

The Effects of Mode, Pitch, and Dynamics on Valence in Piano Scales and Chord Progressions

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ABSTRACT

Previous research has investigated how emotional characteristics of the piano vary with different pitches and dynamic levels for individual notes. Going further, this work considers valence trends with different pitches, dynamic levels, and modes in piano scales and chord progression. The results confirm that for scales, Harmonic Minor was significantly more negative than the other Minor modes, while for chords, Natural Minor was significantly more negative than the other Minor modes.

The results shed light on what types of musical examples are most likely to result in contrary examples, meaning Major but negative in mood, or Minor but positive in mood. Contrary Major examples are most likely to occur in the low pitch range between C1 and C3. Surprisingly, extremely high chords are about equally likely to be judged negative or positive in mood. Contrary Minor examples are most likely to occur in the middle and high register between C3 and C7. Among the factors we tested, pitch range made the biggest difference in valence, perhaps surprisingly even more than mode. These results help to expose valence trends which are especially useful for student composers in developing their musical intuition, as well as for film and computer game composers who need to provide music that follows a mood set by the Director.

1. INTRODUCTION

Previous research has shown that mode is very predictive of mood in music [1-6]. For example, music in a Major key is usually positive in mood while music in a Minor key is negative in mood [5, 6]. In particular, our recent work found that of 300 classical piano examples, mode was predictive of mood 90% of the time [7]. And while 90% prediction is pretty impressive, one might wonder what caused 10% to be contrary examples, meaning Major but negative in mood, or Minor but positive in mood. Was it because they were, for example, lower in pitch, softer in dynamics, slower in tempo, or a combination of factors? In fact, in our previous study of the piano excerpts [7], many of the contrary Major examples were relatively low

in pitch, while most of the contrary Minor examples were relatively high.

This led us to wonder whether it was possible to quantify how valence (i.e., positiveness) changes for different pitches, dynamic levels, and modes apart from a particular musical context in scales and chord progressions. In particular, it would be interesting to see how the different types of Minor compare across their pitch and dynamic ranges.

Understanding valence trends with different musical parameters is useful for student composers in developing their musical intuitions, and also especially for film and computer game composers in rendering their music for different emotive situations.

The results can also help identify which types of musical examples are most likely to be contrary examples that could cause problems for automated music emotion recognition systems.

1.1 Previous Related Work

Previous research has considered at the timbral and emotional effects of factors such as pitch [8], dynamics [2], mode [1-6], rhythmic activity [9], and even special effects such as reverberation [10-12]. Moreover, a variety of studies have investigated valence using individual piano tones [13] and piano excerpts [5, 7]. Other studies have considered various emotional categories for individual piano tones [14] and piano excerpts [15]. In particular, some studies have investigated valence in scales [13] and chords [16]. Other studies have researched various emotional characteristics of scales [17] and chords [18, 19].

The moods of various modes have been considered in several studies [1-6, 15]. Most relevant to the current study, Temperley and Tan [15] considered the valence of the Greek modes, and found that the Ionian mode was significantly more positive than the Lydian and Mixolydian modes, which were significantly more positive than the Dorian and Aeolian modes. Since the Ionian mode is the same as Major, and the Aeolian mode is the same as Natural Minor, their results imply that Major was significantly more positive than Natural Minor. In another relevant study, Eerola et al. [1] considered the effects of mode and other factors such as tempo, dynamics, and register on four musical excerpts with four emotional categories (happy, sad, peaceful, and scary). They found mode was the most

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important in determining the emotional category, followed by tempo, register, and dynamics.

Several studies have considered the emotional characteristics of various instruments such as the piano [13, 14], bowed strings [20], and mallet percussion instruments [21] for individual tones with different pitches and dynamic levels.

The piano results are especially relevant to the current study. Several positive emotional categories were tested, including Happy, Comic, Calm, and Romantic, where higher pitches brought out these positive characteristics more than lower pitches (though there was often some decrease at the very highest pitches). At the same time, the negative emotional categories Angry, Scary, and Sad were all strongest on the lowest pitches. These results suggest that contrary Major examples with negative mood are most likely to be found in the lowest register. Similarly, the results suggest that contrary Minor examples with positive mood are most likely to be found in the high register. Whether these trends hold to the highest pitches for valence is not clear, since some emotional characteristics continued to increase to their extremes in the highest register (Calm, Angry, Sad) while others moderated at the highest pitches (Happy, Romantic, Comic, Scary). It will be interesting to see how this comes out for valence on different pitches and modes in scales and chord progressions.

