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Emotional Responses To Music: Influence Of Psycho-Acoustical Features

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Abstract

This study examined the relationship between music-elicited emotion and the psycho-acoustical features of music. Previous research has shown differences between emotions elicited by different musical selections. This study, however, looks at dynamic ratings of emotion throughout the duration of a selection. Fifteen participants continuously rated each of ten musical excerpts (jazz, classical, 17th-20th century). A LabVIEW instrument recorded the second-by-second ratings in a two-dimensional space of pleasantness and activation. PsySound (Cabrera, 2000) was used to analyze the excerpts for changes in psycho-acoustical features, providing second-by-second measures of dissonance, sharpness, multiplicity, tonalness, and volume. These changes were then correlated with mean changes in emotion for each excerpt. Cross correlation analysis showed that musical feature predictors of emotional responses varied greatly between excerpts. Activation was predicted by dissonance in one excerpt ($r = 0.708$ uncorrected for autocorrelation) but by loudness in another ($r = 0.521$). Tonalness predicted pleasantness in one excerpt ($r = 0.634$) but multiplicity did so in another (0.567). Other features showed lower correlations, perhaps due to low variance in the feature or the overriding influence of more prominent features. Variations in tempo and rhythmic complexity may also be important in eliciting emotion but were not measured in this study.
Keywords: Music, Emotion, Psycho-acoustics

1. Introduction

Though experienced by everyone, emotions remain an elusive and difficult-to-define phenomenon. One research strategy is to use music as a naturalistic means for dynamically eliciting emotion in the laboratory. The present study is an attempt to identify the features of this varied stimulus that produce emotional responses.

Generally three different approaches are used to describe emotion. One approach uses categories, and assumes that emotions are independent of one another. This idea presupposes the existence of basic emotions, from which other, secondary emotions stem. One concern about this approach to understanding emotions is the general lack of agreement as to what the basic emotions are (Sloboda, 2001).

A second approach assumes emotions vary along dimensions. The dimensions serve more as a continuum, in which the degree to which an emotion is felt can be measured. Commonly cited dimensions include valence, activity, and potency. Emotions such as relaxed and excited may be similar in valence but may differ greatly in activation, or the degree to which they arouse or stimulate. Gabrielson (2001) posits that of the emotion dimensions, two emerge as being the most significant -- the valence and activity dimensions.

The final approach involves prototypes. This approach involves less defined categories, where inclusion in a category is established by the object's similarity to a prototype.

The use of music as an elicitor of emotion in the laboratory has been infrequent (Sloboda, 2001). Some assume that the type of emotion elicited by music is different. Additionally, emotions are often explained evolutionarily, i.e. by how they improve biological survival. Emotions resulting from music, however, are harder to fit into an evolutionary framework (Sloboda, 2001). However, given the dynamic nature of music, it is possible that emotions elicited by music more accurately represent the human experience than other static methods, such as pictures. It is also argued that music is an especially valid elicitor in that people judge their emotional responses to music regularly (Sloboda, 2001). Finally, music carries fewer ethical concerns, while a broad range of emotions can still be elicited.

Sloboda and Juslin (2001) propose that there are different sources of emotion in music - intrinsic and extrinsic. The first source, intrinsic, accounts for the variance among responses that are due to the psycho-acoustical features of the music. Sloboda (1991) has found that certain characteristics elicit specific manifestations of emotion. He found that syncopation, enharmonic changes, and melodic appoggiaturas are associated with weeping or piloerection. Because this source is based in psycho-acoustical features that remain constant in repeated exposures, a consistent effect is seen over time.

Extrinsic sources can be further broken down into iconic and associative sources. Iconic sources of emotion develop from similarities between musical structures and events that convey an emotional tone. For example, a slow, quiet selection may communicate calm or peaceful emotions. Several studies have shown such correspondence (e.g. Bruner, 1990). Iconic sources are significant to the point that certain musical structures elicit specific body gestures and expressions (e.g. Clynes, 1977). That listeners show consistency in their labeling of an emotion to a selection of music suggests that the music elicits universal responses.

