Factors Influencing the Pitch-Matching of Junior High Boys

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The skill of pitch-matching is a prerequisite for even the most casual musical participation. While singing accuracy has been carefully researched at the elementary level, there has been comparatively less research done with adolescents. The purpose of the study described here was to examine the influence of perceptual ability, task demands, and singing range on the pitch-matching performance of adolescent boys in various stages of the voice change. We found significant differences between certain, inconsistent, and uncertain singers in their perceptual skills and found that a contextual pitch-matching condition was significantly easier than a single-pitch condition. There was no difference by singing range. Future research should explore the progression of these skills longitudinally and continue to examine performance related to different task demands.

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The skill of vocal pitch-matching is often a prerequisite for participating in even the most casual singing activities. The absence of singing ability can lead to self-perceptions of nonmusicality or tone "deafness" (Sloboda, Wise, & Peretz, 2005) that can inhibit participation in any form of music-making (Clements, 2002). While the development of vocal pitch-matching skills has been studied with a number of different age-groups and under different conditions, a clear picture of the nature of the skills of perception and pitch production has yet to emerge. The lack of clarity may be due to the complex and internal nature of the process, to differences in research approaches, or to the fact that pitch-matching skills seem to emerge

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quite naturally in a majority of people without formal training (Bentley, 1969).

Pitch-matching problems persisting past the elementary years can have a negative effect on an individual's perception of his or her musicality. In a recent interview study, Sloboda, Wise, and Peretz (2005) found that many adults who labeled themselves as unmusical or tone-deaf were really referring to an inability to sing well. Clements (2002) found that musical self-image, not musical ability, was the single biggest predictor of male elementary students' music participation decisions when moving to middle school. For adolescent boys, the development of pitch-matching skills can be further complicated by the voice-change process. If boys have not mastered pitch-matching by the time they reach adolescence, their efforts to match pitch might become complicated by the register shift they experience while going through the voice change (Yarbrough et al., 1995a). These difficulties can interfere with boys' enjoyment of singing activities or, worse, lead boys to assume that they are not musical. Secondary music educators need more information on the factors that can influence pitch-matching performance, particularly in adolescent boys, so that they can begin to identify the skills and experiences that lead to improvements in singing accuracy. In the present study, we explored the pitch-matching skills of adolescent boys as they relate to perceptual skills, type of task, and vocal range.

The bulk of research on singing accuracy has been done with elementary students, perhaps because accurate singing is a primary goal of elementary music instruction. Researchers have explored a number of variables that affect singing accuracy, including the characteristics of the model pitch (Green, 1990; Hermanson, 1972; Petzold, 1966; Sims, Moore, & Kuhn, 1982; Small & McCachern, 1983; Yarbrough, Bowers, & Benson, 1992; Yarbrough et al., 1995a), age (Bentley, 1968; Green, 1990; Klemish, 1974; Petzold, 1966; Yarbrough et al., 1991), gender (Phillips & Aitchison, 1997; 1999), and perceptual skills (Apfelstadt, 1984; Boardman, 1964; Feierabend, 1984; Geringer, 1983; Jones, 1993; Phillips & Aitchison, 1997, 1999; Zwissler, 1971). More recently, researchers have begun to address the impact of these variables on adolescent singing accuracy as well.

In a 1991 study, Yarbrough and colleagues explored the variables that influenced the pitch-matching of inaccurate singers in grades K–3 and 7–8. They found that children in all grades responded best to the female vocal model, that there were no differences based on using hand signs or syllables to respond, and that there were significant differences in accuracy only between kindergartners and eighth graders. Bowers (1993) examined the influence of male and female models in different ranges for adolescent male singers. She found that boys responded best matching pitches located around middle C and that uncertain male singers were least accurate in response to a female high and most accurate with a baritone model. Yarbrough et al. (1995a) explored the effect of a male falsetto timbre on the accuracy of uncertain boy singers in grades K–8. They found that uncer-

tain boy singers in Grades 6 and 7 were most accurate in response to high-voice and falsetto models, while the Grade 8 subjects were most accurate in response to a low baritone model. All subjects matched the same interval G–E in the appropriate octave. Additionally they found improvement in students' pitch-matching accuracy between grade levels at the younger ages, but noted pitch-matching ability losses between fifth and sixth and seventh and eighth grades. They believed these losses may be due in part to male voice change, but could not accurately judge this from their data.

