at the University of Finance and Management in Warsaw, volunteered to take part in the experiment. Participants had not received formal musical training. No participants reported past or present hearing problems or articulatory disorders. They received course credits for participating in the experiment.

Materials and Procedure

All participants were submitted to a battery of tests to assess their singing proficiency (Sung Performance Battery [SPB]). The SPB includes tasks requiring participants to repeat isolated pitches, intervals, and short novel melodies. In addition, participants were asked to sing well-known melodies at a natural tempo and at a fixed, slow tempo. In the present study, only the results of tasks involving the production of familiar melodies (*Familiar melody production task* and *Familiar melody repetition task [slow tempo]*) are reported. In the *Familiar melody production task* (hereafter referred to as *Production task*), participants were asked to sing the beginning of three well-known songs with Polish lyrics[18–20]: the full melody (32 notes) of "Brother John," the first 8 bars (25 notes) of "Jingle Bells," and the first 4 bars (20 notes) of "Sto lat" (a familiar Polish melody typically sung at birthdays). The melodies are illustrated in Figure 1. Both starting pitch and tempo were chosen by the participants. In the *Familiar melody repetition task (slow tempo)* (hereafter referred to as *Repetition task*), the same songs as in the previous task were imitated by participants at a fixed slow tempo. The presentation of each melody was preceded by a metronome indicating the beat ("Brother John," 96 beats/min, quarter-note inter-onset interval [IOI] = 625 ms; "Jingle Bells," 125 beats/min, quarter-note IOI = 480 ms; "Sto lat," 80 beats/min, quarter-note IOI = 750 ms). The metronome sounded for 4 beats prior to the melody, and then the melody was presented twice together with the metronome. Finally, the metronome was turned off and participants repeated the melody immediately afterward as accurately as possible. The melody was presented within the vocal range of individual participants. Written lyrics were made available to participants during both tasks.

Figure 1. Score of familiar melodies used in the Sung Performance Battery.

Before asking participants to perform the SPB, a 10-min warm-up session was carried out in which participants sang three well-known Polish songs (“Pieski małe dwa,” “Szła dzieweczka,” and “Wlazł kotek”). A measure of participants’ vocal range was obtained prior to the performance of the SPB using an adaptive automated procedure. The SPB and the adaptive procedure for computing the vocal range were run on MATLAB 7.1 (The Mathworks Inc., Natick, MA). Stimuli were presented over Sennheiser EH2270 headphones (Sennheiser GmbH, Wennebostel, Germany) at a comfortable level. Vocal performance was recorded with a Shure SM58 microphone (Shure Inc., Niles, IL) on a Fostex D2424LV digital recorder (Fostex Company, Tokyo, Japan) (sampling frequency = 44.1 kHz) and subsequently dumped onto an IBM-compatible computer using Audition Software (Adobe Systems Inc., San Jose, CA) for further analyses. The SPB lasted approximately 1 h.

Analysis of Sung Performance

Acoustical analyses of sung renditions were performed on the vowel groups (e.g., “o” in “sto”), as they are the best targets for acoustical analysis, given that vowels carry the maximum of voicing[21] and mark the onsets of musical tones.[22] The onset of vowel groups, determined by visual inspection of the waveform and of the spectrogram, was considered as the *note onset time*. The median of the fundamental frequencies within the vowel group was our measure of *pitch height*. Note onset times and pitch heights served to compute various measures of pitch and time accuracy. Measures of absolute pitch and tempo, with respect to the melody to be imitated, apply only to the Repetition task, as indicated below.

Pitch Dimension Variables

Number of pitch interval errors refers to the number of errors in the production of musical intervals as compared to the musical notation. An error was scored when the sung interval was larger or smaller by 1 semitone than the interval in the notation.

Number of contour errors refers to the number of changes in pitch direction relative to musical notation. Pitch direction was counted as ascending or descending if the sung interval between two notes was higher or lower by more than 1 semitone. Contour errors were coded independently from pitch interval errors.

Pitch interval deviation measures the size of the pitch deviations from the notation by averaging the absolute difference in semitones between the produced intervals and the intervals prescribed by musical notation. Small deviation reflects high accuracy in relative pitch.

