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Linguistic Prosody and Musical Meter in Song

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Four studies addressed the relation between linguistic prosody and musical meter in song. Analyses of song compositions indicated that the Compound Word and Nuclear Stress rules of English coincided with musical rules of metrical accent. Vocalists were asked to perform songs in which compound words and nuclear stress phrases were aligned or misaligned with the musical meter. Syllables aligned with either linguistic or musical accent were sung with greater duration than unaccented syllables. Additional analyses of adjective–noun phrases in song compositions showed musical accent aligned more often with nouns in clause-initial phrases and with adjectives in determiner-initial phrases, consistent with phonological principles of cliticization. Singers' performances showed larger durations for nouns than adjectives in clause-initial than in determiner-initial phrases. Prosodic structure and musical meter had independent effects on sung durations, suggesting that they contribute separately to song performance but with similar organizational principles.

The rhythmic organization of song reflects the integration of prosodic structure in language with principles of musical rhythm. Of the many analogies drawn between music and language, the most salient link may be the influence of rhythmic structure on the meanings of individual elements. Prosody, one dimension of linguistic rhythm, refers to the sound patterns of language above the level of individual phonemes, and is examined through acoustic variables such as frequency changes across an utterance (Ladd & Cutler, 1983). We focus on one aspect of prosody, stress, which carries information about syntactic structure and semantic content. For example, the meanings of the phrases "the blackbird" and "the black bird" depend on the relative stress patterns with which they are pronounced. Primary stress on "black" in "the blackbird" refers to a particular species of bird, whereas stress on "bird" in "the black bird" refers to a bird of a particular color. The acoustic variables affecting the production and perception of prosodic stress include duration, intensity, and frequency (Lehiste, 1972).

Similarly in music, rhythmic structure or patterns of accent strength affect the relative importance with which musical events are interpreted. Meter is one dimension of musical rhythm that carries information about the relative importance of events. Metrical structure is the periodic alternation of strong and weak beats, usually forming a nested hierarchy of accent levels. Musical events aligned with higher metrical levels usually receive strong accent, are

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emphasized by performers (Drake & Palmer, 1990; Sloboda, 1983) and are better remembered by listeners (Palmer & Krumhansl, 1990). Metrical grid notations embodying these periodic hierarchical properties have been proposed for music (Lerdahl & Jackendoff, 1983), similar to those used in phonology (Liberman & Prince, 1977; Selkirk, 1984). (It is interesting to note that some phonological theories, such as Liberman and Prince's and Selkirk's, draw on metrical constructs from music theories.) As in speech, accentuation of musical meter involves changes in the acoustic variables of duration and intensity (frequency is less free to vary in music performance) (Drake & Palmer, 1990; Sloboda, 1983).

The interrelationship of linguistic and musical rhythm is most evident in song, in which lyrics are coordinated with musical accompaniment. Evidence from memory tasks suggests that recall of song lyrics is facilitated by the song's rhythmic structure (Hyman & Rubin, 1990; Wallace & Rubin, 1988), and melody recognition is aided by the presence of the song lyrics with which it was first learned (Serafine, Crowder, & Repp, 1984; Serafine, Davidson, Crowder, & Repp, 1986). These facilitative memory effects of lyrics and musical accompaniment point to the importance of their interrelationship.

Song composition and performance provide a rich domain for study of the relationship between linguistic and musical rhythms. Study of song composition may be fruitful because it reflects composers' sensitivity to rules of prosodic structure. Performance of Western tonal song compositions is a good domain in which to study rhythmic emphasis because it allows considerable leeway in rhythmic interpretation and production. Thus, a vocalist may form an interpretation of a song, emphasizing linguistic or musical rhythmic structures through changes in duration, intensity, etc. Several studies indicate that the emphasis given to events in music performance can influence the subsequent perception of musical meter and rhythm (Clarke & Baker-Short, 1987; Gerard & Drake, 1991; Sloboda, 1983) suggesting that, as in speech (e.g., Fowler & Housum, 1987), musical emphasis serves a communicative purpose.

What rules of linguistic prosody might coordinate with musical meter in song? Two common prosodic rules in English are the Compound Word and Nuclear Stress rules. The spoken prosody in "the blackbird" reflects the Compound Word rule of English, which assigns primary stress to the leftmost (or first) word in a compound word (Chomsky & Halle, 1968). The spoken prosody in "the black bird" reflects the Nuclear Stress rule of English, which assigns primary stress to the final word of a phrase. The Compound Word and Nuclear Stress rules are claimed to account for distributions of word class stresses (Selkirk, 1984), syllable lengthening (Fowler, 1977), and the rhythmic structure of poetry (Kiparsky, 1977) in English and in other languages. For example, phrases and compound words differ in their relative stress assignments in traditional English poetry by Shakespeare, Milton, and Pope. In particular, compound words such as "blackbird" tend to appear in strong–weak positions relative to the underlying metrical pattern of poetry, whereas phrases such as "black bird" tend to appear in weak–strong positions (Kiparsky, 1977). Compound words and phrases may also differ in how they are aligned with metrical structures in music. In the example in Fig. 1, these rules are reinforced by the musical meter with stressed syllables aligned with metrical accents (the vertical line denotes the beginning of a measure or metrical unit, and the first event in the measure is usually considered most important, as reflected in the metrical grid). The potential alignment of prosodic stress and musical accents in song may serve to reinforce each rhythmic component.

We investigate in this paper the general hypothesis that prosodic stress tends to align with musical meter in Western art

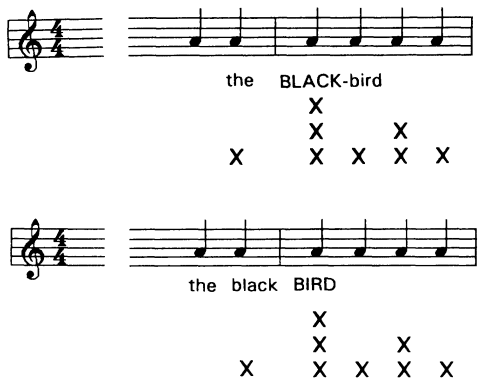

FIG. 1. Example of prosodic structure of compound noun and two-word phrase aligned with musical meter.

song. We first test the alignment of Compound Word and Nuclear Stress rules with metrical accent in song. Each syllable of compound nouns and adjective–noun phrases was analyzed for its metrical accent strength in a corpus of English song compositions. We then report an experiment in which vocalists perform compound noun and adjective–noun phrases aligned or misaligned with the musical meter. The sung syllabic durations are examined for emphasis of musical and linguistic accents; vocalists may emphasize events during performance by manipulating their relative timing.