While the effects of model characteristics have been carefully examined, the role of the matching task itself has not been explored. The numerous studies on singing accuracy have used a variety of tasks to measure students' ability including matching to a single pitch (Demorest, 2001; Porter, 1977; Roberts & Davies, 1975), an interval (Green 1990; Klemish, 1974; Price et al., 1994; Roberts & Davies, 1975; Yarbrough et al., 1991; Yarbrough, Bowers, & Benson, 1992), a single pitch within a melodic context (Geringer, 1983), and accuracy of patterns and whole phrases (Apfelstadt, 1984; Joyner, 1969; Petzold, 1966; Roberts & Davies, 1975; Zwissler, 1971). Some of the variability in the findings of singing accuracy research might be explained by the differences in task difficulty, yet most studies to date have not directly compared students' performance on more than one kind of vocal matching task.[1]

Perception and Production

Researchers have also explored the possible relationship between singing accuracy and other musical skills, most notably perception. It is logical to assume that if students are having difficulty with accuracy, it may not be due to a vocal deficit but rather to an inability to hear pitch differences. Early researchers in singing accuracy consistently hypothesized a relationship between singing accuracy and melodic perception (see, for example, Boardman, 1964; Zwissler, 1971), and more recent findings (Feierabend, 1984; Jones, 1993; Phillips & Aitchison, 1997; Watts, Moore, & McCaghren, 2005) seemed to support that belief. Other research has gotten mixed results when relationships between perception and singing accuracy were examined.

A frequently cited study by Geringer (1983) examined the relationship of discrimination and pitch-matching abilities of preschool ($n = 72$) and fourth-grade students ($n = 72$). Subjects were given both a pitch-discrimination test and a vocal pitch-matching test. The discrimination test consisted of 12 trials of tonal pairs; subjects were asked to tell the researcher whether the tones in the pairs were the same or different, or whether they were uncertain. The vocal pitch-matching test asked subjects to sing back the final pitch of a short do-re-mi-re-do sequence. Subjects were then assigned to ability-level groups (high, middle, and low) for each of the age-groups based on their performance on the discrimination test. Geringer found that

vocal pitch-matching ability differed by age-group, but that there was no difference between discrimination-ability groups on pitch-matching scores. There was a moderate correlation between the two factors for the high-ability fourth graders, although overall there seemed to be a lack of correlation between pitch discrimination and vocal pitch-matching. The findings of studies by Apfelstadt (1984) with kindergarten students, Roberts and Davies (1975) with 6–8-year-olds, and Bradshaw and McHenry (2005) with adults seem to support the lack of relationship between perception and production.

Some of the differences in these findings might be due to differences in the pitch-matching task or the perceptual task used. Studies have frequently used either same/different discrimination tasks or the Gordon tonal Primary Measures of Music Audiation (PMMA) (Apfelstadt, 1984; Bradshaw & McHenry, 2005; Jones, 1993; Phillips & Aitchison, 1997, 1999; Watts, Moore, & McCaghren, 2005) to measure perceptual skill. A number of researchers have questioned the efficacy of high/low or same/different judgments for young children (Abril, 2001; Costa-Giomi & Descombes, 1996; Flowers & Costa-Giomi, 1991; Hair, 1981) and Apfelstadt (1984) questioned whether the PMMA was the best measure of melodic discrimination, as it did not require directional judgments. In the first year of a longitudinal study, Phillips and Aitchison (1997) found a relationship between singing accuracy and the PMMA for third graders, but no relationship between accuracy and discrimination as measured by the MAT. Since the discrimination task of the Music Achievement Tests (MAT) would be closer to Geringer's measure, it would seem that the nature of the perceptual task is significant. However, in reporting on those same students a year later (Phillips & Aitchison, 1999), they found no relationship between singing accuracy and scores on the Intermediate Measures of Music Audiation (IMMA). While the dependent measure did technically change between the 2 years (PMMA to IMMA), these tests are thought to measure the same skill. Two studies with adults used same/different discrimination paired with single-pitch matching with conflicting results (Bradshaw & McHenry, 2005; Watts, Moore, & McCaghren, 2005). The study in which a significant relationship was found between production and discrimination (Watts et al., 2005) used a more complex discrimination task and a sample that included both accurate and inaccurate singers.