Initial pitch deviation (only for the Repetition task) measures the amount of pitch transposition, by computing the absolute pitch difference in semitones between the first note of the melody to be imitated and the first note of the produced melody.

Time Dimension Variables

Tempo is the mean IOI of the quarter note.

Number of time errors indicates the number of errors in the production of note durations. A time error was scored when the duration of the sung note was 50% longer or shorter than its predicted duration based on the preceding note, as prescribed by the musical notation.

Temporal variability measures the size of time deviations, by computing the coefficient of variation of the quarter-note IOIs (i.e., SD of the IOIs divided by the mean IOI). Small temporal variability indicates high accuracy in relative duration.

Tempo deviation (only for the Repetition task) measures the amount of tempo change, by calculating the absolute difference in percent of the quarter-note IOI between the tempo of the melody to be imitated and the tempo of the produced melody.

Results

All participants produced complete performances (117 renditions in the Production task, and 117 in the Repetition task). The distribution of pitch and time accuracy measures for the tested population often deviated from normality (in the Production task: pitch interval errors, K–S statistic = 0.17, $P < 0.01$; contour errors, K–S = 0.15, $P < 0.05$; pitch interval deviation, K–S = 0.18, $P < 0.01$; tempo, K–S = 0.16, $P < 0.05$; time errors, K–S = 0.27, $P < 0.001$; in the Repetition task: contour errors, K–S = 0.16, $P < 0.05$; initial pitch deviation, K–S = 0.14, $P < 0.05$; time errors, K–S = 0.29, $P < 0.001$). Most occasional singers performed quite proficiently both when producing a well-known melody from memory, and when imitating the same melody at a slow tempo. Yet, there are some noticeable extreme cases (i.e., poor singers) largely deviating from the group average.

Means and variability of pitch and time accuracy measures averaged across the three melodies for both tasks are reported in Table 1. The results from a group of 20 occasional singers performing at a spontaneous tempo,[c] and from a subgroup of 13 occasional singers performing at a slow tempo from a previous study[4] are also reported for comparison.[d] Significant differences between the Production task and the Repetition task (slow tempo), as assessed by *t*-tests, are indicated.[e] Participants were very accurate at singing at the expected tempo in the Repetition task (i.e., on average, the performed tempo was within 6% of the intended tempo). As can be seen, repeating familiar melodies at a slow tempo improved accuracy on both the pitch and time dimensions. In the Repetition task, occasional singers made fewer pitch interval errors, fewer time errors, and deviated less from the score both in terms of pitch intervals and relative durations, as compared to the Production task. A tendency to make fewer contour errors in the Repetition task than in the Production task was observed. However, it did not reach significance.

To examine whether all individuals similarly benefited from singing in the Repetition task (i.e., after listening to the target melody and

---

[c] These results are the average of three renditions provided by each occasional singer in our previous study.[4]

[d] Note that in Dalla Bella *et al.*,[4] a stricter criterion was used to score time errors (25% of the duration of the previous note) as compared to the present study (50%). This can partly explain differences between the two studies in terms of time errors.

[e] As several variables were not normally distributed, nonparametric tests (Wilcoxon) were also performed, confirming the results obtained with parametric tests.

TABLE 1. Mean Values for Pitch and Time Accuracy Variables in the Production Task and in the Repetition Task from the Present Study and a Previous

	Present study ($n = 39$)		Study of Dalla Bella *et al.*[4]	
Variable	Production task *M* (SE)	Repetition task (slow tempo) *M* (SE)	Production task ($n = 20$) *M* (SE)	Production task, slow tempo ($n = 13$) *M* (SE)
Pitch dimension				
No. of pitch interval errors	4.4 (0.5)	3.3 (0.5)[a]	4.9 (1.1)	1.2 (0.5)
No. of contour errors	2.8 (0.3)	2.5 (0.2)	1.0 (0.3)	0.2 (0.2)
Pitch interval deviation (semitones)	0.6 (0.04)	0.5 (0.04)[a]	0.6 (0.1)	0.3 (0.03)
Initial pitch deviation (semitones)	na	1.6 (0.2)	na	na
Time dimension				
Tempo (quarter-note IOI, ms)	431.4 (10.8)	610.7 (5.3)[a]	281.9 (10.9)	497.0 (8.7)
No. of time errors	0.9 (0.1)	0.7 (0.1)[a]	2.0 (0.4)	0.9 (0.4)
Temporal variability (CV IOIs)	0.20 (0.01)	0.16 (0.01)[a]	0.11 (0.01)	0.07 (0.01)
Tempo deviation (% IOI)	na	5.4 (0.4)	na	na

[a]Significant differences between the Production task and the Repetition task (slow tempo) as assessed by *t*-tests.