1.2 Organization of the Paper

The next section describes the listening test that we designed to expose the valence trends. The following section describes the results for the listening test. The final section discusses the implications of these results in identifying contrary examples. It also ranks the importance of pitch, dynamics, mode, and excerpt type (scales vs. chords) in predicting valence. Moreover, we consider the similarities in the valence trends for different modes and dynamic levels. Finally, we briefly discuss musical applications of our results.

2. METHOD

We conducted a listening test to determine the trends in valence for different pitches, dynamics, modes, and excerpt types (scales and chord progressions). The details of the test are given in this section.

2.1 Stimuli

The stimuli in our listening test consisted of short excerpts with different modes, pitches, and dynamic levels. We tested four modes: Major, Melodic Minor, Natural Minor, and Harmonic Minor. For pitch, we considered seven different pitch levels from C1 to C7 with notes ranging over one octave. For dynamics, we used two dynamic levels loud (*forte*) and soft (*piano*). There were two excerpt types: scales and chord progressions. The total number of excerpts was 112 (4 modes \times 7 pitches \times 2 dynamic levels \times 2 excerpt types).

The scale excerpts consisted of an ascending and descending sixteenth note scale. For example, the scales for the four modes starting from C4 are shown in Figure 1. The chord excerpts were 3-chord progressions of supertonic, dominant, and tonic. We picked chord voicings that would keep the notes within the same octave as in the scales so that the effects of pitch would be easier to isolate. For example, the chords for the four modes based on C4 are shown in Figure 2. The scale and chord excerpts were all based on C, whether Major or Minor.

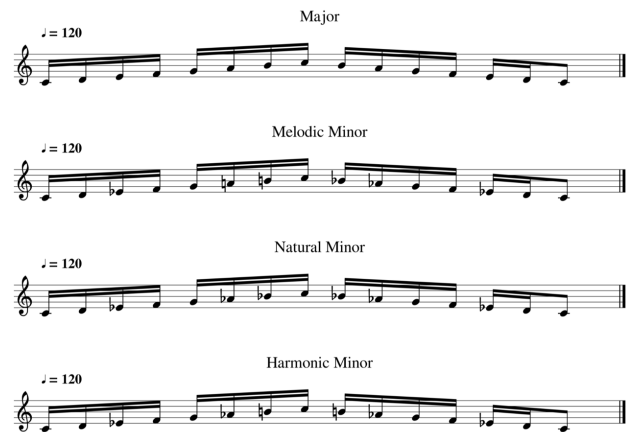


Figure 1. Scale excerpts for Major and Minor modes starting from C4.

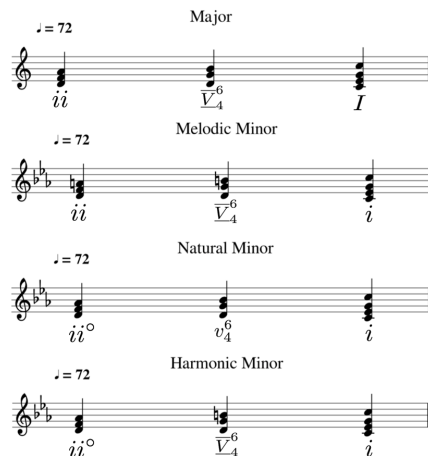


Figure 2. Chord progression excerpts for Major and Minor modes based on C4.

The motivation for choosing a relatively fast tempo for the scale excerpts was that the scale excerpts would be basically representative of fast movements in Bach and Mozart, where scales are frequent and prominent. For the chord progressions, we wanted a moderately slow tempo that would be basically representative of the slow movements in the music of Bach and Mozart. Many other choices are of course possible, but these give two contrasting simple points of reference for comparing trends in valence with different pitches, dynamics, and modes.

The scale and chord excerpts were played using the Steinway grand piano samples in GarageBand [22]. The excerpt duration was 2 seconds for the scale excerpts and 2.5 seconds for the chord excerpts. We felt they were sufficiently long enough to establish the character of each

mode. Previous studies have confirmed that listeners can determine the emotional character of excerpts even for durations shorter than those used in our study [16].

2.2 Subjects and Listening Environment

There were 73 subjects hired to take our listening test, ranging in age from 18 to 32 with an average of 22.3 (42 were male, 31 were female). Nearly all of the subjects were university students and without known hearing problems. Subjects were average attentive listeners, rather than specialists with highly trained ears (e.g. professional musicians, music conservatory students, or recording engineers). About one-third of subjects had played the instrument for at least five years.

The subjects were seated in a quiet room. Sounds were presented via a computer program through professional quality headphones (Sony MDR-7506) at moderate loudness levels.