A similar lack of relationship has been reported in studies examining instrumentalists' tuning ability and their pitch perception (Geringer & Witt, 1985; Yarbrough et al., 1995b; Yarbrough et al., 1997). Geringer and Witt (1985) compared the tuning performance and perception of high school, collegiate, and professional strings players and found no significant relationships. In a series of studies, Yarbrough and colleagues (Yarbrough et al., 1995b; Yarbrough et al., 1997) compared wind players' ability to tune their instruments to their ability to tune a dial controlling a pitch generator and found no relationship between these skills. The lack of relationship was partic-

ularly salient given that the dial-tuning task was an active rather than passive perceptual task, making it very different from previous vocal studies.

Demorest (2001) examined the pitch-perception and pitch-matching abilities of junior high boys. Subjects ($N = 34$) were male general music or choir students in Grades 7 through 9 whose voices had begun to change. Subjects were given both a perception task and a vocal pitch-matching task. The perception task was a dial-tuning task similar to Yarbrough et al. (1995b) that required subjects to move a tuning dial on a synthesizer until the synthesizer pitch-matched a prerecorded reference pitch. All reference pitches were between C at 130.81Hz and A at 220Hz. The vocal production task required subjects to match a series of single pitches from a prerecorded male vocal model singing with as little vibrato as possible within two range classifications: high A at 220Hz to E at 329.63Hz, and low C at 130.81Hz to A at 220Hz. Each subject's comfortable singing range was taken into consideration when determining which range classification he was asked to respond to. Subjects were divided initially into two categories, certain, those who matched all five given pitches, and uncertain, those who missed two or more pitches. At this point, an interesting category emerged. Six boys matched four out of five pitches, but missed the fifth pitch by quite a large distance. These six were dubbed inconsistent singers. In the first analysis, the inconsistent singers were grouped with the uncertain singers to examine relationships to perception scores and vocal range. There was a significant difference in the perception performance for the two groups, with certain singers doing significantly better at tuning the dial. There were no differences by vocal range. Because the inconsistent group did not fit neatly into either category, a second analysis was done without those six singers. Results of both analyses indicated that there was a significant difference in the perception task performance between certain and uncertain singers, with the differences increasing when the inconsistent group was removed from the analysis. Analysis of the perceptual means indicated that the inconsistent group was most similar to the certain group in their perceptual performance.

The purpose of this study was to explore the influence of perceptual skills, type of pitch-matching task, and vocal range on the pitch-matching ability of adolescent boys. We tested two hypotheses based on the results of Demorest (2001).

1. There would be a significant difference in perceptual performance based on vocal matching skill.

2. There would be no difference in pitch-matching skill by vocal range.

An additional purpose was to compare two types of matching tasks, single-pitch and context-pitch, to determine if less-accomplished singers would match pitch better under different task conditions.