We then test conditions under which the Nuclear Stress rule can be violated in song, with the result that the adjective receives more stress than the noun. We describe principles responsible for some of these violations of the general prosodic rule and examine the alignment of adjective–noun phrase stress with musical meter in a corpus of English song compositions. We then report an experiment in which vocalists perform the adjective–noun phrases under different phonological conditions. Stress patterns under these conditions are less well documented than the Compound Word and Nuclear Stress rules, and so the final studies not only explore relations between linguistic prosody and musical meter, but also provide further documentation for the linguistic concepts that motivate the studies.

COMPOUND WORD AND NUCLEAR STRESS RULES IN SONG COMPOSITION

We first examine how composers treat the Compound Word and Nuclear Stress rules in aligning lyrics with music. In an unrestrictive case, the composer is free to vary both the music and the words. The collaborative work of Gilbert and Sullivan offers an example; they jointly composed music and lyrics for operettas, allowing some flexibility in the alignment of musical and linguistic accent. If the musical compositions respect the linguistic prosody, then the musical metrical accent should be stronger for the first syllable in compound nouns and for the second syllable in adjective–noun phrases.

To test this prediction, we analyzed the metrical accent strength of each syllable in all two-syllable compound nouns and adjective–noun phrases in the vocal line of the themes from Gilbert and Sullivan's 14 operettas (Binney & Lavender, 1977). Only the first instances of verse repetitions were included in the analyses. Each syllable's metrical accent strength was determined by a hierarchical analysis of the subdivisions of beats in each musical measure according to the composer's notated time signature (as shown in Fig. 1). Typically, binary meters (such as 2/4 and 4/4) exhibit binary alternation (strong/weak) and ternary meters (such as 3/4 and 6/8) exhibit ternary alternation (strong/weak/weak). Thus, each syllable in compound nouns and adjective–noun phrases was coded for its relative metrical accent strength (strong/weak) and prosodic accent strength (strong/weak).

The number and percentage of compound nouns and adjective–noun phrases that received stronger musical accent on each syllable are shown in Table 1. The interaction of musical and linguistic accents was significant ($\chi^2(1) = 66.6$, $p < .01$); compound nouns were more likely to receive stronger metrical accent on the first syllable, and adjective–noun phrases were more likely to receive stronger metrical ac-

TABLE 1
LINGUISTIC AND MUSICAL ACCENT ALIGNMENT

Prosodic accent	Metrical accent: 1st syllable	Metrical accent: 2nd syllable
in Gilbert & Sullivan operettas (words and music set together)		
1st syllable (compound words)	43	5
2nd syllable (2-word phrases)	16	79
in English poetry set to music (words previously written)		
1st syllable (compound words)	96	9
2nd syllable (2-word phrases)	91	67

cent on the second syllable. Musical duration (as indicated in the musical score) and melodic contour (changes in pitch direction or interval), two other potential compositional variables for indicating musical accent, were evaluated as well; neither distinguished between the syllables of compound nouns and adjective–noun phrases. Thus, the Compound Word and Nuclear Stress rules tended to align with the musical meter in the musical genre of jointly composed lyrics and musical accompaniment.

We next examined poetry set to music, a different musical genre that imposes greater restrictions on the composer. One reason is that poetry contains another rhythmic component: poetic meter, a global periodic rhythm that arises as a function of the prosodic structure of individual words and an underlying metrical template selected by the poet, such as iambic pentameter. A second constraint is that the words (and their rhythmic structure) in poetry are already fixed (only the musical rhythm may be altered by the composer). Therefore, in the case of poetry set to music, correspondence between musical and linguistic accent presumably results from the linguistic prosody affecting the musical composition (rather than the reverse). To examine this case, we analyzed all two-syllable compound nouns and adjective–noun phrases in a collection of English poems set to music by 18th, 19th, and 20th-century English-speaking composers (Arne, Castelnuovo–Tedesco, Chambers, Ireland, Luff, Morley, Owen, Stevens, and Purcell).

Table 1 shows the number and percentage of compound nouns and adjective–noun phrases that received musical metrical accent on each syllable. Again, there was a significant interaction between linguistic and metrical accent placement ($\chi^2(1) = 33.5, p < .01$); compound nouns were more likely to receive stronger metrical accent on the first syllable than on the second syllable. Thus, linguistic and metrical rhythm tended to align in the genre of poetry set to music. However, the adjective–noun phrases did not tend to receive stronger metrical accent on the second syllable. The tendency for compound nouns to show fewer violations of their typical linguistic stress patterns than adjective–noun phrases is also found in analyses of English poetry, where the words of a line are often mapped onto a highly constraining poetic meter (Kelly & Rubin, 1988; Kiparsky, 1977). For instance, the most popular poetic meter in English verse is iambic pentameter, in which each line contains ten syllables with the odd syllables receiving weak stress and the even syllables strong stress. If poets generally align syllables with strong and weak positions in accord with their stress patterns in normal speech, then compound words such as "blackbird" should tend to align with strong-weak positions and adjective–noun phrases such as "black bird" with weak-strong positions. These patterns do in fact emerge in the works of Shakespeare, Milton, and other English poets, with stronger effects for compound nouns than phrases (Kiparsky, 1977).

Compositional alignment of linguistic and musical rhythm in song may aid comprehension by allowing the listener to predict the relative stress or accent of one dimension from another. Gleason and Bharucha

(1990) demonstrated a comprehension advantage for words in sentences whose prosodic structure was paired with a coinciding beat pattern over those paired with a conflicting beat. Substantial evidence suggests that coinciding accent structures in musical contexts also aid perception, expectation, and memory for events (Deutsch, 1980; Drake, Dowling, & Palmer, 1991; Jones, Boltz, & Kidd, 1982). The interrelationships among musical rhythmic structures are also emphasized in performance; performers typically modify information in the musical composition to convey interpretations of musical structure, such as choices of phrasing, melody, and dynamics (Nakamura, 1987; Palmer, 1989). The next study addresses the question of what organizational principles operate in performance of song, where linguistic and musical rhythm usually coincide but sometimes conflict.

Compound Word and Nuclear Stress Rules in Song Performance

Performance of Western tonal music allows considerable expressive variation for the purpose of emphasizing or clarifying musical structure. Typically, multiple rhythmic structures are emphasized through a complex combination of expressive changes in intensity, frequency, duration, or timbre. In vocal performance, the lyrics are usually of primary importance but their method of production may be influenced by their musical context. Thus, musical meter as well as Compound Word and Nuclear Stress rules may be emphasized in song performance. One possibility is that vocal performers accentuate the alignment of linguistic and musical rhythm in order to maximize their predictability and reduce attentional demands on the listener. Another possibility is that the alignment of linguistic and musical rhythm is already fixed by the composer, and no additional accentuation by the performer may be necessary (or accentuation may be necessary only when the structures are misaligned).