Note: $P < 0.01$; na = not available.

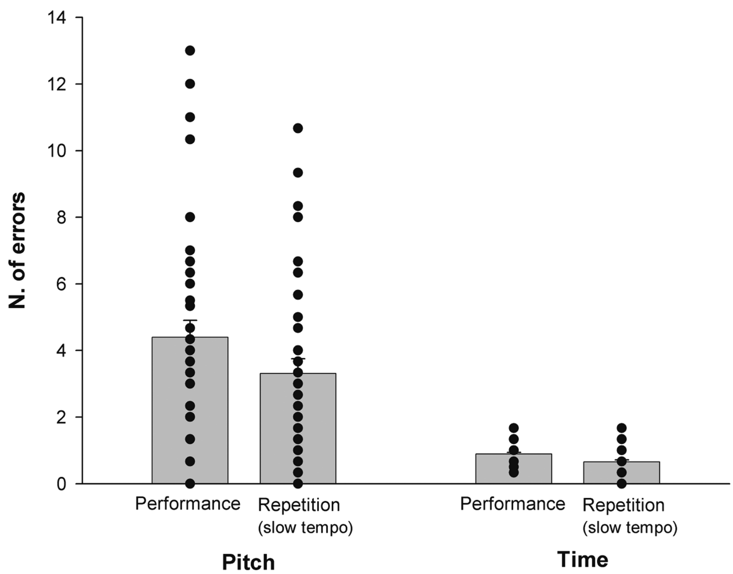

Figure 2. Pitch and time errors in the Performance task and in the Repetition task. Dots indicate individual data. Error bars are standard errors of the mean. (In color in *Annals* online.)

performing at a slow tempo), individual results in terms of pitch interval errors and of time errors were examined (Fig. 2). The majority of participants were more proficient in the Repetition task. Twenty-six (67%) made fewer pitch interval errors (3.2, on average) in the Repetition task as compared to the Production task (5.2 errors). The other participants either did not shown any change ($n = 4$, 10%) or exhibited worsened accuracy ($n = 9$, 23%) in the Repetition task. Similar results were obtained on the time dimension. Twenty-two participants

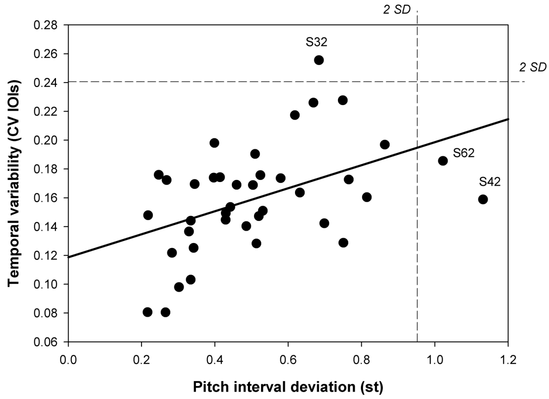

Figure 3. Temporal variability shown by occasional singers in the Repetition task plotted against pitch interval deviation. The dashed lines indicate cutoff scores for poor singing.

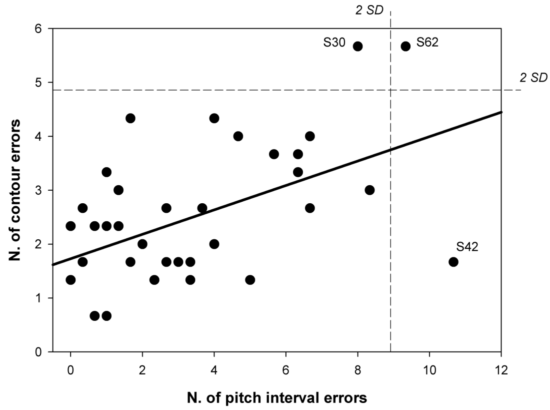

Figure 4. Number of contour errors made by occasional singers in the Repetition task plotted against the number of pitch interval errors. The dashed lines indicate cutoff scores for poor singing.

