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The Effects of Pitch and Dynamics on the Emotional Characteristics of Piano Sounds

Chuck-jee Chau **Andrew Horner**
Department of Computer Science and Engineering
The Hong Kong University of Science and Technology
Clear Water Bay, Kowloon, Hong Kong
chuckjee@cse.ust.hk, horner@cs.ust.hk

ABSTRACT

The piano is an instrument extensively used in classical, jazz, and pop music, since its broad pitch range and ample dynamic levels allow the instrument to become self-contained and versatile for various kinds of music. Previous work has found the piano to be emotionally neutral among eight tested non-sustaining instruments. This paper further explores the emotional characteristics of piano sounds with a listening test comparing isolated one-second sounds of different pitches and dynamics on the piano over ten emotional categories: Happy, Sad, Heroic, Scary, Comic, Shy, Romantic, Mysterious, Angry, and Calm. In the experiment, the loud bass was ranked the most Angry and Heroic, and the effect dropped with increasing pitch. The soft treble was ranked the most Calm and Shy, and the effect dropped with decreasing pitch. The trend was clear across the octaves. Both loud and soft sounds have distinguishing emotional characteristics. In contrast, the emotional categories Mysterious and Happy were not much affected by dynamics.

1. INTRODUCTION

Previous research has shown that both sustained [1, 2, 3] and non-sustained [4, 5] instrument sounds have strong emotional characteristics. For example, it has found that the trumpet, clarinet, and violin are relatively joyful compared to other sustained instruments, even in isolated sounds apart from musical context, while the horn is relatively sad. The marimba and xylophone are relatively happier compared to other sustained instruments, while the harp and guitar are relatively depressed.

In our recent study of non-sustained instrument sounds [4, 5], several musical instruments were tested: plucked violin, guitar, harp, marimba, xylophone, vibraphone, piano, and harpsichord. Among the eight instruments, the piano was found to be ranked neutral for eight emotional categories: Happy, Sad, Heroic, Scary, Comic, Shy, Joyful, and Depressed. It was often ranked in the middle, indicating neutral emotional characteristics relative to the other tested instruments. Perhaps one might find this surprising since the piano has the widest repertoire among all instruments in classical, jazz, and pop music, and there are also abundant transcriptions written for the piano. What is the range of emotional characteristics for the piano?

Previous work has only studied single mid-range pitches of the instrument, and the loudness was also equalized to allow consistent comparison. We were curious about the effects of pitch and dynamics in isolated sounds on the emotional characteristics of the piano.

We then formulated the current study to carefully compare the emotional characteristics of piano pitches at different dynamic levels. The study includes representative pitches ranging from the lowest to the highest octave. The dynamic levels included loud, medium, and soft (*forte*, *mezzo*, and *piano*). All sounds were isolated with a duration of one second. They were compared pairwise over ten emotional categories.

This work provides a systematic overview of the emotional characteristics of the piano across the different octaves at different dynamics. This research will help recording and audio engineers, composers, and pianists manipulate the emotional characteristics of the instrument in live performances and recordings.

2. BACKGROUND

Much work has been done on emotion recognition in music, especially addressing melody [6], harmony [7], rhythm [8], etc.

Researchers have gradually established connections between music emotion and timbre. Scherer and Oshinsky [9] found that timbre is a salient factor in the rating of synthetic sounds. Peretz *et al.* [10] showed that timbre speeds up discrimination of emotion categories. It was also found that timbre is essential to musical genre recognition and discrimination [11, 12].

Eerola *et al.* [1, 13] showed a direct connection between music emotion and timbre. Eerola carried out listening tests to investigate the correlation of emotion with temporal and spectral sound features. The study confirmed strong correlations between features such as attack time and brightness and the emotion dimensions valence and arousal for one-second isolated instrument sounds.

We followed up Eerola's work with our own studies of music emotion and timbre [2, 3, 4, 14, 15] to find out if some sounds were consistently perceived as being happier or sadder in pairwise comparisons. We designed listening tests to compare sounds from various string, wind, and percussion instruments. The results showed strong emotional characteristics for each instrument. The horn and flute were highly ranked

for Sad, while the violin, trumpet, and clarinet were highly ranked for Happy. The oboe was ranked in the middle. In another experiment, the harp, guitar and plucked violin were highly ranked for Sad, while the marimba, xylophone, and vibraphone were highly ranked for Happy. And piano was ranked in the middle.

3. EXPERIMENT

Our experiment was a listening test, where subjects compared pairs of instrument sounds over different emotional categories.

3.1 Test Materials

3.1.1 Stimuli

The stimuli used in the listening tests were sounds of a grand piano with different combinations of dynamics (loudness) and pitch.