To address these alternatives, we examined vocalists' performances of poetry set to music (art song). We compared performances in which the stress patterns of compound nouns and adjective–noun phrases were either aligned or misaligned with the musical meter. Syllable interonset duration measures were examined for effects of both rhythmic structures; interonset duration was chosen because it often influences perceived stress in speech (Lehiste, 1972) and perceived accent in music (Drake et al., 1991; Jones & Ralston, 1991). Because most Western art songs are written for voice with instrumental accompaniment, vocalists who accompanied themselves on piano were chosen as subjects and the duration measures were examined in both the vocal part and piano accompaniment. The notated durations of all test syllables were identical in the song composition; therefore, any duration differences could be attributed to the performer's interpretation of structural importance.

Method

Subjects. Ten skilled vocalists from the Columbus, Ohio area participated in the study. Each vocalist was proficient in piano (mean of 10.8 years of training) as well as voice (mean of 11.3 years of training) and regularly accompanied themselves on piano during practice. Vocalists who accompanied themselves were chosen so that interpretive effects in the vocal and piano parts of the song could be attributed to a single performer.

Materials and apparatus. The song "To Jane," based on a poem by Percy Bysshe Shelley set to music for soprano voice and piano by Ned Rorem, was chosen from the previous song collection for study. The song was adjusted to contain the compound noun "moonlight" and the adjective–noun phrase "soft notes" in the same linguistic context (each was preceded by the word "the"). (The original phrases: "But the notes," "As the moon's soft splendor,"

"with your dear voice revealing a tone," and "Where music and moonlight" were adjusted respectively to: "*The soft notes,*" "*The moonlight* with soft splendor," "with *the soft notes* revealing a tone," and "Where song and *the moonlight.*") The resulting test phrases and their musical settings are shown in Fig. 2. Each test phrase appeared twice in the song, once with musical and linguistic accents coinciding, and once with the accents conflicting. The notated durations of syllables and musical events were identical for all test phrases. Thus, any changes in syllable durations that singers produced could not be attributed to biases in the test materials.

Both the voice and the piano parts were recorded for analysis. A cardioid (directional) microphone was placed approximately 6 in. from the vocalist's mouth over the piano keyboard, to isolate the voice part. The voice was recorded on cassette tape and digitized at 10 kHz sampling rate and 16-bit resolution for computer analysis of each syllable duration and relative amplitude. The resolution of the timing measurements was 1 ms, and voltages were normalized to arbitrary amplitude values ranging from 0.1 (minimum) to 10.0 (maximum). The piano part was recorded independently of the voice part on a computer-monitored acoustic upright piano (Yamaha Disklavier), whose optical sensors and solenoids allowed precise measurement without affecting the sound or touch of the instrument. Frequency, timing, and hammer velocity (correlated with loudness) of piano events were recorded on an AT/PC computer. Hammer velocity values ranged from 0 to 127 (in arbitrary units) and the resolution of the timing was 2 ms for keypress events.

Procedure. Each vocalist was sent a copy of the song several weeks beforehand for practice. When ready, they came in to perform the song (usually 1 to 3 weeks after

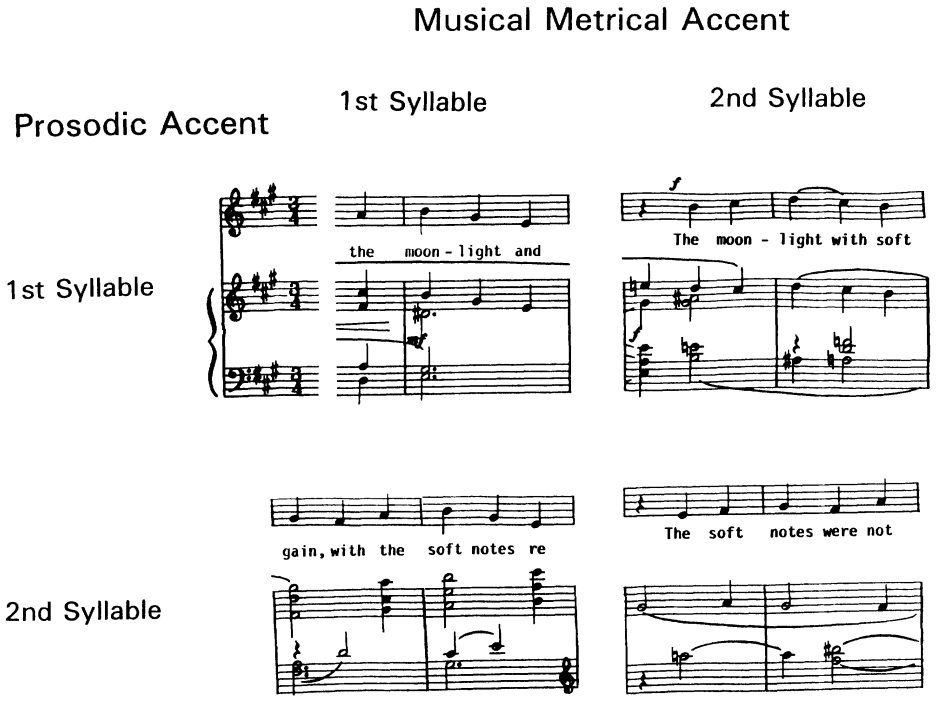

FIG. 2. Compound noun and two-word test phrases aligned or misaligned with musical meter in modified song "To Jane."

receiving it). None of the vocalists had previously seen the song. During the recording session, the vocalists first performed the piece while accompanying themselves on piano (the voice-and-piano condition). In a second condition, they sang the piece without piano accompaniment (voice-alone condition), and in a third condition they played the piano part without singing (piano-alone condition). The latter two conditions were included to ensure that attentional demands of the voice-and-piano condition did not create qualitative changes in performances of either the voice or piano parts. The vocalists performed the piece in each condition until they heard a performance with which they were satisfied, and only those performances were included in the analyses. Afterwards, they were asked to read aloud each test phrase, presented on a separate line of a sheet of paper. The presentation order of test phrases was counterbalanced in a Latin square design. The entire procedure lasted one hour and singers were paid a total of $20 for their practice time and recording sessions.

Results

Interonset duration and amplitude measures were examined for effects of linguistic and musical accents in sung phrases, piano accompaniment, and spoken phrases.

Interonset durations. Each syllable duration in the test phrases was measured from the onset of the target syllable to the onset of the next syllable. The durations of piano events aligned with each syllable were measured similarly from the onset of one event keypress to the next. Because the notated durations of syllables and musical events were identical for all test words, any duration differences can be attributed to the performer's interpretation of accent.