(56%) made fewer time errors (0.5, on average) in the Repetition task than in the Production task (one error). Eleven occasional singers (28%) exhibited comparable performance in the two tasks; six (15%) performed worse in the Repetition task than in the Production task. However, note that most of the participants who did not show an improvement (11 out of 13 on the pitch dimension; 13 out of 17 on the time dimension) were already very proficient in the Production task (i.e., with very few errors as compared to the group average). Moreover, in general, participants made very few time errors. Hence, in most cases a floor effect very likely hindered any further improvement.

Additional analyses were carried out on data obtained in the Repetition task to investigate the relations between the various measures of pitch and time accuracy. In addition, we explored potential dissociations between such measures at an individual level. To this end, for each measure of singing proficiency we set cutoff scores for poor singing, corresponding to the average value of that variable for the overall group plus 2 SD. Occasional singers exhibiting measures of singing accuracy beyond this cutoff score were qualified as "poor singers." We first examined whether accuracy on the pitch dimension was related to accuracy on the time dimension. In Figure 3, pitch interval deviation is plotted against temporal variability. The occasional singers who sang out of tune also sang out of time ($r = 0.46$, $P < 0.01$). Nevertheless, two participants were qualified as poor singers on the pitch dimension (S42, S62), despite singing in time; conversely, one was a poor singer on the time dimension (S32), but sang in tune. To examine whether occasional singers making pitch errors also tended to violate contour, the number of pitch interval errors was plotted against the number of contour errors (Fig. 4). The number of contour errors increased with the number of pitch interval errors ($r = 0.52$, $P < 0.01$). However, one occasional singer (S42) made more than 10 pitch interval errors with very few contour errors (<2). S30 exhibited the reverse pattern. Finally, we examined whether relative measures of accuracy (i.e., based on pitch intervals or relative durations) were related to absolute measures of accuracy (i.e., pitch or tempo transposition). In Figure 5, pitch interval deviation is plotted as a function of initial pitch deviation. Larger pitch transposition was associated with larger interval deviation ($r = 0.64$, $P < 0.001$). Yet, three occasional singers (S26, S30, and S33), despite transposing the melodies to be imitated by more than 4 semitones, exhibited normal pitch interval deviation. Conversely, S42 and S62 produced interval deviation on average more than 1

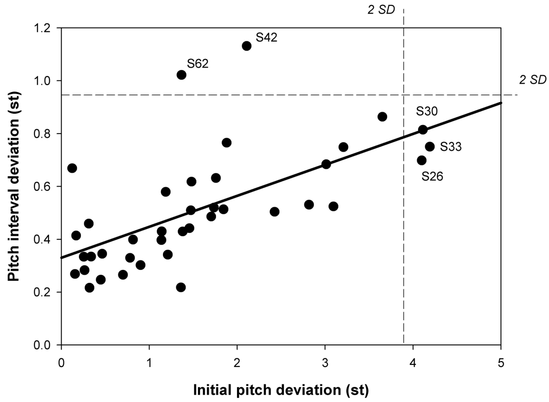

Figure 5. Pitch interval deviation shown by occasional singers in the Repetition task plotted against initial pitch deviation. The dashed lines indicate cutoff scores for poor singing.

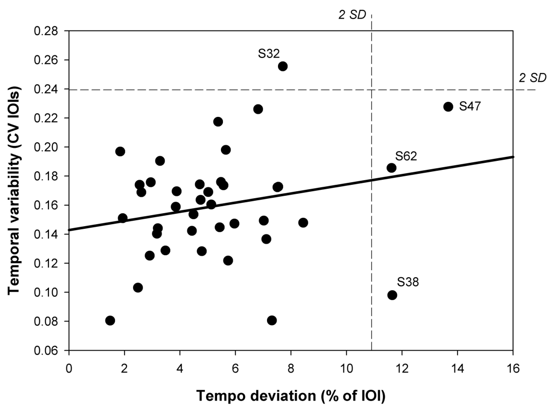

Figure 6. Temporal variability shown by occasional singers in the Repetition task plotted against tempo deviation. The dashed lines indicate cutoff scores for poor singing.

semitone from the score in spite of little transposition (<3 semitones). In Figure 6, temporal variability is plotted against tempo deviation. Renditions were not more temporally variable with increasing deviation from the original tempo ($r = 0.23$, $P =$ n.s.).[f] Three occasional singers (S38, S47, and S62), despite large deviation from the original tempo (> 10% of the IOIs), did not exhibit above-threshold temporal variability. S32 showed the reverse pattern.