Finally, associative sources include the relationships listeners have between a piece of music and factors outside of the music. This differs from iconic sources in that listeners do not have to learn to associate iconic sources. Additionally, associative sources are unique to the individual. Music can act as a trigger for memories that are often emotionally laden. While their emotional effect is often significant, associative sources have no specific attachment to the music. A person can associate any type of emotion to a musical selection, despite its psycho-acoustical features. It is dependent only upon the individual. Associative sources differ in that while changing the musical structure can alter the emotions that stem from intrinsic and iconic sources, it will not necessarily change the emotions elicited from associative sources. Thus, emotion produced through associations may be evoked by whole pieces of music rather than changing within the piece as the features of the music change. It is important to note that not only can music elicit emotion but it can also be perceived as expressing emotion. The potential interaction of all these sources may help account for the variability in emotional response to music.

In order to examine what elicits emotion, the musical stimulus must be coded or quantified in some way. Past efforts have detected a significant emotional response, and then determined the musical feature that caused it (Sloboda, 1991). This method does not carry much validity. It is more objective to code the music before examining emotional response. The point is that the identification of musical features responsible for emotional changes is more persuasive if musical features and emotional responses are coded independently and their relationship examined afterward.

Certain methodological problems arise when using such dynamic stimuli. The most common methods used are either an open-ended format, a checklist, or a rating scale. In initial studies of emotion as elicited by music, participants asked to rate music were forced to give either an overall impression after a musical selection was finished, or rate small, truncated excerpts. This methodology does not adequately encompass the dynamic nature of music and the human emotional response thereto. One rating is hardly sufficient to capture the complete spectrum of emotions elicited by a lengthy and varied piece of music.

The open-ended format is the least conducive for continuous response. Listeners are free to respond as little or as much to each change in emotion as they want. The method is advantageous because there are no constraints on how a listener can describe their emotion outside of language itself. However, if there are rapid changes, it is difficult for listeners to keep up with the music while accurately recording their responses. The second method, the checklist, presupposes a categorical approach to emotion. A listener chooses one word from a given set to describe their emotion at a given time. This creates the problem of deciding which and how many words to include in the set. If too few are used, the participant cannot accurately describe their emotion. If too many are chosen, the participant will require too much time to find the appropriate word, and their sampling rate will decrease greatly. Again, because of the demands on the listener, a high sampling rate is hard to attain using this method. Listeners must continually search for and check the word closest to their emotion.

The final method, the rating scale, is more congruent with the dimensional approach to emotion. While three dimensions of emotion are often mentioned, there is debate on the number needed to obtain an accurate measure of emotion while not overloading the listener's cognitive ability. In congruence with Gabrielsson's findings that valence and activity have emerged as the two most significant, two dimensions have commonly been agreed upon. The two-dimensional emotional space is easily captured on a computer. Schubert (1999) found the resolution more than adequate to capture emotional response. It also allows for a high sampling rate.

A further methodological complication that arises from using music as an elicitor of emotion is data analysis. Because both the music and the felt emotion occur over time, two time series must be compared. Allowances must be made for the difference between the occurrence of the psycho-acoustical feature and the resulting emotion as well as differences between the emotion event and when it was recorded. Another important issue is autocorrelation present within each time series (Schubert, 2001).

Past studies have discovered relationships between music and emotion. Features such as melody, dynamics, rhythm, major and minor chords, and tempo have been compared with listener's aesthetic response, tension response, happiness ratings, and arousal. Findings indicate that loud or high pitched chords and rapid rhythms are interpreted as happier (Gabrielsson, 2001). Loudness has been the best predictor of arousal and has resulted in higher intensity emotions (Schubert, 2001).

It has been shown that these psycho-acoustical features can elicit varying emotional responses. However, many of the studies conducted have only examined emotional differences between selections. Fewer have examined how emotions vary and change within a piece, and how changing musical structures influence this. This study is an attempt to further examine how psycho-acoustical features influence emotion within a musical selection.

