Discrimination between Tone Quality and Intonation in Unaccompanied Flute/Oboe Duets
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The purpose of the study was to investigate discrimination in tone quality and intonation. Four-hundred-eighty (480) music and nonmusic graduate and undergraduate subjects checked good and bad quality/intonation classifications by listening to each of twenty-four oboe and flute duet performances. The duets were unaccompanied and performed either with good or bad quality and close to equal temperament or were adjusted 50 cents sharp between one instrument and the other. Results of the study indicated that there was a significant difference between the music and nonmusic majors across categories, with the music majors making more correct discriminations than nonmusic students. A significant difference in subjects' indications of total intonation performance errors showed 38% "sharp" responses and 62% "flat" responses. This finding, while somewhat surprising, is consistent with prior research. Subjects perceived more intonation errors (although incorrectly) than tone quality errors. When indicating a preference for tone quality subjects were actually responding to intonation variables as opposed to quality variables throughout almost all of the comparisons.

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One of the most important aspects of performance for any musician is playing or singing with satisfactory intonation. A problem arises, however, in the relationship between tone quality and intonation. These aspects have stimulated a growing interest in the study of intonational and quality judgments in relationship to each other. The relationship between perceptual discrimination and performance is largely inferential, although aural discrimination ability appears to be a major prerequisite to intonational proficiency. This study was undertaken to investigate patterns of judgmental discriminations and preferences with regard to tone quality versus intonation of flute and oboe duet performances of simple melodies.

The experimental study of auditory phenomena constitutes a major portion

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of the scientific investigation of relevant variables in musical performance. Subtle discriminations of the ear to frequency change, intensity, and duration have long been investigated. Previous studies have focused upon the relation of pitch to intensity (Morgan, Garner, and Galambos, 1951; Stevens, 1935), the differential sensitivity of the ear to pitch changes with successive tones (second tone higher or lower than the first), and frequency modulations of single tones in various experimental situations (Harris, 1952; Knudson, 1923; Kranz, 1923; Madsen, Edmonson, & Madsen, 1969; Sergeant & Harris, 1962; Shower & Biddulph, 1931; Vance, 1914).

Considerable research exists measuring perceived proclivities of pitch and tempo in relationship to both perception and performance. It appears that there is greater acuity in detecting pitch "flatness" combined with a tendency to perform toward greater "sharpness" (Cameron, 1907; Madsen, 1962, 1966, 1974; Madsen, Edmonson, & Madsen, 1969; Madsen & Geringer, 1976; Madsen, Wolfe, & Madsen, 1969; Madsen, 1960; Papich & Rainbow, 1974; Salzberg, 1980; Shoen, 1922; Siegel & Siegel, 1977; Small, 1937). Similarly, it

Figure 1—Form that subjects were to complete

Check what is wrong with the following. You may check as many aspects as you choose.

Oboe

_____ Nothing

_____ Bad quality
_____ Bad intonation (sharp)
_____ Bad intonation (flat)

Flute

_____ Nothing

_____ Bad quality
_____ Bad intonation (sharp)
_____ Bad intonation (flat)

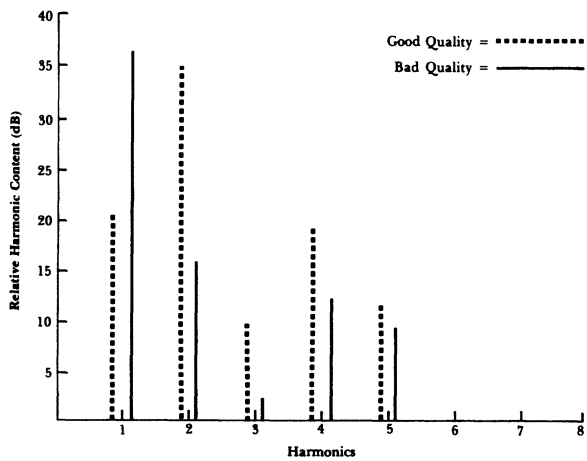

Figure 2—Harmonic Content of Judged Good versus Bad Flute Tone Quality

seems that the direction of tempo discrimination is toward greater acuity to detect "slowness" combined with a tendency for performed "fastness" (Drake, 1968; Kuhn, 1974, 1977; Kuhn & Gates, 1975; Madsen, 1979).