2.3 Listening Test

The listening test was designed to uncover valence trends for different pitches, dynamics, modes in both scales and chord progressions. The 112 excerpts were presented in a random order one-by-one, and afterwards each subject was asked: "What is the mood of the music?" (see Figure 3). To allow subjects to get used to the test and minimize the effects of learning, 10 random test trails were added at the beginning where the listener responses were not used in further processing of the data. The total length of the listening test was about 7 minutes.

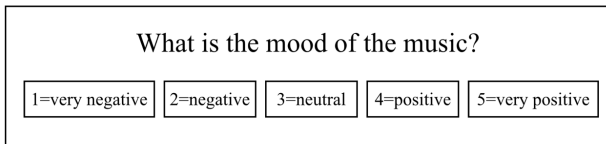


Figure 3. Graphical user interface of listening test.

3. VALENCE RESULTS

This section presents the results from our listening test to uncover the effects of mode, pitch, and dynamics on valence for scales and chord progressions. All significance tests were done with Welch's t-tests at the $p < 0.05$ level.

In our listening test, listeners were asked to judge the valence of each excerpt according to one of the five valence categories: 1) very negative, 2) negative, 3) neutral, 4) positive, 5) very positive. Listener responses were translated numerically as shown in Table 1:

| | |
|---------------|------|
| Very Positive | 1.00 |
| Positive | 0.75 |
| Neutral | 0.50 |
| Negative | 0.25 |
| Very Negative | 0.00 |

Table 1. Numerical scoring of listener responses.

Figure 4 shows the valence results for scales averaged over all listeners and their 95% confidence intervals. In terms of pitch, valence was generally positive for C3 or above, and negative below that. It was also a log-like curve based on pitch. Major-*forte* had the highest average valence, followed closely by Major-*piano*. Between the Major curves and the various Minor curves there was a gap. Major was statistically significantly greater than Melodic and Natural Minor, which were significantly greater than Harmonic Minor. Indeed, Harmonic Minor was consistently the lowest point in Figure 4 for C2-C7. Overall, the *forte* sounds for each of the four modes were only greater than the *piano* sounds in Figure 4 by 0.004, which was not a significant difference.

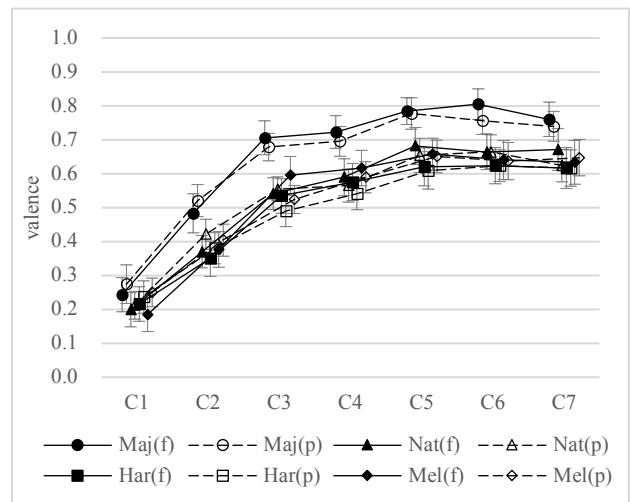


Figure 4. The valence results for scales averaged over all listeners and the 95% confidence intervals. In the figure, Maj = Major, Nat = Natural Minor, Har = Harmonic Minor, Mel = Melodic Minor, f = *forte*, and p = *piano*.

Figure 5 shows the valence results for the chord excerpts. The shape of Figure 5 parallels Figure 4, but the values are 0.1 lower on average. Regarding pitch, once again, C3-C6 were positive for Major and negative below that, but were neutral for C7. Minor curves were relatively neutral for C3-C7, and negative below that. The Major curves were on top with *forte* generally more than *piano*, and after a gap, the Minor curves were bundled closer together. However, for the chord excerpts, Natural Minor was consistently on the bottom. Major was significantly greater than Melodic Minor, which was significantly greater than Harmonic Minor, which was in turn significantly greater than Natural Minor. The *forte* notes were slightly greater than *piano* notes for a difference of 0.017, which was significant.

Since most real-life musical excerpts are a mix of both melodic and harmonic elements, Figure 6 shows the valence results for both the scale and chord excerpts together. Valence was generally neutral or positive for C3-C7, and negative below that. For the combined excerpts, Major was significantly greater than Melodic Minor, which was significantly greater than Natural and Harmonic Minor. Indeed, the Melodic Minor points were consistently largest among the Minor points for C2-C7. The difference

between *forte* and *piano* was only 0.011, which was not significant.

