The Effect of Scale Degree Modifications on Average Interval Size

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ABSTRACT

In speech prosody, small pitch movement is characteristic of sadness. Small melodic interval size is similarly known to be correlated with judgments of sadness in music perception. Starting with melodies in the major mode, a study is reported in which the effect of different scale modifications on the average interval size is examined. Lowering the third and sixth scale tones from the major scale is shown to provide an excellent way of reducing the average melodic interval size for a sample of major-mode melodies. The results are consistent with the view that melodic organization and the major-minor polarity are co-adapted, and that the minor mode is well tailored to evoke, express or represent sadness.

1. INTRODUCTION

Often, we can hear that a person is sad merely through the sound of their voice. Hearing a friend on the telephone, the sound of the voice alone may be sufficient to convey the impression of sadness without having to rely on visual cues or even to attend to the semantic content of the speech. Linguists have identified a number of acoustic cues associated with sadness. One such cue is the magnitude of pitch movements. Specifically, sad affect is associated with low variability of the fundamental pitch of the voice; that is, sad voice is more "monotone" (Fairbanks & Pronovost, 1939; Banse & Scherer, 1996; Bergmann, Goldbeck & Scherer, 1988; Breitenstein, van Lancker & Daum, 2001; Davitz, 1964; Eldred & Price, 1958; Huttar, 1968; Skinner, 1935; Sobin & Alpert, 1999; Williams & Stevens, 1972). In musical terms, we might say that sad voice is associated with a narrow pitch range or that sad voice employs smaller melodic intervals. By contrast, wide pitch excursions are associated with excitement, such as joy or anger.

At least in the case of Western music, (and probably many other musical cultures), it is common to create music that is representative, expressive or evocative of sad affect (e.g. Beeman, 2005; Feld, 1982/1990; Magowan, 2007). In Western music, sadness has long been associated with the minor mode (e.g., Zarlino, 1558). Informal observations of this association have also been confirmed through experimental studies. For example, Heinlein (1928) and Hevner (1935) showed that when an unfamiliar melody is transposed to the minor mode it is commonly described by Western-enculturated listeners as sounding sadder.

The association between sad affect and the minor scale was used by Huron (2008) to examine the hypothesis that sad music employs smaller pitch movements. Huron calculated the average melodic interval size for nearly 10,000 Western classical instrumental themes and found that the average interval size is slightly smaller for themes written in the minor mode compared with the major mode. Although other factors are undoubtedly involved, taken at face value, the research implies that smaller melodic intervals may contribute to the perception of sadness, at least in the case of Western-enculturated listeners.

Of the many factors contributing to interval size in music, one factor is the scale itself. For example, a pentatonic scale might tend to encourage larger average melodic intervals than the major scale merely because there are fewer scale tones per octave. If all pitch transitions were equally probable, the average interval for random pitch sequences in the major mode would be 3.43 semitones. By contrast, if all pitch transitions were equally probable, the average interval for random pitch sequences in the common pentatonic mode would be 3.60 semitones. Of course, in real music, not all pitch transitions are equally probable, so the actual average interval size will depend on the nature of the melodic organization.

In this study, we explore the influence of scale structure on average interval size based on actual melodies. Specifically, we will begin with the major scale and make systematic pitch modifications; for each modification we will determine its effect on the average interval size for a sample of melodies. Our goal is to determine which scale modifications most reduce the average melodic interval size. If smaller interval sizes are robust acoustic cues for sadness, one might expect that the scale that results in the smallest average interval size would also tend to most contribute to the perceived sadness of a melody.

To anticipate our results, we will see that among the optimum modifications to the major scale, lowering the third and sixth scale tones (as in the harmonic minor scale) provides one of the best means for reducing the average melodic interval size. Although other interpretations are possible, the results are consistent with the idea that transposing a major-mode melody to the harmonic minor scale is among the very best pitch-related transformations that can be done to render a sad affect.

2. METHOD

Our method involved assembling three contrasting samples of melodies in the major mode, calculating the average melodic interval size for each melody, and then determining whether the average interval size increased or decreased for different scale modifications. In this study, we will limit ourselves to modifications of the Western diatonic major scale. In principle, the same method could be applied to any scale from any culture.