2. Methods

2.1 participants

Fifteen college students participated in the study. Eight of the students attended Bethel College, and the remaining seven were drawn from Mid-America Bible College, Hutchinson Community College, and Friends University. The students' ages ranged from 19 to 29 years, with a mean age of 22.4. Nine were male and six were female. Six of the participants had not participated in band, orchestra, choir, or private lessons in college or high school. The other nine students had some experience in at least one of those areas during high school or college.

2.2 apparatus

LabVIEW (National Instruments, Austin, TX) was used to create a virtual instrument to record the emotional response to the musical excerpts. A two-dimensional emotional space was created, based on Barrett and Russell's model (1999). The space consisted of a vertical dimension of activation and a horizontal dimension of pleasantness. Emotion words of varying degrees of activation and pleasantness formed a circumplex around a central point which indicated a neutral feeling. Among the emotion words used were alert, happy, contented, lethargic, and tense. Participants could use a computer mouse to control an indicator within the space signifying their current state of emotion. The closer they moved the indicator toward an emotion word, the greater the degree to which that emotion was felt. LabVIEW recorded the position of the indicator every second, in coordinate form, the first number indicating degree of pleasantness and the second the degree of activation.

PsySound was used to quantify the psycho-acoustical features of the ten musical excerpts. PsySound reads 16-bit signed integer files, at a sampling rate of 44100 Hz (Cabrera, 1999). These files are analyzed using successive overlapping 93 ms windows. PsySound then generates a second-by-second numerical representation of different features. Seven characteristics, dissonance, multiplicity, sharpness, two measures of tonalness, and two measures of loudness were examined in this study.

Dissonance can be described as a type of roughness (Cabrera, 1999). Four measures of dissonance are calculated by PsySound, using two different algorithms for both spectral and tonal dissonance. Tonal dissonance differs in that it only takes into account components of the spectrum that relate to tone. The measure used in this study was tonal dissonance. The two measures of tonalness used are pure and complex. Tonalness is defined as "the degree to which a sound has the sensory properties of a single complex tone such as a speech vowel" (Parncutt, 1989). As intonation gets increasingly worse, tonalness decreases. Pure tonalness (Ptonal) is a measure of how audible spectral pitches are. Complex tonalness (Ctonal) is a measure of how audible virtual pitches are. Spectral pitch is the pitch of an individual pure tone component, where as virtual pitch is the overall pitch, and is associated with grouping spectral pitches. (Parncutt, 1989, p. 25)

Multiplicity (Mult) measures how many tones are perceived simultaneously in a sound. Sharpness (SA) provides a rating of a sound on a scale from dull to sharp (Cabrera, 1999). This feature of sound is also called brightness or density, and can be thought of as a pitch-like aspect of timbre. Two measures of loudness were also used. Loudness (N) is the "subjective impression of the intensity of the sound" and is measured in sones. (Parncutt, 1989) The second is a measure of the loudness level in phones (LN).

2.3 experimental stimuli

Ten non-vocal musical excerpts were chosen for this experiment, representing a wide number of genres. The selection was also intended to cover a range of tempos and styles. Each excerpt was under two minutes long. The excerpts are as follows: (1) “Alabama”, John Coltrane; (2) “Symphony #5, 4th Movement”, Dimitri Shostakovich; (3) “Hobo Ho”, Charles Mingus; (4) “Scheherazade”, Mikolay Rimsky-Korsakov; (5) “Tanguedia III”, Astro Piazzolla; (6)“The Dreams and Prayers of Isaac the Blind”, Osvaldo Golijov; (7) “Prelude #5 in G Major”, Sergei Rachmaninoff; (8) “Sarabands, Sutie #6 in D Major”, Johann Sebastian Bach; (9) “Piece en forme de Habaner”, Maurice Ravel; (10) “Gran jota”, Francisco Tarrega.