All sounds were from the RWC [16] sample library. The sounds were played by the same pianist on a Steinway grand piano. Three different level of dynamics were used: *forte*, *mezzo*, and *piano*, with *forte* being the loudest, *piano* the softest, and *mezzo* in between. To avoid the effect of intervals of pitches interfering the experiment results, we chose only the C pitches of the piano (C1–C8), with C1 the lowest and C8 the highest (as shown in Figure 1). All sounds used a 44,100 Hz sampling rate.

Any silence before the onset of each sound was removed. The sound durations were then truncated to 1.0 second using a 30 ms linear fade-out before the end of each sound. In all cases, the fade-outs sounded like a natural damping or release of the sound.

3.1.2 Emotional Categories

The subjects compared the stimuli in terms of ten emotional categories: Happy, Sad, Heroic, Scary, Comic, Shy, Romantic, Mysterious, Angry, and Calm. When picking these ten emotional categories, we particularly had dramatic musical genres such as opera and musicals in mind, where there are typically heroes, villains, and comic-relief characters with music specifically representing each. The emotional characteristics in these genres are generally more obvious and less abstract than in pure orchestral music.

We chose to use simple English emotional categories so that they would be familiar and self-apparent to non-native English speakers, which are similar to Italian music expression marks traditionally used by classical composers to specify the character of the music. These emotional categories also provide easy comparison with the results of our previous work [2, 3, 4, 14, 15].

3.2 Test Panel

There were 26 subjects hired for the listening test, with an average age of 20.8 (ranging from 19 to 24). All subjects were undergraduate students at the Hong Kong University of Science and Technology. None of them reported any hearing problems.

3.3 Test Procedure

The subjects were seated in a "quiet room" with less than 40 dB SPL background noise level. Residual noise was mostly due to computers and air conditioning. The noise level was further reduced with headphones. The Sound Blaster sound card uses 24-bits with a maximum sampling rate of 96 kHz and a 108 dB S/N ratio.

The subjects were provided with an instruction sheet containing definitions of the ten emotional categories from the Cambridge Academic Content Dictionary [17].

Every subject made pairwise comparisons on a computer among all the 24 combinations of pitch and dynamics for each emotional category. During each trial, subjects heard a pair of sounds from different instruments and were prompted to choose the sound that represented the given emotional category more strongly. Each combination of two different instruments was presented once for each emotional category. For each emotional category, the overall trial presentation order was randomized (i.e., all the Happy comparisons were first in a random order, then all the Sad comparisons were second, and so on). However, the emotional categories were presented in order to avoid confusing and fatiguing the subjects.

The listening test took about 3 hours, with a short break of 5 minutes after every 30 minutes to help minimize listener fatigue and maintain consistency.

3.4 Analysis Procedures

The voting results from the subjects were used for the correlation figures. The Bradley-Terry-Luce (BTL) model [18] was then used to derive rankings based on the number of positive votes each sound received for each emotional category. For each emotional category, the BTL scale values for all the combinations of dynamic and pitch sum up to 1. The BTL value for each sound is the probability that listeners will choose that sound when considering a certain emotional category. The 95% confidence intervals of the BTL values were obtained to test the significance of the instrument ranks.

4. EXPERIMENT RESULTS

The raw results were votes for each sound pair and each emotional category. Figure 2 displays the BTL scale values of the sounds, with the corresponding 95% confidence intervals.

From the charts, it can be observed that the low notes (C1–C3) were significantly ranked more Angry than the high notes (C5–C8). For the low notes, the *forte* dynamics were significantly more Angry than *piano*. The difference is not as much for the high notes. The rankings were generally in order by pitch. The rankings were much more compressed for *piano*, and in-between for *mezzo*.

On the other hand, Shy was the opposite with wide-spread rankings for *piano*.The high notes at *piano* were significantly more Shy than at *forte*, and the dynamics did not make a difference for low notes. The rankings also followed the pitch order.

Heroic showed similar behavior as Angry. Romantic and Romantic were similar to Shy.

It is interesting that the extremes (C1 and C8) were not always highest or lowest. For example, for Comic at *forte*, C1 and C7 were ranked similarly and the mid-range pitches were

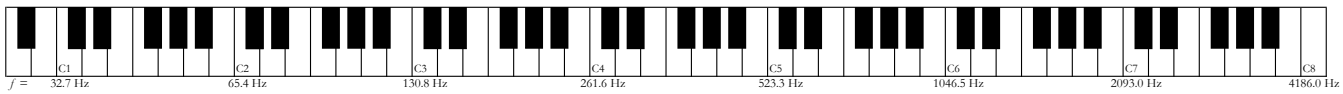

Figure 1: Selected piano pitches and the corresponding frequencies.