On the basis of the reported dissociations between accuracy measures, we propose to classify poor singers according to two axes: pitch versus time accuracy, and relative measures versus absolute measures of accuracy (Table 2). As can be seen, poor singers were mostly affected on the pitch dimension than on the time dimension. Only S62 was impaired in both dimensions. The other poor singers were either selectively transposing pitch or tempo, or they were producing inaccurate intervals (i.e., poor-pitch interval singers) or inaccurate relative durations (i.e., poor-duration singers). Impaired production of pitch direction did not systematically accompany deficient production of absolute of relative pitch.

Discussion

Occasional singers can sing proficiently both on the pitch and on the time dimensions when they perform well-known songs from memory. Repeating the same melodies at a slower tempo leads to higher pitch accuracy (i.e., fewer pitch interval errors, and reduced deviation from the score), and higher time accuracy (i.e., fewer time errors, and reduced temporal variability) than singing the songs from memory at a spontaneous tempo. That performing at a slower tempo positively affects the production of pitch intervals is consistent with previous findings.[4] However, in our previous study we did not find any effect on time accuracy. The additional positive effect on time accuracy observed here may depend on task factors. Here participants imitated a well-known song after it was presented auditorily with a metronome, whereas in our previous study just a metronome was provided. In the present study, temporal information about the melody to be imitated (e.g., note durations) was very likely available in short-term memory at the time of performance, thus facilitating the reproduction of the appropriate durations. In sum, these findings provide compelling evidence that singing proficiency can be significantly enhanced by slowing down tempo and by prior presentation of the melody to be produced together with a metronome.

[f] All correlations were confirmed by nonparametric Spearman's tests.

TABLE 2. Classification of Poor Singers Based on Absolute and Relative Accuracy Measures for Pitch and Time Obtained in the Repetition Task and Percentages of the Tested Sample for Each Category of Poor Singers

	Absolute measures (initial pitch deviation/tempo deviation)	Relative measures (pitch interval deviation/temporal variability)
Pitch	*Pitch transposers (8%)*	*Poor-pitch-interval singers (5%)*
	S26	S42
	S30[a]	S62[a]
	S33	
Time	*Tempo transposers (8%)*	*Poor-duration singers (3%)*
	S38	S32
	S47	
	S62	

[a]With impaired production of contour.

A few individuals are poor singers. They more often sing out of tune (e.g., by singing intervals deviating from the score by more than 1 semitone, or by transposing pitch by more than 4 semitones) than out of time. In addition, poor singers are more often deficient on absolute measures of pitch and time accuracy (i.e., they transpose pitch or change tempo when asked to imitate a melody) than on relative measures (i.e., by producing incorrect pitch intervals or relative note durations as compared to the musical notation).

Poor singing, instead of being a monolithic disorder, is not a condition systematically affecting all measures of singing proficiency. Very selective impairments emerged, as revealed by acoustical measures. As previously observed,[1] some occasional singers (pitch transposers) systematically transpose pitch when they imitate a melody. This deficit can occur in isolation (i.e., with tempo correctly imitated). Here we also found that some individuals (tempo transposers) can exhibit the opposite pattern (i.e., performing at a slower or faster tempo without pitch transposition). Furthermore, deficits on absolute measures of pitch and time accuracy are not systematically associated with impaired production of pitch intervals or relative duration (i.e., relative measures of accuracy). Conversely, we found cases of impaired production of pitch intervals (i.e., poor-pitch-interval singers) or relative durations (i.e., poor-duration singers) in the absence of pitch and tempo transposition. Finally, in keeping with recent evidence,[11,16] some individuals are unable to produce the appropriate pitch interval size, still producing the correct pitch direction. The opposite condition is also found.