2.4 procedure

One experimenter collected the emotion data using the ten excerpts. Participants were given a six practice excerpts to accustom themselves to using the LabVIEW instrument and moving the indicator. They then listened to the musical excerpts in random order to control for order effects while simultaneously reporting their emotional responses using the LabVIEW virtual instrument. A second experimenter then analyzed the excerpts using PsySound to produce the measures described above.

2.5 data analysis

Emotion ratings were averaged across all participants. The resulting means and PsySound numerical output were transferred into SYSTAT for evaluation. Cross correlation plots were created for every psycho-acoustical feature against both pleasantness and activation. A cross correlation plot shows the correlation between two time series at all possible lags in a given range. In this instance, the two time series were the emotion rating data and the psycho-acoustical feature quantification as per PsySound. Lags indicate that one series occurred before or after the other series. Given the order they were entered in this case, a negative lag indicates that the musical feature occurred that many seconds before the emotion rating. A positive lag indicates that the emotion rating occurred that many seconds before the musical feature. From the cross correlation plots, optimal lags were determined. These were then used to appropriately lag the emotion rating. Given human response time for both emotional response and reporting, the emotion rating would be expected to occur after the psycho-acoustical feature. Once the emotion rating was lagged, SYSTAT was used to calculate correlations between the two, but no correction for autocorrelation was employed.

3. Results

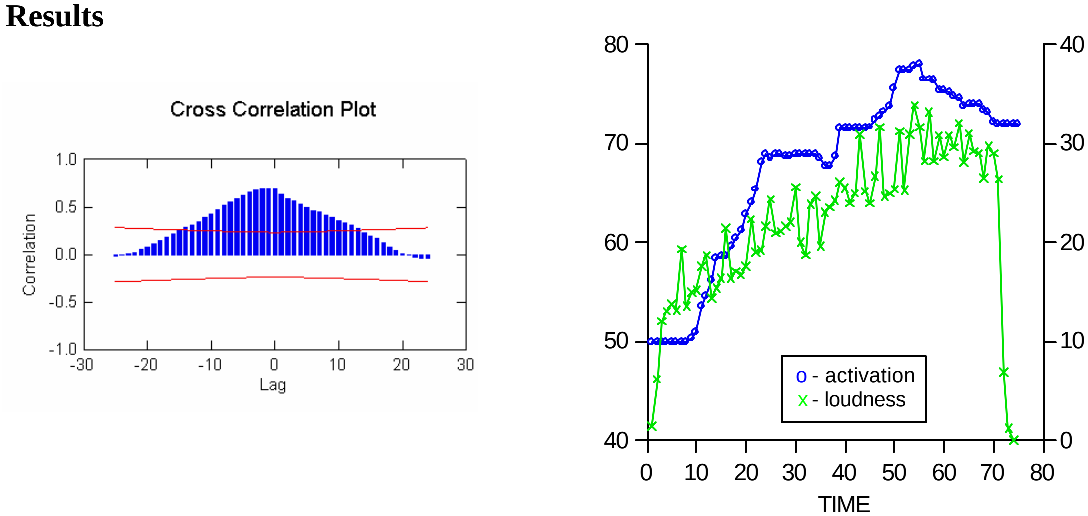

Figure 1. The left panel shows the cross correlation plot for activation and loudness from Piazzolla’s “Tanguedia III”. The right panel shows the measures as they vary throughout the excerpt.

As can be seen in the cross correlation plot from the activation and loudness (N) measures of Piazzolla’s “Tanguedia III” in figure 1, the peak occurs approximately at a lag of -3. Using this lag, a correlation between the two was calculated to be .821. Figure 2 shows both measures as they vary across the excerpt. While loudness has many smaller oscillations, it shows general increase throughout the first part of the song, as does the activation rating. Loudness has little net increase between 20 and 42 seconds. Similarly, the activation rating plateaus for this duration. At about 54 seconds, the song reaches its peak loudness, and while there are again small variations, there is an overall net decrease in loudness after this point. Very soon after loudness begins to decrease, activation does as well.