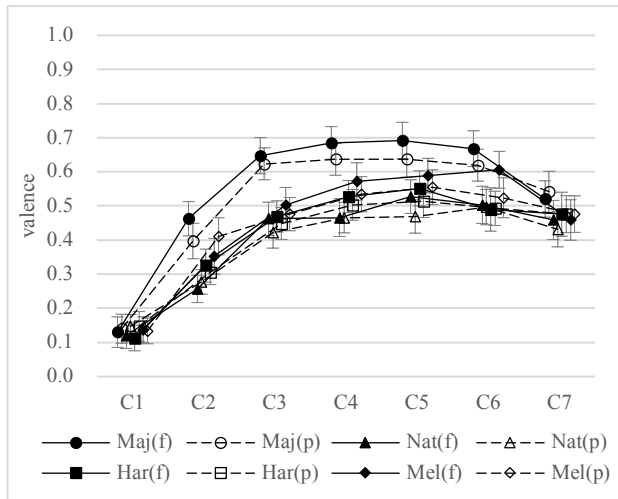


Figure 5. The valence results for chord progressions averaged over all listeners and the 95% confidence intervals.

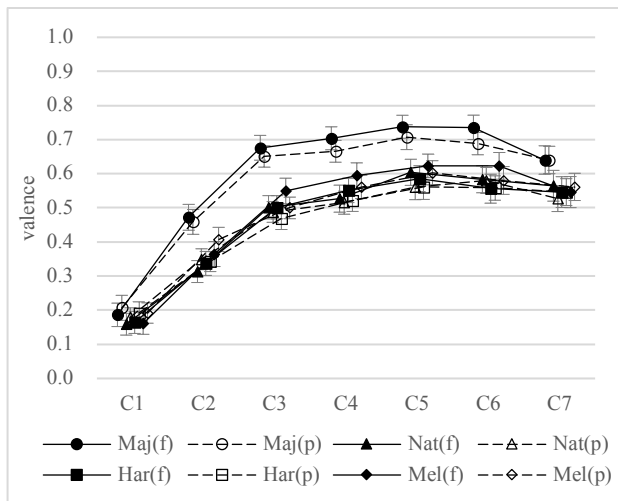


Figure 6. The valence results over both scale and chord excerpts together and the 95% confidence intervals.

4. DISCUSSION

4.1 Contrary Examples

The main questions driving our listening test were: Are there discernable pitch and dynamic trends that indicate where contrary examples (Major but negative in mood, or Minor but positive) are most likely to occur? And if so, what are the inflection points (i.e., where the valence is about 50%)? Figures 4-6 give a clear idea about these trends for scales, chords, and a mix of scales and chords. For Major, valence was clearly positive for C3 and above. The inflection point was about at C2, though perhaps a little higher than C2 for the soft chord excerpts. Excerpts at C1 were decisively negative and clear examples of contrary excerpts.

For Minor, there was some variation among the different Minor modes in Figures 4-6, with Melodic Minor significantly more positive than Natural and Harmonic Minor in

general. Excerpts at C1 and C2 were clearly negative for all Minor modes. For scale excerpts, the 50% inflection point was at or a little below C3. For chord excerpts, the inflection point was about C3 for Melodic Minor, C4 for Harmonic Minor, and C5 for Natural Minor. For scale excerpts, above C3 the valence was slightly positive and the most likely region for contrary Minor examples. Chord excerpts were fairly neutral from C3 to C7. Loud Melodic Minor chord excerpts were the most positive of the group, especially between C4 and C6, yet they were consistently less than the corresponding scale excerpts. In other words, while contrary examples are possible for Minor chord excerpts, they are borderline contraries rather than strong ones.

Overall, Figures 4-6 imply that contrary examples are more likely to occur in Minor excerpts since the pitch range extends over a wide range from C3 to C7, while only including the extreme low range of C1 to C2 for Major excerpts. Indeed, in our investigation of 300 classical piano excerpts, we found 74% of the contrary examples were Minor and only 26% Major [7].

On the other hand, Figures 4-6 also imply that very strong contrary examples are most likely for extremely low Major examples which were very negative in valence. The strongest Minor contrary examples were scale excerpts between C5 and C7, but these were significantly less positive than Major excerpts at C1 were negative.

4.2 Ranking of Factors

Our listening test considered how valence changed based on several factors: pitch, dynamics, mode, and excerpt type (scales and chords). One might wonder which of these factors made the biggest difference in listeners' judgements. We calculated the differences each of these factors made in valence, which are summarized in Table 2.

| | |
|--------------------|-------|
| Pitch | 0.45 |
| Mode | 0.14 |
| Pitch (C3-C7 only) | 0.103 |
| Scale-Chord | 0.102 |
| Dynamic | 0.028 |

Table 2. The difference in valence made by various musical factors on listeners' judgements.