In modifying the pitch of a scale tone, one consideration is the amount of modification. In the case of Western equally-tempered pitch set, the smallest modification would be a semitone. Larger modifications are possible but raise potential perceptual difficulties. Obviously, if we were to raise the supertonic pitch by two semitones the resulting scale tone would be indistinguishable from the mediant pitch. It is therefore unlikely that the resulting pitch would be heard as a "modified supertonic." In the major scale, any modification greater than one semitone will lead to such confusions. Moreover, even in the case of semitone modifications, there are four changes that will lead to similar scale degree confusions: raising the third scale tone, lowering the fourth scale tone, raising the seventh scale tone, and lowering the tonic. In this study, we limited ourselves to pitch modifications of just one semitone, and we excluded from consideration those semitone modifications which result in pitches equivalent to other scale tones.

Intuitively, one might suppose that lowering one or another scale tone might tend to result in smaller melodic intervals. However, this is not necessarily the case. Lowering a scale tone might well result in larger average melodic intervals. If, in some hypothetical culture, all of the scale tones occurred with equal probability and the successions of different scale tones were randomly ordered, then modifying one of the scale tones would have no effect on the average interval size. Figure 1 illustrates this effect for some hypothetical seven-note scale. In this case, the fourth tone has been lowered. Notice that intervals, such as 1-4, 2-4 and 3-4 will all be smaller; however, the intervals 4-5, 4-6 and 4-7 will all be larger in size. In this case, it is not clear that lowering the fourth scale tone would have any effect whatsoever on the average interval size for melodies employing this scale.

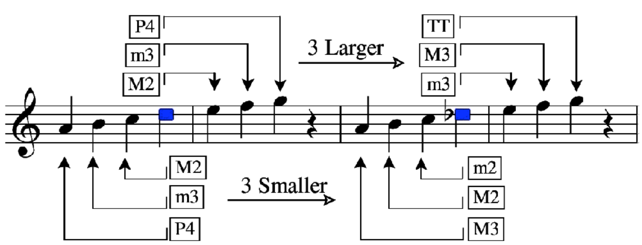

Figure 1: This modification (Db) does not lower the average interval size.

In real music, however, scale tones are not equally common, and some tone successions occur much more frequently than others. Figure 2 shows the probability of different scale-tone successions for a large sample of Germanic folk melodies in the major mode. In the figure, the width of each arrow is proportional to the probability that one tone is followed by another. Pitch transitions whose probabilities are less than 0.015 are not indicated. Notice that there is considerable variability in the likelihood of different tone successions. For example, the third and fourth scale tones are closely linked. In the case of the seventh scale tone, there is a much stronger connection to the first scale tone (7-1) than to the sixth scale tone (6-7). In the major scale, if we were to lower the seventh scale tone by one semitone, the distance between 6 and 7 would be reduced, but the distance between 7 and 1 would be lengthened. Since alternations between 7 and 1 are more common than between 6 and 7, the likely consequence of lowering the seventh scale tone would be to increase the average melodic interval size.

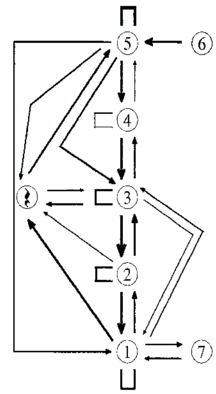

Figure 2: The probability of different scale tone successions for a large sample of Germanic folk melodies in the major mode. (Huron 2006)

Given the fact that some scale tones are more common than others and that some scale-tone successions are more common than others, modifying the pitch of a given tone might be expected to influence the average melodic interval size, unlike the neutral situation illustrated in Figure 1. Accordingly, we systematically modified the different scale tones and measured the effect on the average interval size for samples of real major-mode melodies. In order to pursue this approach, we first identified a suitable sample of melodies.

3. SAMPLE

Since we are interested in melodic intervals, we restricted our musical sample to single-line melodies and themes. For this study, only melodies in the major mode were used. Creating a "representative" sample of music in the major mode raised significant challenges. Instead of attempting to create a representative sample, we proposed to examine three subsamples, each exhibiting a different set of stylistic properties and biases.

3.1 Subsamples

National Anthems:
Out first sample used 151 major-mode national anthems including countries such as Albania, Colombia, North Korea, Palau and Zimbabwe. Although the anthems originate from different cultures, they all share a basically Western-European musical template which includes the tendency to employ the major scale. This sample was selected from a longer list of 195 national anthems. Roughly a dozen anthems were deemed not to be clearly in the major mode and so were excluded from the sample. In addition, in order to minimize the potentially confounding effect of modulation, anthems longer than 50

measures in length were excluded. According to this latter criterion another dozen anthems were eliminated.