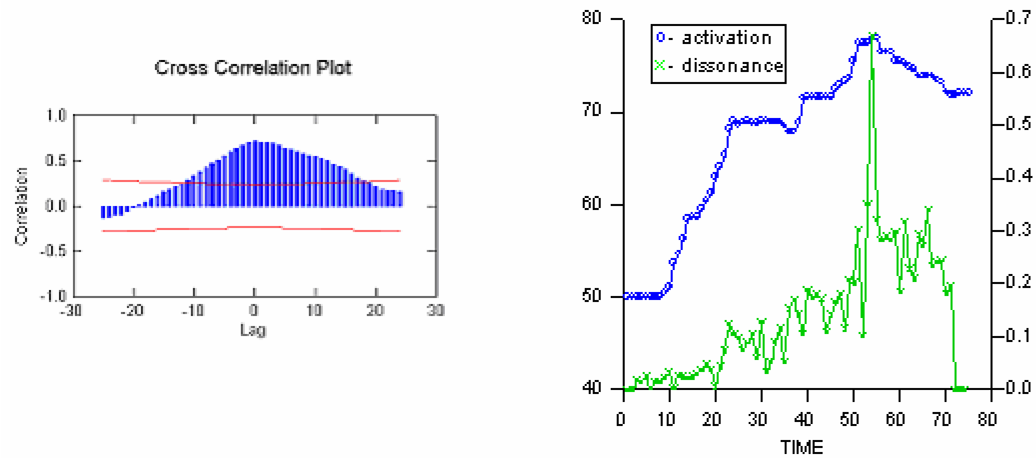

Figure 2. The left panel shows the cross correlation plot for activation and dissonance from Piazzolla's "Tanguedia III". The right panel shows the measures as they vary throughout the excerpt.

Figure 2 shows the cross correlation plot for the activation and tonal dissonance measures of "Piazzolla's Tanguedia III". The peak for this plot is approximately 0. At this lag, the correlation between activation and tonal dissonance is .708. As can be seen in Figure 2, the highest rating of activation occurs at the peak of the tonal dissonance. There is a similar trend in tonal dissonance and activation; they increase throughout the first part of the song, peak around 55 seconds, and then decrease until the end.

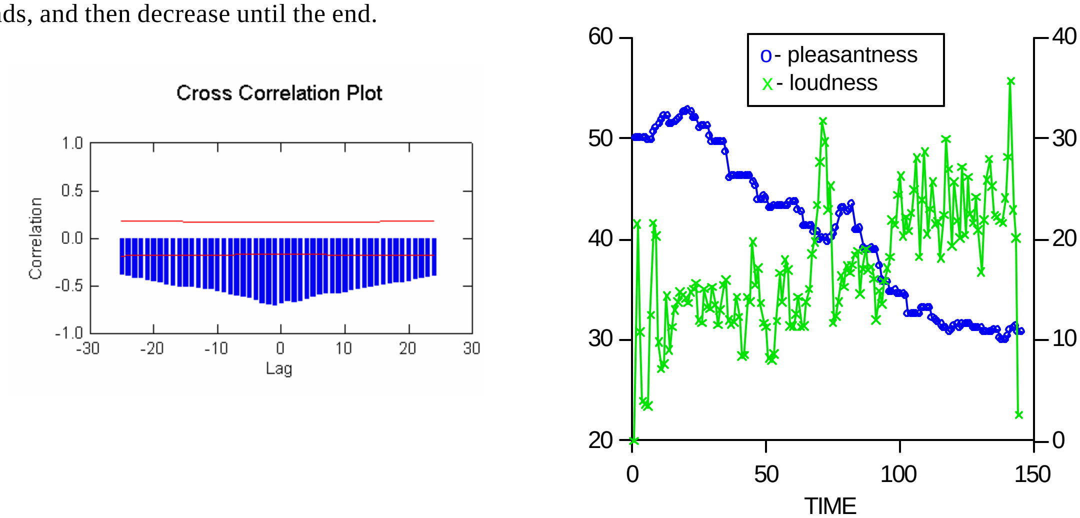

Figure 3. The left panel shows the cross correlation plot between pleasantness and loudness (N) for Golijov's "The Dreams and Prayers of Isaac the Blind". The right panel shows the measures as they vary during the excerpt.