Duration differences for each test phrase (first syllable minus second) were taken as a measure of relative stress adjusted for overall tempo changes. The mean duration differences for the sung test phrases from the voice-and-piano condition are shown in the top of Fig. 3. An analysis of variance (ANOVA) on the duration differences by musical accent (on first or second syllable), linguistic accent (on first or second syllable), and condition (voice-and-piano or voice-alone) yielded a significant effect of both musical ($F(1,9) = 23.5$, $p < .01$) and linguistic accents ($F(1,9) = 18.0$, $p < .01$). As seen in Fig. 3, duration differences were larger (longer first syllable) when the first syllable in a test phrase aligned with an accent. Test phrases aligned with both musical and linguistic accents showed largest duration differences, and phrases aligned with neither accent showed smallest differences. There was no interaction between

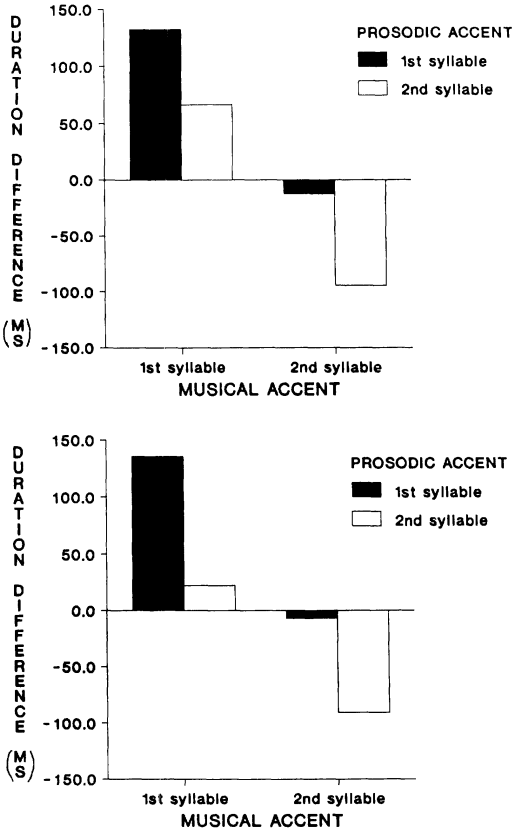

FIG. 3. Mean syllable duration differences (first syllable minus second) of test phrases in vocal line of "To Jane" performances: (a) voice-and-piano condition; (b) voice-alone condition.

the two accent structures. Syllable durations in the voice-alone condition, shown in the bottom of Fig. 3, revealed the same results. There was no effect of condition on duration differences or interaction with musical or linguistic accents. Thus, playing the piano accompaniment did not alter the relative durations of the vocal part.

The mean duration differences for piano events aligned with the test phrases were analyzed for each condition. An ANOVA on the piano events indicated no significant effects of musical or linguistic accents or of condition, or interactions between variables.

The spoken test phrases were measured by onset-to-offset duration (because the last word of each phrase had no subsequent onset for comparison), and the duration differences (first syllable minus the second) were used as a measure of prosodic stress. Because the phrases were spoken in isolation, phrase-final lengthening may contribute to lengthening of the last syllable in all phrases. However, an ANOVA on the spoken duration differences yielded a significant effect of linguistic accent ($F(1,9) = 8.2$, $p < .02$), with larger duration differences (longer first syllable) for compound nouns ($= 29$ ms) than for two-word phrases ($= -46$ ms). Thus, the spoken test phrases also reflected the predicted patterns of prosodic stress.

Amplitudes. Maximum amplitude values for each syllable were examined for effects of linguistic or musical accent in the voice-alone condition (it was not possible to examine syllable amplitude in the voice-and-piano condition due to the presence of the piano part). An ANOVA conducted on the amplitude differences (first syllable minus the second) for each test phrase indicated no significant effects of musical or linguistic accents. An ANOVA on the raw amplitude values for each syllable did indicate a significant effect of phrase, $F(1,9) = 7.7$, $p < .05$, with the syllables in "soft notes" sung quieter than those in "moonlight." This literal interpretation is typical of the artistic form of mood-painting, in which semantic content is accentuated through musical expressiveness. Analyses of the spoken test phrases also indicated no significant effects of linguistic accent on amplitude differences. Thus, amplitude did not differentiate the prosodic accents during speech or singing.

Discussion

Vocal performances of poetry set to music revealed several influences of musical meter and linguistic prosody. First, both accent structures were emphasized in performance by singers' lengthening of syllable durations. The Compound Word rule was evidenced by relative lengthening of the first syllable in compound nouns and the Nuclear Stress rule by relative lengthening of the second syllable in adjective–noun pairs. Musical meter affected durations as well, with lengthening of accented events. Second, the musical and linguistic accents contributed independently to syllable durations. Finally, these effects were consistent in the vocal part both in the presence and absence of the piano accompaniment.

An alternative explanation for the influence of musical meter in these song performances is melodic contour, or changes in direction of successive pitches. Melodic contour can aid melody recall and reproduction by creating salient accents (Boltz & Jones, 1986; Drake et al., 1991), which may have contributed to the syllable duration lengthening in this study. As seen in Fig. 2, the melodic contour of the vocal line changes direction on the syllables aligned with metrical accent in the top line of the test phrases. The finding of no alignment of melodic contour with musical meter in the song compositions makes this interpretation unlikely. However, the next performance study attempts to control for melodic contour in further investigation of the role of metrical accent in song.

Although the vocal part reflected both linguistic and musical accents, the accom-

panying piano part did not. One possible explanation is that the subjects were primarily vocalists (rather than pianists) and may attend more to the interpretive aspects of the vocal part than the piano part. Another explanation is that the song represents a composer's interpretation of the words set to music and the vocal part plays the primary role in conveying this interpretation with the piano part playing a secondary role. This second explanation is consistent with the text analyses indicating composers' reference to the linguistic accent in setting poetry to music.

There were also differences in the relative emphasis given to syllables of compound nouns and adjective–noun phrases; in the compositional analyses and vocal performances, the difference between syllables of compound nouns tended to be greater. As noted earlier, similar differences are found in poetry, in which compound words are almost invariably aligned with strong–weak positions, whereas phrases are more likely to violate their general tendency to appear in weak–strong positions (Kiparsky, 1977; Kelly & Rubin, 1988; Tarlinskaya, 1989). This difference may partly reflect the possibility that prosodic stress plays a larger role in the specification of lexical items than of phrasal items. If word-level stress is crucial in speech perception, then lexical stress may be more resistant to contextual modification than phrasal stress (although it can be modified by context, cf. Kelly, 1989). In addition, phrasal stress must be flexible enough to permit contrastive stress on different words, whereas syllabic stress patterns within words (as in compound words) tend not to be greatly modified by contrastive stress. The next two studies address additional factors that may modify phrasal stress patterns.