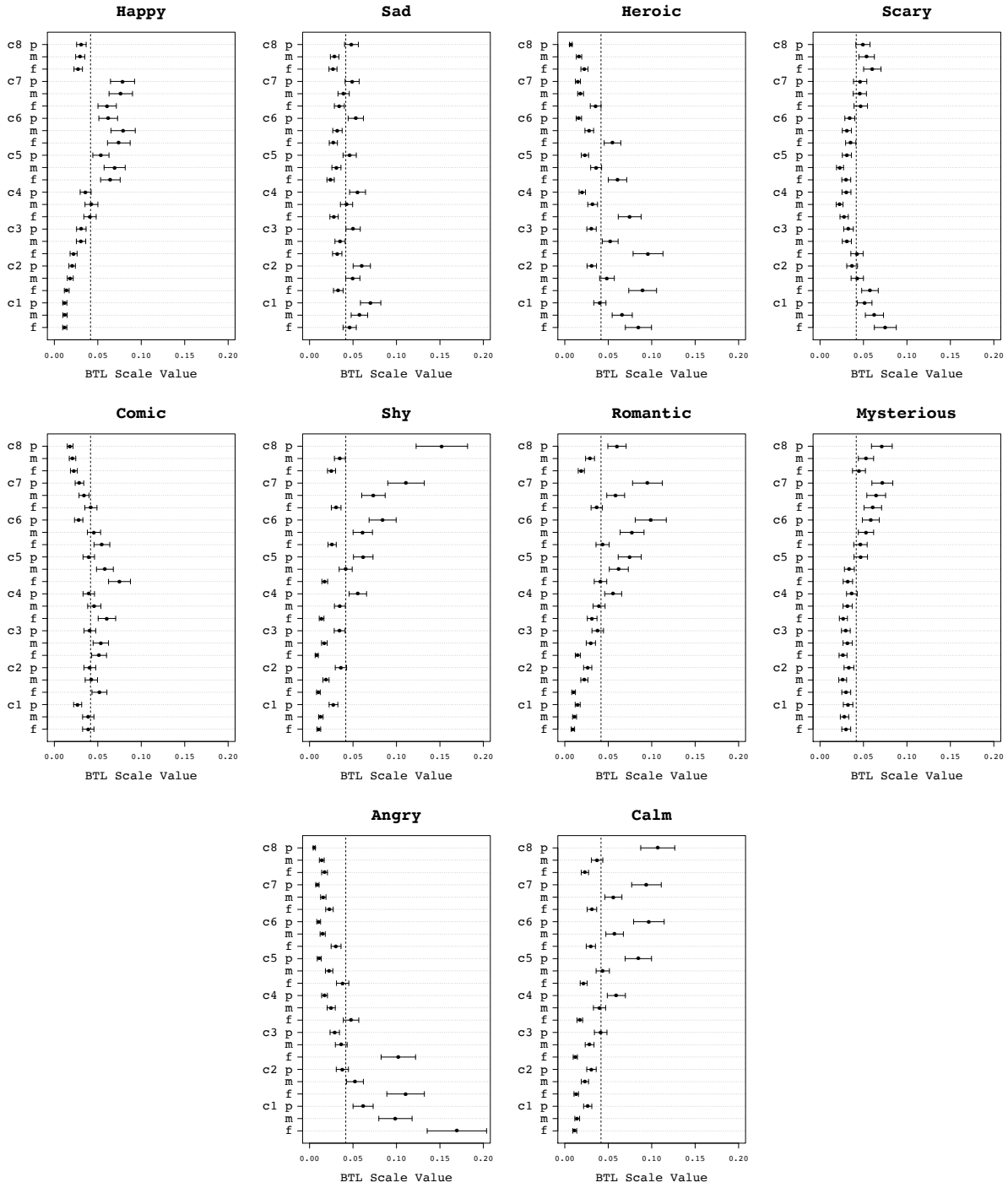

Figure 2: BTL scale values and the corresponding 95% confidence intervals. The dotted line represents no preference. p = *piano*, m = *mezzo*, f = *forte*

ranked highest. C1 and C8 were together ranked highest for Scary.

Sad is not as sensitive to the pitch difference. A difference in ranking is seen among the dynamic levels instead. In contrast, Happy and Mysterious are less sensitive to dynamics.

5. DISCUSSION

Based on the results, our main observations are the following:

1. The emotional characteristics for different pitch at different dynamics on a piano is distinctly distinguishable.
2. Many of the emotional characteristics show a trend across the octaves. Some of the emotional characteristics are more significant in the middle octaves.
3. Low notes at *forte* often shows opposite emotional characteristics compared to high notes at *piano*.

Although this is only the preliminary analysis of the emotional effect of dynamics and pitch in the piano, our results have shown discernible differences. The results of the tested pitches were generally consistent, with a slight variation in a consistent trend.