METHOD

Subjects were adolescent boys in Grades 6–9 ($N = 60$) from three middle schools whose administrations agreed that the students could participate in the study. The majority of participants were volunteers from the choir programs, but participants from one school included boys enrolled in an "exploratory" general music class. Each boy's comfortable singing range was determined prior to testing through teacher recommendations and by having them sing for the researchers a familiar song and a few additional isolated pitches in a comfortable range. Based on the singing assessment, students were assigned to matching tasks with a range-appropriate pitch set. While the boys' ranges varied in specific classification from unchanged to new baritone (Cooksey, 1992), they were assigned to either the high-voice condition (A_3–E_4 [where middle C is C_4]; $n = 29$) or the low-voice condition (E_3–A_3; $n = 31$) for testing. These range categories, while less specific than the stages of change, represented comfortable tessituras for middle school choir-part assignments of "bass" and "tenor or cambiata." Each boy was tested using an author-designed perceptual pitch-matching task and vocal pitch-matching task, which were presented in a counterbalanced order.

Subjects' perceptual matching was measured on a computer using the Pitch Matching Perception Test (PMPT). As mentioned, previous measures of students' pitch perception have used some kind of same/different discrimination tasks or a tuning task involving fine gradations of pitch. For this investigation we sought to replicate as closely as possible the act of "matching" a pitch perceptually rather than discriminating between pitches or fine-tuning to a pitch. The PMPT, a researcher-designed computer program, played a reference pitch that sounded continuously, followed one second later by a comparison pitch that was set a tritone above or below the referent in a random order. Both tones used a sampled nonvibrato clarinet timbre. Students were asked to tune the comparison pitch to the referent by moving an onscreen slider that started in one of three randomly generated positions independent of pitch direction. To simulate matching versus tuning, the comparison tone moved only by semitones, so there was no need to fine-tune the pitches, simply to match them to each other. The PMPT provided an "active" measure of perception that was more analogous in precision to the vocal matching task. When subjects were satisfied that the pitches were matched, they clicked a separate "done" button. Like the vocal measure, the perceptual measure was assigned by range (low: C_3–A_3; high: A_3–E_4), and there were six pitches total to be matched. Reliability for the perceptual measure was $\alpha = .76$, which remained consistent (.76–.77) between the high and low versions of the test and was considered adequate for a test with only six items.

Subjects' vocal pitch-matching was measured with an eight-item task that featured four pitches in one of two matching conditions: single-pitch or context-pitch. Previous studies have used a variety of

stimuli ranging from single pitches to entire songs to test singing accuracy. This study used two matching conditions to determine if there was a performance difference. The single-pitch condition represented the most common approach to pitch-matching, in which a teacher sings or plays a pitch and the student is asked to match it. The single-pitch condition is also most representative of the act of pitch-giving in a group singing or choral rehearsal context. Subjects were asked to match a pitch sung by a male vocal model with minimal vibrato because some pitch-modeling studies have suggested that older boys actually find that model easiest to match (Bowers, 1993; Price et al., 1994; Yarbrough et al., 1995a). Students' efforts were recording digitally on a Tascam DA-P1 Digital Audio Tape recorder with a sampling rate of 44.1KHz using an Audio-Technica AT825 stereo microphone. All subjects were placed approximately 1 foot from the microphone and the height was adjusted to match their height. The stimuli were presented on a Panasonic portable CD player placed behind the microphone facing the participants. All stimuli were presented at approximately the same volume.

The context-pitch condition used a matching task similar to the one developed by Geringer (1983). Students heard the same male vocal model sing a series of pitches (such as *do–mi–sol–mi–do,* or *do–re–mi–re–do*) to set a tonal context. All the stimuli were sung on the syllable "doo." Students were asked to match only the final pitch of the sequence. In the trial period for each condition, subjects were instructed to match pitch using the same syllable as the model and practiced sustaining their tone for at least 2 seconds. Both tasks included a training period to familiarize students with each task. All subjects performed the tasks in the same sequence, with the single-pitch condition first, then the context-pitch condition. The combined 8-item test had a total reliability of $\alpha = .93$, which remained relatively constant (.91–.94) between the high and low versions of the measure. Each 4-item test condition separately had a reliability of $\alpha = .91$ for the single-pitch condition and $\alpha = .88$ for the context-pitch condition.