Clitic Phrase Differences in Song Composition

Although the stress assignments for adjective–noun phrases generally follow a weak–strong pattern in English according to the Nuclear Stress rule, there are some interesting modifications of this pattern. For instance, the adjective tends to group phonologically with a preceding word under certain syntactic conditions. In "the soft notes" the determiner and adjective can form a phonological group apart from the noun. Such phonological units are called clitic groups because each group consists of a single stressed item to which one or more unstressed items are attached or cliticized (Hayes, 1989). When clitic groups like "the soft" are formed, the stress on the adjective can increase relative to the preceding unstressed item, and hence can weaken or modify the usual stress contrast in adjective–noun pairs created by the Nuclear Stress rule.

Clitic group formation seems to be at least partly dependent on syntactic structure. In general, syntactic proximity, as measured by the number of syntactic boundaries separating unstressed words from a stressed word, influences eventual clitic group formation. For example, in "the $[_{N'}$ cold lakes," the determiner and adjective are separated by one syntactic boundary, whereas in "in $[_{N''}$ $[_{N'}$ cold lakes," the preposition and adjective are separated by two boundaries and in "that $[_{S}$ $[_{N''}$ $[_{N'}$ cold lakes," the complementizer and adjective are separated by three boundaries. Finally, when the adjective itself begins a clause with no preceding item, as in "Cold lakes are dangerous," the adjective cannot separate from the noun to form its own clitic group and the Nuclear Stress rule should prevail (aside from certain pragmatic factors that might cause "cold" to be relatively stressed, cf. Ladd, 1984). Thus, the likelihood that the noun is stressed relative to the adjective increases as the number of boundaries before the adjective decreases in proceeding from the determiner-initial to the clause-initial phrases.

The symbols in these examples, drawn from X-bar syntax, denote sentence constituents or sequences of words that act as

units according to certain criteria (Jackendoff, 1977; Radford, 1988). We use one criterion here—pronominal substitution—to support the existence of these constituents. According to pronominal substitution, one justification for identifying a series of words as a constituent is that they can be replaced by a single pronoun such as "they," "it," or "one." (Pronouns are one case of pro-forms, or general-purpose linguistic variables constrained by the grammatical roles of the items they replace; the substitution criterion applies to other pro-forms as well.) For example, N″ stands for full noun phrases like "the cold lakes," all of which can be replaced by the pronoun "they." N′ denotes a constituent smaller than a full noun phrase, but larger than a noun. In particular, it denotes all of the noun phrase except the determiner. Support for this syntactic unit is provided by facts about pronominal substitutions because N′ can be replaced by some pronouns such as "one" (e.g., "I would like this French cheese and that one"). In the examples given above, one might still wonder why "that" and "cold" in "I know that cold lakes are dangerous" are separated by three boundaries—S, N″, and N′—when S and N′ seem sufficient. The S boundary is necessary because a new clause is being introduced. N″ does not appear to be required because no determiner is present. However, facts about pronominal substitutions indicate that N″ is represented in this example. In particular, the pronoun "they" can replace "cold lakes" in this sentence. This pronoun can only replace an N″ and not an N′, as shown by the ungrammaticality of "I know that the they are dangerous." Therefore, to account for the acceptability of "they" in "I know that they are dangerous," and N″ must be posited. For more detailed justifications of pronominal analyses, see Radford (1988).

One source of evidence in support of this syntactic account of clitic group formation is provided by poetic structure. As noted earlier, adjective–noun structures generally appear in weak–strong positions in traditional English poetry. However, this pattern is occasionally violated, and Hayes (1989) has shown that the violations are partly explicable by reference to clitic groups and the syntactic variables that affect their formation. In particular, Hayes shows in an analysis of Longfellow's poetry that the probability that adjective–noun pairs appear in weak–strong position is directly related to the number of syntactic boundaries separating the adjective from an immediately preceding unstressed word.

We examined the concept of cliticization in relation to musical meter in song composition. We focused on two classes of adjective–noun structures; the first class consists of determiner-initial adjective–noun structures, which are supposedly the most susceptible to clitic group formation between the adjective and preceding unstressed item, and hence the adjective should receive additional stress relative to the noun. The second class consists of clause-initial adjective–noun structures, which had no unstressed material preceding them, and hence the adjective should receive no additional stress and the noun should receive the most stress. These two classes represent the extreme cases of clitic stress predictions.

The analysis was based on a second collection of English poetry set to music by English-speaking composers (Barber, Bowles, Copland, Crist, Dello Joio, Diamond, Griffes, Ives, Josten, La Forge, Owen, Rorem) and from jointly composed lyrics and music (Rodgers & Hammerstein—"The Sound of Music," "Allegro," "Oklahoma," "Carousel," "The King and I;" "Gilbert and Sullivan—"The Gondoliers"). We attempted to choose a different set of songs from the same musical genres as those used in the previous text analyses. The two song genres were combined to maximize the sample size of each phrase type (the numbers of items did not allow analyses of song genre differences). All instances of two-syllable adjective–noun

pairs forming the following phrases were analyzed: determiner-initial adjective–noun pairs (such as "the sick sheep"), and clause-initial adjective–noun pairs (such as "sick sheep"). Each phrase was analyzed for its musical metrical assignment in the composition (strong/weak or weak/strong). The distribution of metrical assignments by phrase is shown in Table 2.

Adjectives of determiner-initial phrases were more likely to align with metrical accent, whereas nouns of clause-initial phrases tended to align with metrical accent, although evidence of the Nuclear Stress rule was weaker than in the previous text analysis. This interaction between clitic accent and musical meter was significant ($\chi^2(1) = 10.3$, $p < .01$). Thus, song settings of English lyrics tended to maintain the relative emphasis given to adjectives and nouns according to clitic rules of stress assignment. The next experiment examines whether knowledge of cliticization principles is evidenced in vocal performances of poetry set to music.

Clitic Phrase Differences in Song Performance

We assessed in this experiment the degree to which clitic phrase stress and musical meter are emphasized in song performance. Vocalists performed a modified song in which determiner-initial and clause-initial adjective–noun phrases were either aligned or misaligned with the musical meter. Again, interonset duration measures in both sung and spoken phrases were examined for effects of linguistic and musical accents. Because the notated durations of all syllables within the adjective–noun phrases were identical in the song composition, we can attribute any duration differences to the performer. In addition, melodic contour accents were not aligned with other accents in this song, allowing a better test of the role of musical meter than in the previous study.