Instrumental Themes:
Our second subsample included 150 randomly selected major-key instrumental themes from the Barlow and Morgenstern "Dictionary of Musical Themes" (Barlow & Morgenstern, 1948). This collection includes themes from the period-of-common-practice Western art-music literature with a bias towards orchestral works from the 19th century.

American Songs:
Our final subsample employed 100 major mode works from a collection of songs most well-known to residents of the United States, including such songs as "Jingle Bells, Happy Birthday" and "Auld Lang Syne."

Although we would not claim that our sample of major-mode melodies is representative of Western music-making in general, our three subsamples includes both instrumental and vocal works, music of European and American origin, art-music and popular styles, music spanning a period of roughly four centuries, and instances of music from a genre that spans many countries. The sample also include whole melodies and selected thematic statements.

It should be noted that the average passage lengths differ for the three subsamples. For the national anthems, the average length was 104 notes; for the American songs, the average length was 53 notes; for the Barlow and Morgenstern themes, the average length was 11X notes. Also, notice that in general, effect sizes are likely to be smaller for the shorter sampled passages.

All of the musical materials were encoded in the Humdrum "kern" format and were processed using the Humdrum Toolkit (Huron, 1995). Our total sample represents passages from some 400 individual works. In carrying out our analyses, we report combined results averaged from the three subsamples.

4. PROCEDURE

For each work in the three subsamples, the average melodic interval size was measured only for immediately consecutive tones - no intervals were calculated for tones separated by a rest. After calculating the average interval sizes, we compared the modified versions to the original versions. For example, when raising the 2nd scale degree on the National Anthem subsample, we found that the average interval sizes of 76 anthems were made *smaller* than the unmodified major mode version, 18 stayed the same, and 57 were made larger.

Mod.	**Anthems**	**Songs**	**Themes**	**Totals**
	sm./same/lar.	sm./same/lar.	sm./same/lar.	+inc., -dec.
2#	76 / 18 / 57	34 / 29 / 40	361 / 355 / 219	-60
3b	77 / 11 / 63	60 / 17 / 26	378 / 260 / 297	-75

Figure 3: An example of how the calculations were carried out.

The results from the leftmost column shows the scale-degree that was modified, and in what direction. The numbers that are shown under each category denote the number of songs that were made "*Smaller/Same/Larger*". The "Totals" shown on the right were obtained by subtracting the number of pieces made "smaller" by the number of pieces made "larger". These differences were then averaged together with songs from the other two categories to reveal an average for that particular modification. A positive number indicates that there was a general increase in average interval size among the three subsamples. Similarly, a negative number would indicate a general decrease in average interval size. Numbers at, or close, to zero would suggest that there was little or no change in the average interval size as a whole.

In interpreting the results of the various scale modifications, several caveats should be kept in mind. In the first instance, some modifications effectively reduce the number of scale tones. Specifically, lowering the first and fourth scale degrees, and raising the third and seventh scale degrees effectively transforms a heptatonic (seven-note) scale into a hexatonic (six-note) scale. (For a similar reason, modifications larger than one semitone have been excluded.) Secondly, modifying many scale tones concurrently may tend to cause the scale to be heard as an entirely different scale rather than as a modification of the major scale. For example, modifying four, five, or six pitches simultaneously may make it impossible for listeners to hear the result as a "modified" version of the major scale. Even three pitch modifications may be questionable. Similarly, one might argue that modifying the tonic pitch (such as raising it by one semitone) will significantly change the character of the scale (again with the result that it will sound like an entirely new scale rather than a modified major scale). With these caveats in mind, we present the results of three simulations.

5. RESULTS

Table 1 identifies the effect on average interval size for each of the scale modifications according to the three subsamples. The right-most column ("total") provides a summary result for all three subsamples. For each subsample, we subtracted the number of melodies in which the average interval size was smaller, from the number of melodies in which the average interval size was larger. In order to weigh all three subsamples equally, we then averaged together the three values to arrive at our summary value. The summary value represents the average difference in the number of melodies that exhibited larger melodic intervals minus the number of melodies that exhibited smaller melodic intervals. Positive values indicate that, on average, the melodic intervals were larger. Negative values indicate that, on average, the melodic intervals were smaller. Pitch modifications that violate the interpretive caveats identified above (such as raising the seventh scale tone) are marked in parentheses and colored in Grey and surrounded by parentheses.