Pitch Analysis

Subjects' vocal responses were analyzed using a procedure similar to that of Demorest (2001). The digital recording was downloaded to a Macintosh G4 computer. Each pitch-matching attempt was extracted as a separate Audio Interchange File Format (AIFF) sound file (from 1–2 seconds long), deleting the attack and release and sampling based on the most consistently sung pitch of each attempt. While all subjects were instructed to sustain for at least 2 seconds, not all of them complied in the task, which produced slightly different lengths in the resulting sound files. Estimation of fundamental frequency (designated F_0 for the rest of this article) was provided by the spectral analyses component of the AudioSculpt 1.7.3 PPT software program. The resulting fundamental frequencies for each sound

Table 1
Scores by Matching Ability

Pitch-Matching Ability	Total Perception Score	Single Pitch Correct	Context Pitch Correct
Certain (n = 36)	3.89 (1.92)	3.94 (0.23)	3.97 (0.17)
Inconsistent (n =12)	3.83 (1.85)	1.67 (1.16)	2.75 (1.29)
Uncertain (n =12)	1.75 (1.55)	0.25 (0.62)	0.42 (0.52)
Total (n = 60)	3.45 (2.00)	2.75 (1.65)	3.02 (1.52)

Note. Standard deviations in parentheses.

sample were averaged to produce a mean F_0 for each sung pitch. The pitch distance between the reference pitch and the matching pitch was calculated using a hertz-to-cents (deviation) conversion macro in Excel. Because of the normal fluctuation of pitch associated with vocal timbre, a "match" was defined as any F_0 that fell within a quarter-tone (50 cents) on either side of the stimulus pitch F_0. The 50-cent deviation level corresponds to the judgment that a human listener might make in deeming a pitch a little sharp or flat, but essentially a match. While cent deviation was recorded for missed pitches, the statistic used in the analysis was the number of pitches matched in each condition. Based on their performance on the vocal matching task, subjects were classified as either certain (7–8 pitches correct, mean = 7.91, n = 36), uncertain (0–1 pitches correct, mean = 0.67, n = 12), or inconsistent (2–6 pitches correct, mean = 4.42, n = 12). As in Demorest (2001), there was a group of singers who demonstrated some matching skills but could not use them reliably. The perceptual measure yielded a total accuracy score (0–6) and a deviation score by semitone for each pitch. Table 1 gives the means and standard deviations for the perceptual task and the single-pitch and context-pitch vocal matching condition by group.

RESULTS

To test Hypothesis 1, we compared the performance of the three subject groups on the perceptual task to see if there were differences in perception based on vocal matching ability. An additional between-subject variable of vocal range was included in the analysis to address the second hypothesis of no difference based on range. An analysis of variance (ANOVA) revealed a significant difference in perceptual scores based on vocal matching ability [F (2, 54) = 6.06, $p < .01$] with no main effect for range and no significant interactions. A Scheffé post-hoc analysis determined that significant differences in perceptual performance existed between the uncertain singers and the other two groups, but not between the certain and inconsistent groups (see Table 1).