TABLE 2
Linguistic and Musical Accent Alignment in Adjective–Noun Phrases

Prosodic accent	Metrical accent	
	Adjective	Noun
Adjective (determiner-initial phrases)	66	25
Noun (clause-initial phrases)	25	31

Method

Subjects. Twelve skilled vocalists from the Columbus, Ohio area participated in the study. Each vocalist was proficient in piano (mean of 11 years of training) as well as voice (mean of 12.8 years of training) and regularly accompanied themselves on piano during practice.

Materials and apparatus. The song "David," based on a poem by Frances Frost set to music for voice and piano by Paul Bowles, was chosen from the previous text analyses for study. The vocal part was adjusted to contain the determiner-initial phrases "the dark birds" and "the young lambs" (with greater stress on the adjective) and the clause-initial phrases "dark birds" and "young lambs" (with greater stress on the noun). (The original phrases: "Only the shepherd boy walks to stare," "while midnight swings through the starry air," "The young lambs stir," and "That the flock may slumber" were adjusted respectively to: "Now *the dark birds* fly around," "*Dark birds* fly swiftly through starry air," "*The young lambs* dream," and "*Young lambs dreaming.*") The "lambs" phrases were set so that the adjective aligned with the musical meter; the "birds" phrases were set with the noun aligned with the musical meter. The test phrases and their musical settings are shown in Fig. 4. Thus, each type of phrase appeared twice in the song, once with musical and linguistic accents coinciding, and once with the accents conflicting. The notated durations of syllables were identical

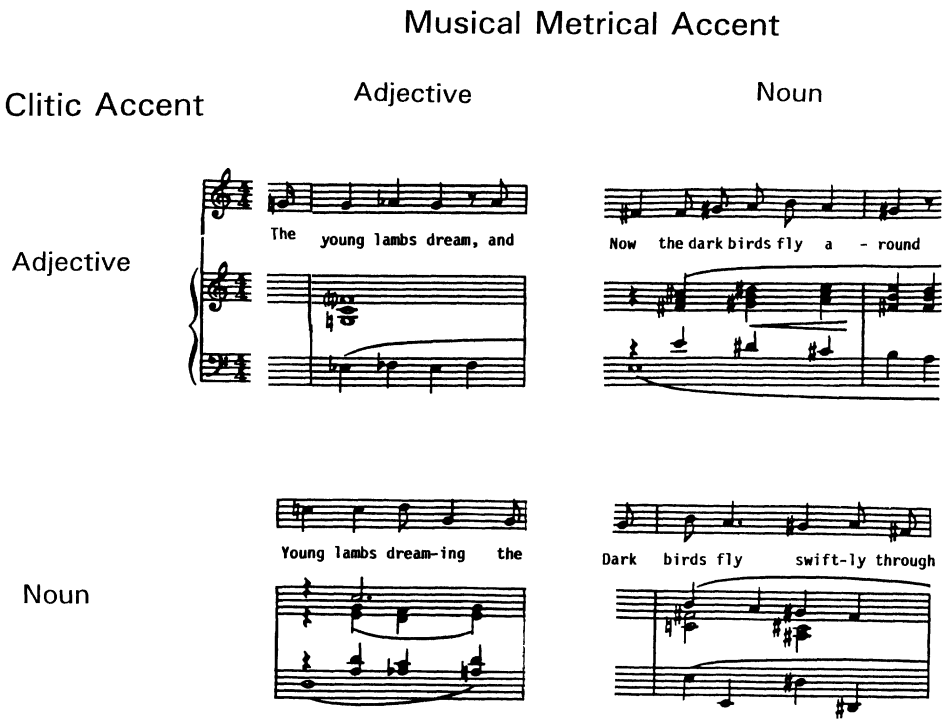

FIG. 4. Adjective–noun test phrases aligned or misaligned with musical meter in modified song "David."

for the phrases "the dark birds" and "dark birds" and identical for "the young lambs" and "young lambs." Duration and amplitude measurements were taken again for the voice part; the piano accompaniment did not have musical events coinciding with each test word and therefore was not analyzed. The same recording equipment was used as in the previous study.

Procedure. The procedure was the same as in the earlier experiment, with the exception that the piano-alone condition was excluded. Each vocalist was sent a copy of the song several weeks beforehand, in order to practice it. None of the vocalists had previously seen the song. When ready, each came in and performed the excerpt until they heard a performance they thought satisfactory. After the voice-and-piano performances were recorded, the procedure was repeated for the vocal part alone. Finally, the vocalists read aloud the test phrases, each presented on a separate line on a sheet of paper. The presentation order of spoken phrases was counterbalanced according to a Latin square design. The entire procedure lasted about one hour and vocalists were paid $20 for their practice time and recording session.

Results

Interonset durations. Because the notated durations differed for the two test phrases, the percentage difference in syllable duration ((noun minus adjective)/noun) was taken as a measure of relative stress adjusted for overall duration. Thus, a positive value indicates greater syllable lengthening of the noun and a negative value greater lengthening of the adjective. The sung syllable percentage differences in the voice-and-piano condition are shown in the top of Fig. 5. An ANOVA on the syllable differences by musical and linguistic accents and by condition (voice-and-piano or

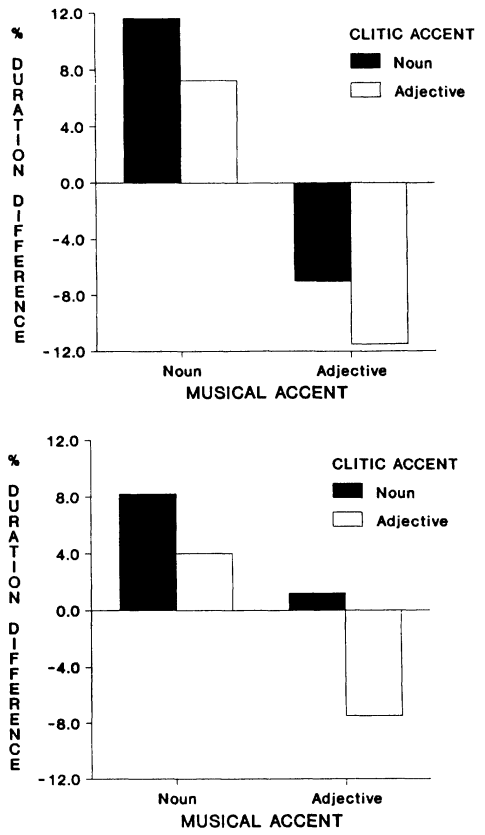

FIG. 5. Mean percentage duration differences ((noun minus adjective)/noun) of test phrases in vocal line of "David" performances: (a) voice-and-piano condition; (b) voice-alone condition.

voice-alone) indicated a significant effect of musical meter, $F(1,11) = 13.4$, $p < .01$, with larger syllable percentage differences (longer noun) when the metrical accent was aligned with the noun. There was also a significant effect of clitic accent, $F(1,11) = 86.7$, $p < .01$, with larger percentage differences in clause-initial phrases (which predicted more stress on nouns) than in determiner-initial phrases. There was no interaction between musical and clitic accents. The sung syllables in the voice-alone condition, shown in the bottom of Fig. 5, yielded the same pattern of syllable differences. There was no effect of condition and no interaction of condition with musical or clitic accents, indicating that playing the piano accompaniment did not alter the vocal part.