Figure 3 shows the cross correlation plot between pleasantness and loudness (N) for Golijov's "The Dreams and Prayers of Isaac the Blind". The greatest correlation occurs at a lag of –2. The correlation between the two at this lag was -.705. The negative correlation indicates that as loudness increased, pleasantness decreased. Figure 6 shows this well. Pleasantness declined throughout the entire piece, with the exception of a small jump at approximately 80 seconds, and an initial increase at the start of the song. This jump at 80 seconds was preceded by a sharp increase in loudness. Loudness showed extreme fluctuation at the beginning. The variations diminished between 15 and 45 seconds. At approximately 60 seconds, a sharp increase began. Loudness decreased again, until 95 seconds, when there was another increase and it oscillated around 44 units.

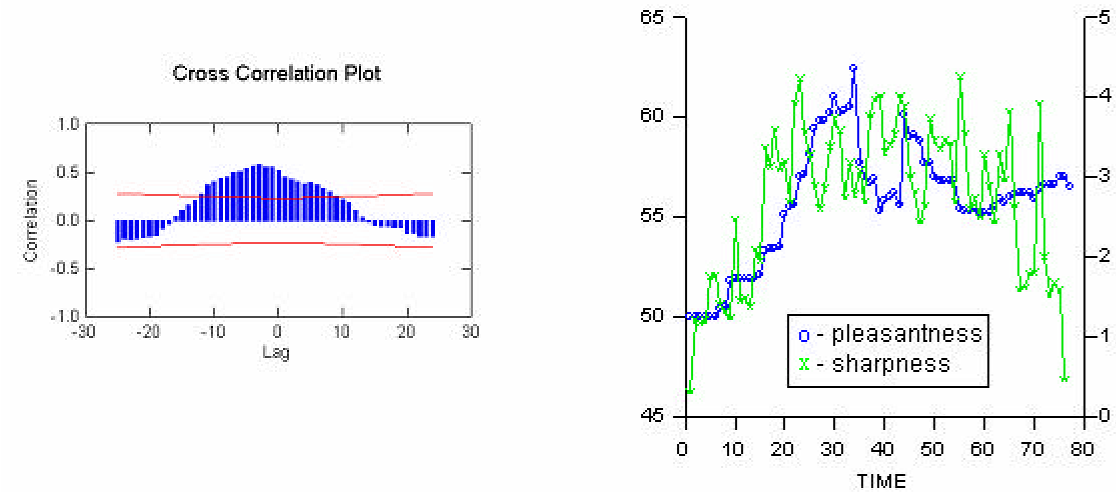

Figure 4. The left panel shows the cross correlation plot between pleasantness and sharpness for Charles Mingus' "Hobo Ho". The right panel is a plot of both features throughout the excerpt.

The cross correlation plot for pleasantness and sharpness of Charles Mingus' "Hobo Ho" can be seen in figure 4. At the peak lag of –3 seconds, the correlation is .648. As can be seen in Figure 4, both pleasantness and sharpness show an initial increase. Sharpness shows a net increase for the first 20 seconds. It then fluctuates with little net gain or loss, until approximately 55 seconds into the piece, when it decreases with the exception of one peak. Pleasantness increases for longer initial segment, until approximately 33 seconds. At this point it declines until about 42 seconds when it increases again. After this increase it decreases until about 55 seconds, and then increases minimally until the end.

The preceding set of graphs does not nearly encompass all the results. These are among the most prominent relationships found. As there were seven psycho-acoustical features to be compared with two dimensions of emotions for ten tracks, there were many resulting correlations. Due to space, such graphs cannot be created for each pairing of a psycho-acoustical feature and emotion rating. Therefore, a more comprehensive list is given in Figure 9, including those already graphed. In addition, to avoid reporting large numbers of correlations that might turn out to be spurious, a minimum absolute value of r of 0.4 was adopted; it was further assumed that correlations arising from lags of 5 or more seconds were unlikely to be meaningful. The abbreviations and track numbers refers to the feature and excerpt as listed in the methods section.