5.1 Single-Pitch Manipulations

	National Anthems	American Songs	Instrumental Themes	Average Score
Modifi cations	*Sm/Same/Lg*	*Sm/Same/Lg*	*Sm/Same/Lg*	*+ increase, - decrease*
2b	56 / 18 / 77	39 / 28 / 36	215 / 357 / 363	67
2#	76 / 18 / 57	34 / 29 / 40	361 / 355 / 219	-60
3b	77 / 11 / 63	60 / 17 / 26	378 / 260 / 297	-75
(3#)	(63 / 11 / 77)	(26 / 17 / 60)	(296 / 257 / 382)	(77)
(4b)	(84 / 28 / 39)	(52 / 47 / 4)	(327 / 428 / 180)	(-142)
4#	29 / 34 / 88	4 / 47 / 52	164 / 440 / 331	163
5b	60 / 10 / 81	40 / 9 / 40	348 / 195 / 392	-50
5#	78 / 11 / 62	54 / 9 / 40	392 / 195 / 348	-45
6b	96 / 20 / 35	47 / 31 / 25	364 / 378 / 193	-140*
6#	34 / 21 / 96	25 / 31 / 47	191 / 374 / 370	144
7b	32 / 42 / 77	7 / 61 / 35	141 / 482 / 312	130

Table 1: The greatest decrease in average interval size occurs when scale degree 6 is lowered by one semitone. The second greatest decrease occurs when scale degree 3 is lowered. Modifications that alter the tonic (1-, 1+) and eliminate scale degrees (3+, 4-, 7+) have been removed from the table or shaded in grey and surrounded by parentheses.

5.2 Two-Pitch Manipulations

Average Scores of Two-Pitch Modifications for the Three Subsamples									
	3b	(3#)	(4-)	4#	5b	5#	6b	6#	7b
2b	1	(44)	(-12)	79	63	11	-25	96	106
2#		(8)	(-65)	20	-6	-60	-93	30	-4
3b			-78'	15	-19	-47	-98*	15	15
(3#)				87'	(50)	(23)	(-8)	(100)	(78)
(4b)					(-13)	(-81)	(-122)	(-5)	(-3)
4#						29	12	143	124
5b							-37	52	65
5#								47	42
6b									-25

Table 2: The results of our second simulation in which two pitches were concurrently modified. The number highlighted in blue with an asterisk denotes the most effective two-pitch manipulation in shrinking average interval size. The modifications that are shaded in Grey and enclosed in parentheses indicate an alteration that would eliminate a scale degree, and are thus disqualified from our discussion. In addition, numbers colored in Brown and marked with an apostrophe indicate modifications that eliminate the perceptual third or fourth.

5.3 Three-Pitch Manipulations

Average Scores of Three-Pitch Modifications for the Three Subsamples							
	4b	**4#**	**5b**	**5#**	**6b**	**6#**	**7b**
2b, 3b	-42'	30	26	-12	-46*	36	48
2b, 3#		76'	(69)	(24)	(11)	(99)	(90)
2b, 4b			(14)	(-23)	(-72)	(41)	(45)
2b, 4#				41	23	120	117
2b, 5b					20	92	110
2b, 5#						66	49
2b. 6b							23
	4b	**4#**	**5b**	**5#**	**6b**	**6#**	**7b**
2#, 3#		57'	(18)	-17	-28	57	37
(2#, 4b)			(-27)	(-94)	(-104)	(-8)	(-31)
2#, 4#				5	-33	93	45
2#, 5b					-55*	23	21
2#, 5#						-2	-6
2#, 6b							-59*
	4b	**4#**	**5b**	**5#**	**6b**	**6#**	**7b**
3b, 4b			-49'	-80'	-128'	-26'	-36'
3b, 4#				-16	-25	57	52
3b, 5b					-67	14	33
3b, 5#						-7	-9
3b, 6b							-44*
	4b	**4#**	**5b**	**5#**	**6b**	**6#**	**7b**
3#, 4#				66'	37'	147'	110'
(3#, 5b)					(19)	(89)	(74)
(3#, 5#)						(76)	(68)
3#, 6b							(22)
	4b	**4#**	**5b**	**5#**	**6b**	**6#**	**7b**
4b, 5b					(-59)	(11)	(20)
4b, 5#						(-26)	(-12)
4b. 6b							(-69)
	4b	**4#**	**5b**	**5#**	**6b**	**6#**	**7b**
4#, 5#						97	95
4#, 6b							39
	4b	**4#**	**5b**	**5#**	**6b**	**6#**	**7b**
5b, 6b							-2