Studies that compare both perception and performance within the same experiment for each subject are able to test this propensity more directly (Geringer, 1978; Greer, 1970). However, investigations that compare various age groups, years of music experience, or even subsequent trials also confirm tendencies for older and more musically-experienced subjects to better discriminate slowness and flatness and to perform both faster and sharper (Kuhn, 1974, 1977; Kuhn & Gates, 1975; Madsen, 1962, 1966, 1979; Madsen, Edmonson, & Madsen, 1969; Madsen & Madsen, 1972; Madsen, Wolfe, & Madsen, 1969).

Investigation concerning the discrimination and performance of tone quality has not been extensive. One study demonstrated that timbre, not intonation, significantly influenced localization in the median sagittal plane (Butler, 1973). Principal instrument of a subject as well as instrumental preference has also been found to influence discrimination of timbre (Bernier & Stafford, 1972). While the interrelationship of timbre and pitch has been investigated, these studies have made use of stimuli not usually present in music (Fletcher, 1934; Jenkins, 1961; Lichte, 1941; Lichte & Gray, 1955; Plomp, 1967). However, Swaffield (1974) found that contextual factors including timbre had significant effects on tuning. Tunks (1978) found that there was an overall difference between subjects' ability to tune pairs of instruments: oboe, flute, clarinet, trumpet, horn, trombone, and tuba. The flute/oboe combination seemed to be one of the easier tasks and subjects were better able to tune the flute to the oboe than vice versa. Tunks' study provided the basis for the selection of instruments in the present investigation.

In a study directly related to this investigation it was found that while every subject was initially able to discriminate extreme examples of good versus bad tone quality without accompaniment, preference for the same tones when accompanied became confused with intonation variables (Madsen & Geringer, 1976).

METHOD

Subjects in this study were randomly selected musicians (n = 240) and nonmusicians (n = 240). Musicians were defined as students enrolled within a music program at the Florida State University or the University of Texas, Austin. Nonmusicians were defined as students not enrolled in a music degree program or participating in a musical organization who had less than three years of private or group music study during their public school experience. Subjects listened to 24 duet performances (two randomized sets containing the 12 experimental conditions) and were asked to respond to each duet according to the intonation and tone quality of the soloists. In order to determine any noticeable differences in perception, subjects were asked to complete the form in Figure 1.

The simple musical phrases containing quality differences and intonation adjustings finally selected for experimental presentation included such songs as "Erie Canal," "Laredo," and "Jingle Bells." Recordings were made using pro-

fessional performers who attempted to play as "musically" as possible except in regard to the parameters being investigated. Recordings were made while each performer viewed a chromatic stroboscope so that the versions selected for the taped presentation could be such that all pitches were either close to equal temperament or purposefully sharpened 50 cents. Based on past research, flatted examples were intentionally omitted. Also, the study was designed with an unequal number of good/bad and sharp/in-tune trials. Bad quality performances were included in 66% of the trials, while only 33% contained sharpened performances. Final selections were within ± three cents. The final performances contained the 12 experimental conditions twice, each using 24 different melodies. A panel of four music-faculty members confirmed the quality and intonation errors of the final trials selected for testing (r = .98 agreements/agreements plus disagreements).

Further, a series of harmonic analyses were made to ascertain the differential spectral characteristics of the good/bad tone qualities. Performers produced what they considered their best and worst tone qualities. Analyses sampled four pitches from each musical excerpt and were made on a sound spectrograph. The chief distinguishing feature between the two qualities and intonation changes are shown in Figure 2.

The relative harmonic content (dB) for good and bad tone qualities was, indeed, different. As can be seen from Figure 2, the good flute quality has more energy for harmonics two to five, relative to the poor quality, which has greater energy on harmonics one, six, and seven. Note the shaded areas for the poor quality on harmonics four to seven, indicating the presence of inharmonic energy ("noise"). Figure 3 indicates differences between oboe good and bad tone quality. The good oboe tone has much more energy at harmonic three (a characteristic of oboe tones), and more acoustical strength for harmonics five and six. The poor quality has a stronger second harmonic, as well as substantial energy at harmonic eight.

Subjects listened to all recorded materials in small groups of 15-21 at both institutions. Pilot investigations involving individual testing with individual earphones to control for recording imperfections and external noise distractons did not indicate significant differences from group presentations.