Table 2 indicates that the biggest difference by far was for pitch, which was 0.45. This number represents the average difference between the maximum and minimum values in each of the 16 curves in Figures 4 and 5. For example, for loud Major scale excerpts the maximum is 0.8 and the minimum 0.25, with a difference of 0.55. Pitch can really make a big difference. However, if we restrict our consideration only to the middle and high pitch range from C3 to C7, the pitch difference is much less, only 0.103. This is similar to the effect of mode and excerpt type. This indicates that very low pitch has a strong outlier effect.

The second biggest difference was for mode at 0.14, where we took the difference between Major and the lowest Minor mode averaged over all pitches, dynamic levels, and excerpt types in Figures 4 and 5 (28 points). Table 3 shows the differences between each of the individual

modes in detail, where the largest difference was between Major and Harmonic Minor, and the smallest difference was between Natural and Harmonic Minor. Table 3 confirms the gap between Major and the Minor modes was larger than between the Minor modes.

| | |
|--------------------------------|-------|
| Major - Melodic Minor | 0.095 |
| Major - Natural Minor | 0.123 |
| Major - Harmonic Minor | 0.125 |
| Melodic Minor - Natural Minor | 0.043 |
| Melodic Minor - Harmonic Minor | 0.035 |
| Natural Minor - Harmonic Minor | 0.030 |

Table 3. Differences between each of the individual modes.

The next biggest difference in Table 2 was between scale and chord excerpts averaged over all modes, pitches, and dynamic levels in Figures 4 and 5 (56 points). The smallest difference in Table 2 was between dynamic levels averaged over all modes and pitches for both scales and chords in Figures 4 and 5 (56 points). It was surprisingly relatively small. However, this result is consistent with our previous results for the emotional category Happy (which is closely-related to valence), where dynamics had relatively little effect [14, 21]. In general, dynamics has a stronger effect on arousal than valence [23].

The ranking of mode, pitch (when restricted to C3-C7), and dynamics were consistent with that found by Eerola [1].

We checked for significance levels between the differences in Table 2 using a Welch's t-tests at the $p < 0.05$ level, and found that pitch differences were significantly greater than mode differences, mode differences were significantly greater than scale-chord differences, and scale-chord differences were significantly greater than dynamic differences. For the restricted pitch range C3 to C7, pitch and scale-chord differences were not significantly different.

4.3 Correlation between Modes, Dynamics, and Excerpt Types

Since the curves in Figures 4 and 5 were similar in shape overall, though Major was higher than Minor, we were curious how strongly correlated they were. Table 4 gives the correlation between each of the modes for the data in Figures 4 and 5.

| | |
|--------------------------------|-------|
| Major - Melodic Minor | 0.984 |
| Major - Natural Minor | 0.964 |
| Major - Harmonic Minor | 0.981 |
| Melodic Minor - Natural Minor | 0.958 |
| Melodic Minor - Harmonic Minor | 0.982 |
| Natural Minor - Harmonic Minor | 0.977 |

Table 4. Correlation between each of the modes for the data in Figures 4 and 5.

The correlation values ranged between 0.95 and 0.99, indicating a very strong near-linear correspondence. Correlations between dynamics (loud and soft) and excerpt types

(scales and chords) were also very strong and near-linear at 0.986 and 0.946 respectively. These very strong correlations indicate that listeners were remarkably consistent in their pitch judgements regardless of mode, dynamics, or excerpt type.

4.4 Musical Applications

The valence trends for pitch, dynamics, and mode for scales and chord progressions in Figures 4-6 and Table 2 help to quantify and visualize how valence varies with these factors apart from a particular musical context. These trends support musical intuition that Major can be negative if it is low and slow enough, and that Minor can be positive if it is high and fast enough. The results also expose some lesser-known trends such as how the Major curves arch over the pitch range for chord excerpts in Figure 5 and become neutral in valence at the highest pitches. This indicates that Major contrary examples can be found at the highest pitches as well as the lowest. Previous studies of the piano have also similarly found that some emotional categories such as Happy and Romantic moderated at the highest pitches [14].

Uncovering and exposing valence trends is valuable in applications such as music arrangement and especially composition for film and computer games. Graphs of valence trends can help student composers in the early stages of developing their musical intuition, helping to fill in the blanks between classic examples studied in composition, arrangement, and orchestration classes.

The results also have promising applications in music emotion recognition and recommendation. For example, graphs of valence trends can expose which pitches and modes are most likely to result in contrary examples and misclassification by automated music emotion recognition systems.

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