Table 3: Blue* = ideal. Black = normal. Brown' = eliminating the perceptual third or fourth. (Grey) = changes that eliminate a scale degree.

6. DISCUSSION AND CONCLUSION

In this study we have sought to explain one aspect of how the minor mode so effectively conveys a sad affect. By modifying one, two, and three pitches of major-mode melodies and comparing the average interval sizes to the unmodified versions, we were able to calculate which modifications could best contribute to lowering the overall average interval size, and consequently contribute to the melody's ability to convey sadness.

For single-note modifications, we found that lowering the sixth scale degree provided the optimal effect of substantially lowering the overall average interval size. The lowered sixth was followed closely by the modification of lowering the third. The reason for such an optimal performance can be traced back to Figure 2, where certain scale degrees in a melody tend to exhibit certain tendencies towards other scale degrees. Since there much activity between 5-6 and not between 6-7, lowering the sixth scale degree offers an effective means of lowering the average interval size. Similarly, by lowering the third scale degree, this model is taking advantage of the third scale degree's tendency to migrate downwards towards the tonic and supertonic, as opposed to subdominant and dominant.

For two-note modifications, we found that lowering the third and sixth scale degrees provided the optimal effect for lowering the average interval size. Again, this is to be expected since there is much movement between the 2-3 and 5-6 scale degrees in Western melodies. This modification is commonly known as the harmonic minor scale and suggests that raising the seventh (in a minor key) might actually contribute to lowering the overall interval size. Therefore, this principle might contribute to the minor mode's unique ability to evoke or convey sadness in Western enculturated listeners, at least in the case of melodies.

Finally, the three-note modifications also presented some interesting information. Contrary to our expectations up to this point, the natural minor was not the most effective modification in lowering the average interval size. However, upon further investigation, it can be seen that the most effective modifications actually utilize the lowering of the subdominant pitch, thereby essentially eliminating the subdominant sound. While this situation does not actually eliminate one of the seven scale degrees, it does eliminate the perception of the fourth scale degree and masks it as a non-scale tone or embellishment of the third. For instance, a modification of the third and fourth might resemble a scale like the following:

1 – 2 – 3b – 4b – 5 – 6 – 7

In this case the scale remains heptatonic (seven-note), but perceptually the fourth has been eliminated, thereby eliminating much of the key structure that is important to scales related to the major-mode. In Table 3, these exceptions are given a brown color, and are labeled with an apostrophe. (i.e. -26')

When eliminating raised thirds and lowered fourths from consideration (even those that do not eliminate scale-degrees), we are left with only a handful of optimal modifications which are very close to one another. The most ideal is [2+, 6-, 7-], which gave a score of -59. As you can see from Table 3, there are a few other modifications before we get to the harmonic minor, with a measurement of -44. However, since the natural minor is rarely used melodically, it does not surprise us to find that it may not be "ideal" for conveying a sad affect.

Overall, we found some very promising results that suggest that the lowered third and sixth scale degrees might contribute to why Western-enculturated listeners consider the minor mode as sadder than the major mode. More work needs to be done in this area before a more convincing argument can be made. For instance, it might be helpful to continue this same exercise for four, five, and six-note modifications to enable us to consider other seven-note scales not possible with our current model. (i.e. The Locrian mode.) It would also be advantageous to work on a way to incorporate this model into scales that use more (or less) notes than the major scale. (i.e. Octatonic or Pentatonic.)

Ultimately, it is important to remember that when considering the question of music and sadness, average interval size may only be a small part of the solution. Certainly culture and exposure play an important role in how a listener perceives music. However, it is logical to assume that there may be other contributing factors in determining the sadness of a melody – such as a decrease tempo, lower range, softer dynamics, and a reduced average interval size.

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