Each vocalist's syllable durations for the spoken phrases were again determined by onset-to-offset duration measures. Syllabic duration differences (noun minus adjective) were examined for clitic accent effects. An ANOVA on the duration differences indicated a significant effect of test phrase, $F(1,11) = 214.4$, $p < .01$, with larger duration differences in phrases containing "lambs" than "birds." There was a nonsignificant effect of clitic accent with larger duration differences (longer noun than adjective) in clause-initial than in determiner-initial phrases. Eleven of the 12 subjects showed the predicted pattern and the twelfth subject spoke in a singsong voice and showed a (nonsignificant) effect opposite that of the others. A Wilcoxon matched-pairs signed-ranks test indicated significantly larger duration differences (longer nouns) in clause-initial phrases than determiner-initial phrases ($p < .05$). Thus, the spoken test phrases tended to reflect the predicted stress patterns of cliticization.

Amplitudes. Difference scores (noun minus adjective) for maximum syllable amplitudes were examined for effects of clitic or musical accent. An ANOVA on the syllable amplitude differences in the voice-alone performances revealed a significant main effect of musical accent, $F(1,11) = 9.6$, $p < .01$, with greater amplitude differences (louder noun) for phrases with nouns in musically accented locations. There were no effects of clitic accent. An ANOVA on the amplitude differences in the spoken test phrases indicated no effect of clitic accent but a significant main effect of test phrase, $F(1,11) = 15.3$, $p < .01$, with greater amplitude differences for "birds" phrases than for "lambs" phrases. Again, amplitude measures did not differentiate linguistic accent in speech or during singing.

Discussion

Syllable durations were lengthened in

song performance in accordance with linguistic predictions of cliticization in adjective–noun phrases. Nouns were lengthened relative to adjectives more in clause-initial phrases than in determiner-initial phrases, in which the adjective could form a clitic group with the preceding article. This relative weighting was found in both spoken and sung phrases. These findings suggest that cliticization of adjective–noun phrases is sufficient cause for emphasis in vocal performance. Musical meter affected syllable durations as in the previous study, with syllables on metrically accented events lengthened. Musical meter was not aligned with melodic contour in this study, suggesting that meter (and not melodic contour) accounted for the similar findings in the previous study. Again, there was no interaction between linguistic and musical accents, suggesting that they contribute separately to the interpretation of relative importance of sung events.

Finally, these studies of clitic phrase differences in composition and performance provide evidence not only about the interrelationship of music and linguistic rhythm but also provide support for specific clitic group principles proposed in linguistics. Prior to this work, the evidence for such principles was drawn from a few areas, such as the rhythmic structure of verse and certain examples of phonetic modifications in spoken English. (For instance, "of" is pronounced as a schwa in "a bottle of beer," where it forms a clitic group with "beer," but with a final /v/ in "She was someone I was just thinking of," where it occurs clause finally and hence is not part of a clitic group.) The present research extends the clitic group principles to a novel domain.

An alternative explanation for these findings may be a preference for rhythmic alternation instead of cliticization principles. A variety of evidence suggests that speakers and/or listeners prefer alternations between strongly and weakly stressed syllables over other patterns. Stress patterns are adjusted in speech perception and production to create patterns of alternating stress (Martin, 1970; Kelly & Bock, 1988; Kelly, 1989). This rhythmic alternation preference may account for the distributions of stressed syllables in English and other languages (e.g., Selkirk, 1984) and historical changes in the English stress system (Kelly, 1989). The experimental materials used here may have produced the results due to rhythmic alternation preferences rather than cliticization principles. In "the dark birds fly," the determiner may be weakly stressed because of its status as a closed-class function word, which tends to be unstressed in most languages (Gleitman & Wanner, 1982). In order to establish rhythmic alternation after this opening weak stress, a strong–weak–strong pattern would be imposed on the next three words. In this explanation, "dark" would be stressed more than "birds," which would be realized through longer durations on the adjective than the noun. In "dark birds fly," on the other hand, rhythmic alternation would not initially predict a strong–weak–strong or a weak–strong–weak pattern. The Nuclear Stress rule could therefore operate normally and "birds" would be stressed more than "dark," and the noun would receive longer duration than the adjective. Thus, the results from both phrases are consistent with both explanations.

One remaining factor, however, raises some problems for the rhythmic alternation explanation. The notated duration of "fly" in "dark birds fly" is longer than the durations for the accompanying adjective and noun. This difference was not present in "the dark birds fly." Given greater duration on the verb in the former case, and hence more stress, the rhythmic alternation preference would presumably lead to a strong–weak pattern on the adjective–noun. The cliticization account would still predict greater stress on the noun, which was the result obtained in the experiment. The choice between the cliticization and

rhythmic alternation explanations is not yet resolved and requires further experimentation. We should emphasize, though, that even if the rhythmic alternation account turns out to dominate, our main point would remain intact: Prosodic preferences in speech are respected in the performance of song.

General Discussion

Both linguistic prosody and musical meter contribute to the relative weighting of events in song composition and performance. Thus, vocal events in song carry both musical and lexical weightings of relative importance, reflecting composers' and performers' knowledge of phrasal and lexical structure, as well as the hierarchical structure of musical meter. Perhaps more interesting is the lack of interaction between the two sources of rhythmic structure; to the extent that the structures exhibit similar effects with no interaction, the study of musical composition and performance may aid the understanding of linguistic prosody. Sung verse allows the amplification or exaggeration of prosodic patterns present in normal speech; in this sense, sung verse is similar to parental speech which also exaggerates prosodic structures relative to adult speech, such as syllable duration information in motherese that specifies syntactic relations (e.g., Lederer & Kelly, 1991).