Dynamic level and pitch showed the strongest effect on the emotional categories Angry and Shy. The more powerful and lower the sound on the piano, the more Angry and Heroic it sounds. The softer and higher the sound on the piano, the more Calm and Shy it sounds. We also found that categories like Happy or Mysterious were relatively unaffected by dynamics.

Further timbral analysis of the experiment results will give more insights about the emotional characteristics of piano sounds. This will help recording and audio engineers, composers, and pianists better understand the emotional dynamics of the piano and use them to engineer even more expressive recordings and performances, and to present and alter the mood and ambiance of their musical work.

Acknowledgments

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6. REFERENCES

[1] T. Eerola, R. Ferrer, and V. Alluri, "Timbre and affect dimensions: evidence from affect and similarity ratings and acoustic correlates of isolated instrument sounds," *Music Perception*, vol. 30, no. 1, pp. 49–70, 2012.

[2] B. Wu, A. Horner, and C. Lee, "Musical Timbre and Emotion: The Identification of Salient Timbral Features in Sustained Musical Instrument Tones Equalized in Attack Time and Spectral Centroid." in *Proc. 40th Int. Comp. Music Conf. (ICMC)*, 2014, pp. 928–934.

[3] ——, "The Correspondence of Music Emotion and Timbre in Sustained Musical Instrument Sounds," *J. Audio Eng. Soc.*, vol. 62, no. 10, pp. 663–675, 2014.

[4] C.-j. Chau, B. Wu, and A. Horner, "Timbre Features and Music Emotion in Plucked String, Mallet Percussion, and Keyboard Tones." in *Proc. 40th Int. Comp. Music Conf. (ICMC)*, 2014, pp. 982–989.

[5] ——, "The Emotional Characteristics and Timbre of Nonsustaining Instrument Sounds," *J. Audio Eng. Soc*, vol. 63, no. 4, 2015.

[6] L.-L. Balkwill and W. F. Thompson, "A cross-cultural investigation of the perception of emotion in music: Psychophysical and cultural cues," *Music Perception*, vol. 17, no. 1, pp. 43–64, 1999.

[7] J. Liebetrau, S. Schneider, and R. Jezierski, "Application of Free Choice Profiling for the Evaluation of Emotions Elicited by Music," in *Proc. 9th Int. Symp. Comput. Music Modeling and Retrieval (CMMR 2012): Music and Emotions*, 2012, pp. 78–93.

[8] M. Plewa and B. Kostek, "A Study on Correlation between Tempo and Mood of Music," in *Audio Eng. Soc. Conv. 133*. Audio Eng. Soc., 2012.

[9] K. R. Scherer and J. S. Oshinsky, "Cue utilization in emotion attribution from auditory stimuli," *Motivation and Emotion*, vol. 1, no. 4, pp. 331–346, 1977.

[10] I. Peretz, L. Gagnon, and B. Bouchard, "Music and emotion: perceptual determinants, immediacy, and isolation after brain damage," *Cognition*, vol. 68, no. 2, pp. 111–141, 1998.

[11] J.-J. Aucouturier, F. Pachet, and M. Sandler, ""The way it sounds": timbre models for analysis and retrieval of music signals," *IEEE Trans. Multimedia*, vol. 7, no. 6, pp. 1028–1035, 2005.

[12] G. Tzanetakis and P. Cook, "Musical genre classification of audio signals," *IEEE Trans. Speech Audio Process.*, vol. 10, no. 5, pp. 293–302, 2002.

[13] T. Eerola and J. K. Vuoskoski, "A comparison of the discrete and dimensional models of emotion in music," *Psychology of Music*, vol. 39, no. 1, pp. 18–49, 2011.

[14] B. Wu, S. Wun, C. Lee, and A. Horner, "Spectral Correlates in Emotion Labeling of Sustained Musical Instrument Tones," in *Proc. 14th Int. Soc. Music Inform. Retrieval Conf. (ISMIR)*, November 4–8 2013.

[15] B. Wu, A. Horner, and C. Lee, "Emotional Predisposition of Musical Instrument Timbres with Static Spectra," in *Proc. 15th Int. Soc. Music Inform. Retrieval Conf. (ISMIR)*, 11 2014, pp. 253–258.

[16] M. Goto, H. Hashiguchi, T. Nishimura, and R. Oka, "RWC Music Database: Music genre database and musical instrument sound database." in *Proc. Int. Soc. Music Inform. Retrieval Conf. (ISMIR)*, vol. 3, 2003, pp. 229–230.

[17] Cambridge University Press. Cambridge Academic Content Dictionary. [Online]. Available: http://dictionary.cambridge.org/dictionary/american-english

[18] R. A. Bradley, "Paired comparisons: Some basic procedures and examples," *Nonparametric Methods*, vol. 4, pp. 299–326, 1984.