Table 1. The right panel shows the correlations between activation and feature. The left and middle panels show the correlations between pleasantness and feature.

ACTIVATION			
track	*feature*	*lag*	*r*
5	N	-3	0.821
6	N	-3	0.521
7	N	0	-0.455
5	LN	-4	0.773
6	LN	-2	0.587
7	LN	0	-0.426
6	CTONAL	0	-0.439
6	PTONAL	0	-0.422
5	SA	0	0.609
6	SA	-2	0.577
5	TDISS	0	0.708

PLEASANTNESS			
track	*feature*	*lag*	*r*
3	MULT	-4	0.515
6	MULT	-1	0.482
10	MULT	-1	0.567
3	LN	-3	0.644
6	LN	-2	-0.523
7	LN	-3	0.503
3	N	-3	0.577
4	N	-1	0.406
5	N	-5	-0.603
6	N	-2	-0.705
7	N	-4	0.449

PLEASANTNESS			
track	*feature*	*lag*	*r*
3	CTONAL	-4	0.404
6	CTONAL	-1	0.617
10	CTONAL	-1	0.439
3	PTONAL	-4	0.422
6	PTONAL	-1	0.634
10	PTONAL	-1	0.487
5	SA	-5	-0.676
6	SA	-2	-0.723
3	SA	-3	0.648
5	TDISS	-5	-0.671
6	TDISS	-1	-0.411

Table 1 shows the correlations (uncorrected for autocorrelation) between pleasantness and the seven psycho-acoustical features meeting the experimenter's criteria. One measure of loudness (N) met the criteria in five tracks. However, the peak lag was different for all five tracks. The other measure (LN) met the criteria in only 3 excerpts, but in each of those three the other measure of loudness (N) also met them. In two of the tracks, the peak lags were the same for LN and N, and in the third track, it varied by one second. Complex tonalness and pure tonalness each met the criteria in the same three tracks, at the same lags. Multiplicity met the criteria in three tracks, as did sharpness. Sharpness showed a positive relationship to pleasantness with Piazzolla's "Tanguedia III" and Golijov's "The Dreams and Prayers of Isaac the Blind", but correlated negatively with pleasantness in Mingus' "Hobo Ho".

Also shown are the correlations for relationships between activation and the psycho-acoustical features that met the criteria for inclusion. Both measures of loudness (N, LN) showed noteworthy correlations in Piazzolla's "Tanguedia III" and Golijov's "The Dreams and Prayers of Isaac the Blind", and Rachmaninoff's "Prelude #5 in G Major". Their peak lags varied, though. In Piazzolla's and Golijov's pieces they differed by one second, but in Rachmaninoff's piece it was the same. Both measures also showed a positive correlation for the Piazzolla and Golijov excerpts, but were related negatively to activation in the Rachmaninoff excerpt. Pure tonalness and complex tonalness also met inclusion criteria in the same excerpt, Golijov's piece, and both were negatively related. Sharpness met the criteria to activation in the Piazzolla and Golijov excerpts. Tonal dissonance showed a positive relationship to activation in Piazzolla's "Tanguedia III".

4. Discussion

These results demonstrate a relationship between changes in psycho-acoustical features and ratings of emotional response to musical excerpts. All seven features showed a correlation of greater than .4 in at least one excerpt.

If number of excerpts in which the relationship met inclusion criteria determines degree of influence, the measures of loudness seemed to play the most prominent role in influencing emotion. One possible explanation for this is that loudness is a basic element of sound quality and therefore elicits autonomic nervous system arousal. Loudness is also possibly one of the more distinguishable features to an untrained listener. Moreover, the greatest correlation occurred between a measure of loudness and activation.