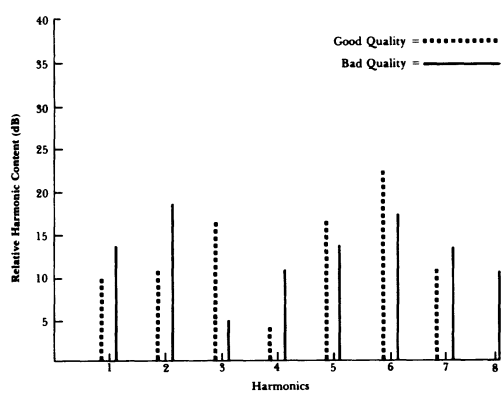

Figure 3—Harmonic Content of Judged Good versus Bad Oboe Tone Quality

RESULTS

Raw data consisted of the frequency of subjects' indications for performance-error categories. Seven performance categories were available for each of the 24 melodies: sharp, flat, bad tone quality (oboe); sharp, flat, bad tone quality (flute); or nothing. Subjects were free to indicate as many categories of error as were deemed appropriate. The study was designed to have 66% quality errors and only 33% intonation errors.

Table 1—Frequency Data for Musicians and Nonmusicians in Attributing What Was Wrong With Oboe/Flute Duets

	Musicians	
	Oboe	*Flute*
1,014 Nothing	1,812 Bad Quality	2,386 Bad Quality
	951 Bad Intonation (Sharp)	793 Bad Intonation (Sharp)
	1,493 Bad Intonation (Flat)	1,401 Bad Intonation (Flat)
	Nonmusicians	
	Oboe	*Flute*
1,168 Nothing	1,198 Bad Quality	1,925 Bad Quality
	764 Bad Intonation (Sharp)	860 Bad Intonation (Sharp)
	1,518 Bad Intonation (Flat)	1,048 Bad Intonation (Flat)

Data were analyzed using the chi-square statistic with rejection of the null hypothesis set at a significance level of .001. Where contingency tables were partitioned into component parts, the conservative methods outlined in Everitt (1977, p. 44) were followed.

Analysis of the overall totals for the 12 experimental conditions (24 melodies) indicates that subjects discriminated across the seven categories (χ^2 = 1962.66). As can be seen in Table 1, subjects responded differentially. There was a significant difference between the music and nonmusic majors across categories (χ^2 = 158.24). As would be expected, the music majors made more correct discriminations than the nonmusic students (χ^2 = 136.15). Subjects at the University of Texas did not differ from Florida State University students across categories (χ^2 = 7.12, $p < .3$), in the number of correct/incorrect responses (χ^2 = .012, $p < .99$), or in any of the individual trials.

There was a significant difference in subjects' indications of total intonation performance errors. There were 3,368 "sharp" responses (38%) and 5,460 "flat" responses (62%) (χ^2 = 495.75). This finding is consistent with prior research. Music majors did not differ from nonmusic subjects in total indications of sharp versus flat (χ^2 = 1.26). Music students, however, differed from nonmusic students by indicating that the oboe was sharp more frequently than the flute (χ^2 = 18.98), while the nonmusic students' responses indicated the oboe to be flat more frequently than the flute (χ^2 = 31.5). Both music and nonmusic subjects indicated the flute to have poor tone quality more often than

the oboe (χ^2 = 157.85), although the music majors were less incorrect (χ^2 = 17.01) in quality discriminations.

Data for the performance condition in which both instruments were in tune and playing with good quality indicated that sujects discriminated between correct and incorrect performances (χ^2 = 478.38). There were no differences between institutions or between music majors and nonmusic majors.

Intonation Trials

When the flute was sharp, subjects did respond differentially (χ^2 = 23.61), but there was no difference between correct and incorrect judgments (χ^2 = .202). Similarly, when the oboe was sharp, subjects responded differently across categories (χ^2 = 39.72), but there was again no difference between correct and incorrect intonation categories. Music majors tended to be more accurate than nonmusic students (χ^2 = 11.78). When both instruments were performing with good quality and the oboe was sharp, responses were not statistically different across the response categories for oboe sharp (correct) versus flute sharp (incorrect) versus responses incorrectly attributing intonation errors to tone quality errors (χ^2 = 2.35). In other words, on the intonation-error trials, subjects responded differentially but not correctly.

Quality Trials

When the flute was played with poor tone quality, all subjects discriminated across categories (χ^2 = 506.10). Music majors discriminated correctly while nonmusic students did not (χ^2 = 18.37). The poor tone quality oboe performance was judged differently across categories (χ^2 = 268.76) but judged incorrectly as having more errors of intonation by both music and nonmusic students (χ^2 = 19.79). Again, for quality-error only trials, subjects responded differentially across categories, but identified quality errors as being intonation errors (with the one exception of music majors correctly discriminating the trial containing the flute bad quality). When both flute and oboe were played with poor quality, subjects discriminated across categories (χ^2 = 341.68), were correct more often than incorrect (χ^2 = 70.69), and identified more quality than intonation errors (χ^2 = 113.99). Again music majors were more accurate than nonmusicians (χ^2 = 12.86). Subjects correctly identified the flute poor quality ten times more frequently than the oboe bad quality. Flute bad quality was apparently more easily discriminated than oboe poor quality, particularly for nonmusic majors.