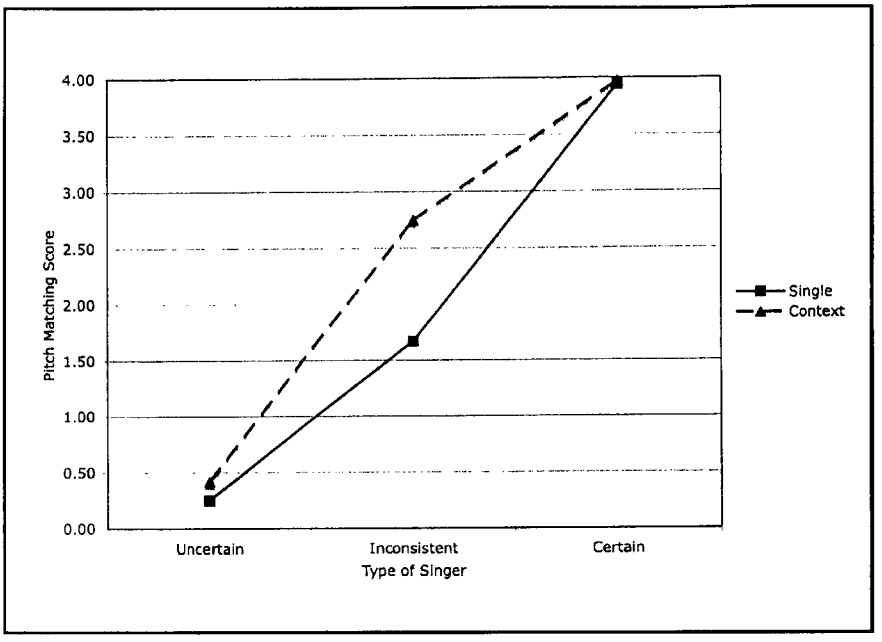

Figure 1. Pitch-Matching Scores by Condition.

To test for potential differences by task condition, a repeated measures analysis of variance was used with the test type (single or context) as the within-subject factor and matching ability and vocal range as the between-subjects factors. Subjects scored significantly higher in the context-pitch condition as revealed by a within-subjects main effect for test condition [$F(1, 54) = 7.22$, $p < .05$]. The graph in Figure 1 reveals that the difference in accuracy is largely the result of one group, the inconsistent singers, which also resulted in a significant test by group interaction [$F(2, 54) = 4.26$, $p < .05$]. There was no significant between-subjects main effect for vocal range or any range interactions.

DISCUSSION

The results of this study replicate the findings of Demorest (2001) and extend them to a larger sample and different array of tasks, demonstrating clear differences in perceptual ability among adolescent boys based on vocal pitch-matching skill. While both studies were done with convenience samples, the replication of earlier findings with a different sample of boys provides a measure of external validity that suggests the findings may be generalizable to this population. An earlier study by Geringer (1983) found no relationship

between the skills of perception and production as he measured them but suggested that such a relationship might develop with maturation. These results support the speculation that perception and production may be more related for older singers, at least for adolescent boys going through the voice change.

The differences in the perception scores by matching ability found in this study also indicate the possibility that perception and production skills, at least for single-pitch matching, may not progress in parallel. The inconsistent singers performed most like the certain singers on the perceptual task, a finding that replicated some earlier studies (Demorest, 2001; Joyner, 1969). The disconnect between singing and perception for the inconsistent singers in this study suggests the possibility that perceptual ability precedes vocal matching ability. Sims (1995) found a similar discrepancy in younger children's ability to respond to differences in articulation with receptive discrimination (labeling) being significantly better than productive discrimination (singing). The performance of the inconsistent singers in this study might explain some discrepancies in earlier studies of untrained adult singers (Bradshaw & McHenry, 2005; Watts, Moore, & McCaghren, 2005) that only considered two classifications, accurate and inaccurate. In these studies some singers labeled inaccurate had perceptual scores that were most similar to accurate singers. Future research should consider defining accuracy as a continuous rather than discrete variable to more accurately explore the relationship of pitch-matching to other skills.

The results also highlight the potential influence of the choice of perceptual task. The active task requires subjects to use their perceptual skills under conditions that give them control over the final outcome. It would be interesting to see if using a similar active perceptual task that does not rely on labeling or tonal memory might reveal relationships between perception and singing accuracy for younger children.