Multiplicity showed positive correlations with pleasantness, but never met inclusion criteria when correlated with activation. This indicates that people report increasing feelings of pleasantness when multiplicity increases. Dissonance consistently had a negative effect on pleasantness, but a positive effect on activation. The two measures of tonalness showed opposite influences on emotion ratings. Tonalness was positively correlated with pleasantness and negatively correlated with activation.

In all of the relationships that met criteria for inclusion, only sharpness and loudness were inconsistent in the direction in which they influenced emotion. Both measures of loudness showed both positive and negative correlations with activation and pleasantness. Sharpness showed positive correlations consistently with activation. There were both negative and positive correlations, however, between it and pleasantness. There was consistency between the two measures of loudness. In the excerpts in which one measure of loudness influences pleasantness negatively, the other does as well. One possible explanation is that loudness influences emotion relative to the music. A crescendo does not necessarily mean an increase in pleasantness. Rather, it augments whatever emotion is being felt. If a piece is happy overall, a crescendo increases the degree to which it makes a person feel happy. If a piece is sad overall, a crescendo increases the degree to which it makes a person feel sad.

That sharpness showed inconsistency in regards to its relationship to pleasantness could be due to many factors. It is possible sharpness exerts its influence in the same manner loudness does. It is also possible that other factors were influencing the pleasantness rating in Mingus' "Hobo Ho" and it was not due to sharpness at all. Because of the interaction of so many variables, it is unlikely that absolute consistency would be seen across all music all the time.

Of note is the difference in peak lags between excerpts and psycho-acoustical features. That the highest correlation between features and emotion ratings occurred at varying lags is consistent with past research. Previous studies have found that abrupt changes in loudness result in a faster change in arousal. The conclusion that the lag structure is dynamic is supported by these results (Schubert, 2001).

If these features are responsible for the changing emotions experienced while listening to music, the question arises of why they did not influence emotional response in all tracks. One possibility is that a feature's prominence varies between excerpts. While dissonance is key for one piece, it may play little role in another. The amount of variation of a feature in a piece also determines its influence. As can be seen in Figure 5, dissonance

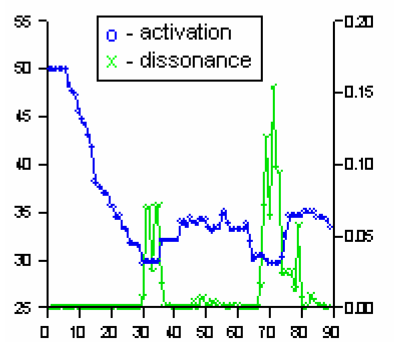

Figure 5 Shows dissonance and activation for Rachmaninoff's "Prelude #5 in G Major"

varies very little throughout the piece, remaining at a fairly constant level. However, at two points it has a fairly significant peak. At the same time dissonance peaks, activation can be seen to drop, only to rise again after dissonance decreases. The correlation between the two is only -.376, not enough for inclusion. Dissonance influences emotional response when fluctuating or varying, but when constant has no effect on changing emotion. There is a steady decrease in activation at the beginning when dissonance remains constant. This suggests that other features are also influencing the activation rating, as one might expect.

A similar trend can be seen in track 6, as shown in figure 6. What seems to result in higher pleasantness ratings is variation in loudness, not a specific loudness. When there was a spike, pleasantness increased. Again, at the beginning when it was fluctuating, pleasantness ratings increased. When the loudness seemed to oscillate around one unit, pleasantness decreased.

It may also be possible that the combination of features has a larger effect than a single feature. In addition, these seven features can hardly be considered to encompass all the features of music. Aspects such as rhythmic complexity or tempo where not considered in this experiment. It is possible that these features were more prominent in the excerpts that showed no correlation to the features examined here. Further research should examine other features.

It should also be noted that this study looked only at intrinsic sources of emotion. Associative sources of emotion may not be consistent across participants nor in keeping with expected elicited emotions based on psycho-acoustical features.

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