Quality versus Intonation

When either the oboe or flute were performed with both sharp intonation and poor quality, subjects were correct more often than incorrect (χ^2 = 108.17 and 35.88 respectively). While there were no significant differences between the total frequency of checked responses for both groups, music students checked more correct responses for both the bad quality and bad intonation categories. Nonmusic majors, however, gave more responses to incorrect categories (χ^2 = 16.39, oboe; χ^2 = 18.63, flute).

When one instrument was performed with poor quality and the other instrument with sharp intonation, results were again consistent. Subjects were correct more often than not (χ^2 = 147.67 and 211.03), and discriminated across categories (χ^2 = 179.43 and 223.92). Although sujects were as correct for the quality trials as for the intonation trials, analysis of incorrect responses revealed that it was the intonation response categories that contained a significantly greater proportion of errors (χ^2 = 42.78 and 17.24). Music majors tended to have a higher proportion of correct responses, although not significantly (χ^2 = 2.43 and 4.39).

When both instruments performed with poor quality and one or the other was sharp, subjects were correct more often than incorrect (χ^2 = 223.82 and 313.65). In both cases, subjects identified the flute poor quality more frequently than the oboe poor quality (χ^2 = 31.0 and 15.5). Nonmusic majors had a higher proportion of incorrect responses (χ^2 = 17.12 and 47.43).

DISCUSSION

This study represents an attempt to combine intonation and tone quality in order to investigate their interrelationship. Researchers who are concerned with adequately controlling stimulus presentations will immediately realize the difficulties in attempting to investigate more than one variable simultaneously. Even though the present investigation is substantiated by past research (Madsen & Geringer, 1976), care should be taken in interpreting current findings, mainly because of limitations concerning the music examples used in the study. Findings from this study are derived from only two performers (emphasizing good versus bad quality/intonation) playing simple short duets. The size of the sample seems adequate (n = 480), yet the validity regarding musical performance is based on limited musical selections. The study contained various melodies, familiar and unfamiliar, performed with various tempi, phrasing, and dynamics. While this would add some credence to the study, it raises other problems. Specifically, there is the possibility that subjects discriminate quality and intonation differently in familiar melodies. This is one of the many aspects that needs additional research. Thus, to consider the present study as anything more than exploratory would not be warranted.

Regardless, several apsects of the study seem interesting and warrant both replication and additional investigation. Nearly all subjects evidenced the ability to correctly judge the performances that were both in tune and played with good quality. Furthermore, spectrographic analysis, stroboscopic analysis, and a panel of experts corroborated the extreme differences between tone qualities and intonation adjustments. Therefore, the magnitude of subjects' responses in not being able to discriminate within context is surprising. The most important finding regarding the present study concerns subjects' ability to detect that something was wrong within a musical example without being able to identify specific factors.

As has been stated in previous research (Madsen & Geringer, 1976), two areas of particular interest seem relevant to applied music instruction. Musically trained persons listening to music apparently exercise a minimum degree of tone quality discrimination within a musical context. Music instructors may be overemphasizing the importance of certain aspects concerning tone quality

in a performance setting by spending a good deal of time attempting to attain a "musical" or expressive tone quality. If listeners cannot discriminate differences between a performer's best and worst tone qualities in context, as this and other studies would tend to suggest, time would seem to be more profitably used in the attainment of good intonation within and between soloist and accompanist/ensemble.

The second important finding concerns the determination of satisfactory intonation in musical performance. Many past research studies have dealt with small differences in variable pitch. The present study suggests that deviations in intonation can be as large as 50 cents (.25 tone) between soloists and yet in musical context be confused with other considerations. Specifically, on the basis of past research, the present experiment was structured to exaggerate this sharp/flat difference by making the sharp accompaniment 50 cents out of tune with no flat discrepancies except, of course, by comparison. Even with this wide difference, it should be emphasized that subjects checked flat much more than sharp. This tendency appears only to operate for deviations on the sharp side. It would appear that even when subjects indicate a preference for tone quality they are actually responding to intonation variables. This preference was indicated throughout most comparisons and warrants further investigation.

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