The findings also suggest that it may be important for teachers and researchers to look carefully at the conditions under which pitch-matching is assessed. While the two extreme groups (certain and uncertain) showed almost no difference in scores by matching condition, the inconsistent group, those developing the skill, performed better when a tonal context for matching was provided. The performance difference in this condition may be because the tonal context for the matching allowed them to use their perceptual skills more easily to guide their voices. In looking at the inconsistent singer group alone, it was found that 4 of the 12 subjects in this group would have been labeled certain singers if only the context matching condition were used. Their scores were a perfect 4 for 4. Only one subject from the inconsistent group had a perfect score in the single pitch condition. If only a single-pitch task had been used, 5 inconsistent subjects would have been labeled uncertain (0–1 correct), while only 2 inconsistent subjects would have been labeled uncertain in the context-pitch condition. For teachers, the choice of matching task

could result in mislabeling students as uncertain who are capable of matching, or assuming that matching in one context automatically transfers to matching in all contexts. Future research should compare a variety of the most popular and relevant matching tasks directly across a number of different age-groups to determine which tasks are most reliable indicators, much in the way model characteristics have been so carefully assessed.

The lack of a difference in perception and production scores between boys in different stages of the change suggests that the register shift brought on by vocal maturation does not significantly influence pitch-matching or perception skills. Singing register does not seem to have an impact as long as the tasks employed are range appropriate. One of the best ways to sort out the complex relationships between the component skills of perception and production, task demands, and maturation would be to follow a group of older uncertain male (and female) singers longitudinally as they mature and develop their skills, as researchers have done with younger children (Rutkowski & Miller, 2003; Petzold, 1966; Phillips & Aitchison, 1999).

One other consideration in comparing these results to previous research is that in this study vocal pitch-matching was operationally defined as an all or nothing enterprise with a quarter-tone (50 cent) margin of error. This definition is quite different from studies exploring vocal "intonation." We would argue in favor of this definition, however, when assessing pitch-matching as opposed to singing accuracy because experience suggests that when singers are developing the skill of matching they tend to be somewhat hit or miss. That is, they either hit the pitch fairly accurately or they miss by a semitone or more, rendering cent deviation a somewhat extreme statistic. This anecdotal assumption is supported by the data from the boys in this study. In the inconsistent group (n = 12), the mean matching score was 4.42 out of 8 pitches but the mean cent deviation for the 36 missed pitches was 151.46 cents, or 1.5 semitones with a range from 51 to 530 cents. The 12 inaccurate singers had a mean pitch deviation of 324.09 cents, or more than three semitones from the target pitch with a range of 53 to 987 cents. From a practical standpoint, elementary teachers and choral directors often seek to develop students' matching skills first, then worry about vocal intonation. As the contents of many methods books reveal, choir teachers often receive more training on how to deal with issues of intonation in a rehearsal setting, but are less well equipped to deal with the more basic issue of matching pitch. We recommend that researchers studying singing accuracy carefully differentiate between studies of vocal intonation and those exploring pitch-matching when determining the dependent measures used.

Vocal pitch-matching would seem to be made up of component skills that may progress sequentially to a certain degree from perception to production across skills and from contextual to isolated pitches within vocal matching. Teachers should be encouraged to exam-

ine older students' perceptual skills as a component of their vocal training, and to use a variety of tasks in developing vocal pitch-matching skills. It should be noted, however, that this study did not examine any of these skills as teaching strategies, only as factors in matching. Previous research in the use of perceptual training (Apfelstadt, 1984; Porter, 1977) has had limited success, suggesting that the interconnection of these two skills is more complex. Researchers need to continue to explore pitch-matching systematically, incorporate a greater variety of ages and tasks within a single study, and begin to explore longitudinal designs to illuminate the progression of these skills within the individual. The better we understand this fundamental musical skill, the more able we will be to teach it and remove a significant barrier to our students' future musical involvement.

NOTE

1. A notable exception is a 1975 study by Roberts and Davies in which 6–8-year-olds identified as "monotones" or "normal" were tested using single-pitch, interval (2–4 notes), melody, and free-song tasks. The authors do not directly discuss or analyze differences in performance between the tests, but remedial training improved performance on single-pitch and interval tasks and did not improve melody or free song. It should be noted that none of the tests used a vocal model and that the "normal" sample averaged between 50 and 87% correct on these same measures.

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