In summary, despite the fact that the majority of persons sing proficiently, there are several "phenotypes" of poor singing. Dissociations along the pitch/time and absolute/relative measure axes indicate that components of the general ability to sing fractionate as a result of a developmental anomaly. These findings suggest that the mechanisms underlying pitch and time processing, and relative/absolute processing of pitch and time, may enjoy some degree of functional independence, a possibility that deserves further enquiry.

Acknowledgments

This research was supported by an International Reintegration Grant 14847 from the European Commission and by a research grant from the Grammy Foundation to S.D.B.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. Pfordresher, P.Q. & S. Brown. 2007. Poor-pitch singing in the absence of "tone-deafness". *Music Percept.* **25:** 95–115.
2. Cuddy, L.L., L.-L. Balkwill, I. Peretz, *et al*. 2005. Musical difficulties are rare: a study of "tone deafness" among university students. *Ann. N. Y. Acad. Sci.* **1060:** 311–324.
3. Welch, G.F. 1979. Poor-pitch singing: a review of the literature. *Psychol. Music* **7:** 50–58.
4. Dalla Bella, S., J.-F. Giguère & I. Peretz. 2007. Singing proficiency in the general population. *J. Acoust. Soc. Am.* **121:** 1192–1189.
5. Bergeson, T.R. & S.E. Trehub. 2002. Absolute pitch and tempo in mothers' songs to infants. *Psychol. Sci.* **13:** 72–75.
6. Halpern, A.R. 1989. Memory for the absolute pitch of familiar songs. *Mem. Cognit.* **17:** 572–581.
7. Levitin, D.J. 1994. Absolute memory for musical pitch: evidence from the production of learned melodies. *Percept. Psychophys.* **56:** 414–423.
8. Levitin, D.J. & P.R. Cook. 1996. Memory for musical tempo: additional evidence that auditory memory is absolute. *Percept. Psychophys.* **58:** 927–935.
9. Peretz, I. 2001. Brain specialization for music: new evidence from congenital amusia. *Ann. N. Y. Acad. Sci.* **930:** 189–192.
10. Peretz, I. & K. Hyde. 2003. What is specific to music processing? Insights from congenital amusia. *Trends Cognit. Sci.* **7:** 362–367.
11. Dalla Bella, S., J-F. Giguère & I. Peretz. 2009. Singing in congenital amusia. *J. Acoust. Soc. Am.* In press.
12. Bradshaw, E. & M.A. McHenry. 2005. Pitch discrimination and pitch-matching abilities of adults who sing inaccurately. *J. Voice* **14:** 431–439.
13. Wise, K.J. & J.A. Sloboda. 2008. Establishing an empirical profile of self-defined "tone-deafness": perception, singing performance and self-assessment. *Musicae Scientiae*. **12:** 3–13.
14. Schön, D., B. Lorber, M. Spacal, *et al*. 2003. Singing: a selective deficit in the retrieval of musical intervals. *Ann. N. Y. Acad. Sci.* **999:** 189–192.
15. Schön, D., B. Lorber, M. Spacal, *et al*. 2004. A selective deficit in the production of exact musical intervals following right-hemisphere damage. *Cognit. Neuropsychol.* **21:** 773–784.
16. Loui, P., F. Guenther, C. Mathys, *et al*. 2008. Action-perception mismatch in tone-deafness. *Curr. Biol.* **18:** R331–332.
17. Griffiths, T.D. 2008. Sensory systems: auditory action streams? *Curr. Biol.* **18:** R387–388.
18. Piatek, A. 2005. *Mój pierwszy śpiewnik*. Siedmiogród. Warsaw.
19. Malko, D. 1992. *Muzyka klasa 5*. WSiP. Warsaw.
20. Woźny, M. 1958. *W krainie melodii*. Zeszyt I. PWM. Wrocław, Poland.
21. Murayama, J., T. Kashiwagi, A. Kashiwagi, *et al*. 2004. Impaired pitch production and preserved rhythm production in a right brain-damaged patient with amusia. *Brain Cognit.* **56:** 36–42.
22. Sundberg, J. & J. Bauer-Huppmann. 2007. When does a sung tone start? *J. Voice* **21:** 285–293.