Why are linguistic prosody and musical meter aligned so frequently in song composition? One explanation is that both rhythmic structures are built on a foundation of binary alternation (called the principle of rhythmic alternation in linguistics, cf. Selkirk, 1984). Although not all musical meters are binary, those that are ternary tend to exhibit binary alternation at lower hierarchical levels (corresponding to shorter event durations in the musical composition). If the stress patterns of lyrics are related to the rhythmic context in which they appear, then the extent to which the two underlying binary alternations of stress are aligned will influence how often the stress assignments of individual lexical items align with the musical meter in song composition. Note, however, that this explanation does not account for the performance data; the emphasis given to different lexical items in performance must be a function of stress assignments more specific than the principle of binary alternation. The performance studies only allowed testing of a limited number of lexical items whose song settings may have coincided with various other factors contributing to musical and linguistic rhythm. Nonetheless, the findings were in accord with the compositional analyses, which included comparisons across many items representing a wide range of musical and linguistic contexts.

The primary finding of agreement between musical and linguistic accent structures in song corresponds well with facilitative effects of coinciding accent structures on perception and comprehension, such as guiding a listener's attention, allowing anticipations, and aiding memory. These findings are also in accord with recall advantages noted for memory of linguistic material when aligned with another information structure that was present at encoding (Serafine, Crowder, & Repp, 1984; Speer & Crowder, 1989). Finally, these findings correspond with related work showing linguistic and musical accent alignment in German poetry set to music (Spencer, 1980), in which musical meter and linguistic stress (binary alternation) were compared. The present analyses, however, are more explicit in differentiating lexical and phrasal categories of linguistic stress.

The correspondence between linguistic and musical rhythm reported here reinforces the theoretical comparisons drawn between rhythmic structures underlying song verse and music in compositional practice (Jackendoff, 1989; Lerdahl & Halle, 1990). An extreme view is that the rhythms underlying music and language are identical morphologically, in that they have

the same roots but have evolved to serve different roles (referred to as *homologous* and not *analogous* structures in evolutionary biology). For instance, one structural similarity is the attempt to keep equal temporal distance between events of equivalent stress, which is a characteristic attributed to stress-timed languages such as English by some theorists (see Levelt, 1989, for a summary). A structural difference is that many items in language (such as words) tend to have fixed stress patterns across different contexts whereas musical items (such as chords) do not have fixed stress—the same musical item plays many roles depending on its context, each of which assumes different stress assignments. This discrepancy in the fixed meaning of lexical and musical elements is parallelled by discrepancies in theoretical approaches to prosodic structure and musical meter. Prosodic theory usually attempts to uncover categorical well-formedness rules that determine whether or not a given line of poetry is in a particular meter (Halle & Keyser, 1971). Theories of musical structure, however, tend to be more flexible in stress assignments (Lerdahl & Jackendoff, 1983); the rules are proposed to uncover a range of particular analyses of stress.

Although the evolutionary perspective is impossible to test adequately, it suggests an interesting historical corollary: that musical rhythm may be more flexible in adjustments over time than linguistic rhythm, due to greater flexibility in individual items' stress assignments. Therefore, historical changes in song compositions may reflect increased alignment of musical and linguistic accent structures through changes in the

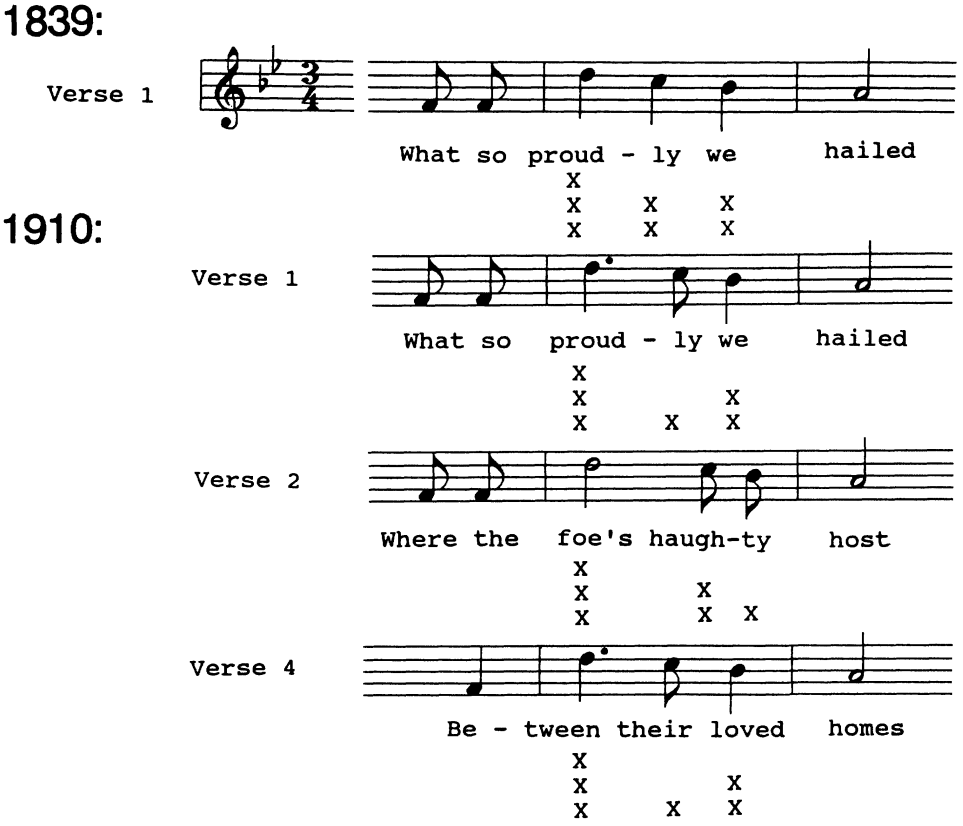

FIG. 6. Historical example of musical metrical accents modified to align with prosodic structure.

musical rather than the linguistic rhythm. The most likely scenario for this hypothesis is song passed on in an aural tradition, where memory constraints play an important role. One example is the national anthem, which originated as a drinking song. The top part of Fig. 6 shows a published score from 1839 (based on a tune which appeared in this form in 1783) and the bottom part depicts a version published in 1910 (Sonneck, 1914). In the earlier version, the musical accent (indicated by the metrical grid beneath) is equivalent for the syllables "-ly" and "we," whereas in the later version, the musical accent is greater for "we"; thus, the metrical accent aligns with the syllable of greater importance. The other verses (shown below) also demonstrate how metrical accent altered to align with syllables of greater importance. Musical duration, as well as metrical accent, changes in some verses; only metrical accent, however, consistently differentiates the syllables. Perhaps the prosodic stress inherent in the text, combined with the prominence of becoming a national anthem, provided enough pressure to force the accents to change toward conformity in later renditions, making the song easier to learn and remember. Such small changes in rhythmic alignment may capture the difference between a memorable and a forgotten song.

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