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Timbre aspects of ride cymbals: Sound coloration analysis using psychoacoustic models and subjective evaluation

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The timbre of a musical instrument is a multidimensional concept that relies on the complexity of human perception. So far, there are only a few studies concerning the timbre of percussion instruments. The sound characteristics of cymbals depend on geometry, material, ways of playing, and so on. On the perceptive side, sound coloration is one of the dimensions most used by musicians to compare the timbre of ride cymbals. In order to get insight into the perception of the sound of ride cymbals, subjective evaluations of recorded cymbal sounds were carried out using rating scales. Psychoacoustic models, such as Sharpness and Tonality, were also used to analyze the sound signals. Based on these objective analysis, together with subjetive evaluations made by musicians, linear regression models were proposed to quantify perceptive dimensions such as brightness and darkness. The coefficients of determination obtained with the regressions indicate that psychoacoustic models could be used as a feasible way to represent sound coloration of ride cymbals.

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1 Introduction

A cymbal is a percussion instrument used in many music genres. It became more famous at the beginning of the 20st century, when music groups started to use drum sets, with cymbals added to them [1]. Nowadays, there is a massive production of different types of cymbals, varying in geometry, materials and the way they are played. These parameters shape the cymbal sound and therefore its timbre as a multidimensional variable.

An usual playing technique is the impact with a drumstick in different spots of the instrument's surface. The term *Ride* is used to describe a specific type of cymbal in a drum set, generally the ones with the largest diameters (18 to 24 inch), but also to describe a way of playing and defining rhythm.

There are many attributes (words, adjectives) in the drummers vocabulary to differentiate cymbal timbre aspects. Two of the most often used to describe the coloration of the sound produced by a ride cymbal are the adjectives *Bright* and *Dark* [1, 2, 3, 4]. In a classification system proposed by a cymbal manufacturer [4], sound color range refers to the overall relative strength of higher to lower frequencies, from very *Bright* to very *Dark*. But questions remains if these terms are related to specific sensations of the musicians.

Psychoacoustics is a field of study with the purpose of investigating auditory sensations. The ability of our hearing system to receive information is determined not only by the qualitative relation between sound and impression, but also by the quantitative relation between acoustical stimuli and hearing sensations [6]. Psychoacoustic models are used to model specific human hearing sensations.

The main goal of this work was to obtain an initial relationship between objective measurements and subjective evaluation of cymbal sounds, in order to quantify hearing sensations described by musicians when mentioning the timbre of this instrument. The objective measurements used in this work are psychoacoustic models related to the sensations of Loudness, Sharpness and Tonality. The subjective evaluation was carried out through listening tests with musicians.

The first step of this work was the recording of sound samples of ride cymbals using the same method of drumstick striking made by a trained musician. After that, all signals were normalized using a Loudness model proposed by Zwicker [5, 6, 7]. After the normalization, the mean values of Sharpness and Tonality, according to the models proposed by Aures [8, 9, 10] were obtained. The normalized samples were used in a subjective listening evaluation with a group of 13 musicians (drummers). The subjective evaluation of the samples were compared and related to the output from results of the psychoacoustic analysis. The next sections show details about how the procedure was carried out, in order to obtain the presented results.

2 Sound samples recording

A set of sound samples was obtained by recording sound pressure signals due to the impact on different ride cymbal models, as shown in the Table 1. The recordings were made in a semi-anechoic chamber using the binaural recording torso HMSIII from *HEAD Acoustics*. There was no standard pattern found in the literature, for cymbal recordings regarding microphone and drummer position. However, it is quite common between drummers to use the ride cymbals positioned below the musician's torso [1]. Therefore, all cymbal models were supported on a cymbal rack at the same height ($h = 1.10\mathrm{m}$), without screwing (just supported). Both musician and recording torso were positioned at a distance of $d = 0.80\mathrm{m}$, in front of each other, facing the center of the cymbal, as shown in Figure 1.

Table 1 – Ride cymbal models used to record samples.

Sample (number)	Company	Cymbal model	Diameter (in.)	Condition
1	Zildjian	Avedis Medium Ride	18”	Used
2	Paiste	1000 Ride	20”	Used
3	Sabian	B8 Pro Ride	20”	Used
4	Impression	Jazz Ride	22”	New
5	Impression	Hard Medium Thin Ride	22”	New
6	Impression	Dark Medium Thin Ride	20”	New
7	Impression	Rock Ride	21”	New
8	Impression	Traditional Medium Thin Ride	21”	New
9	Paiste	502 Ride	20”	Used
10	Paiste	502 Crash Ride	18”	Used

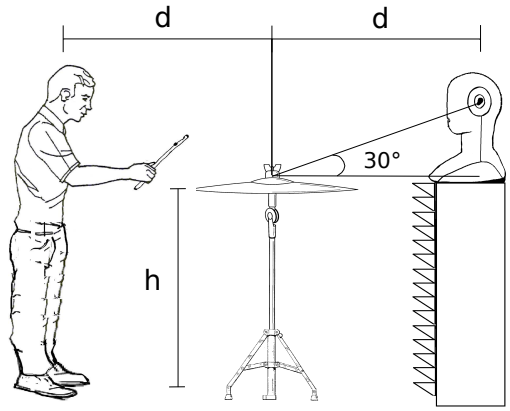
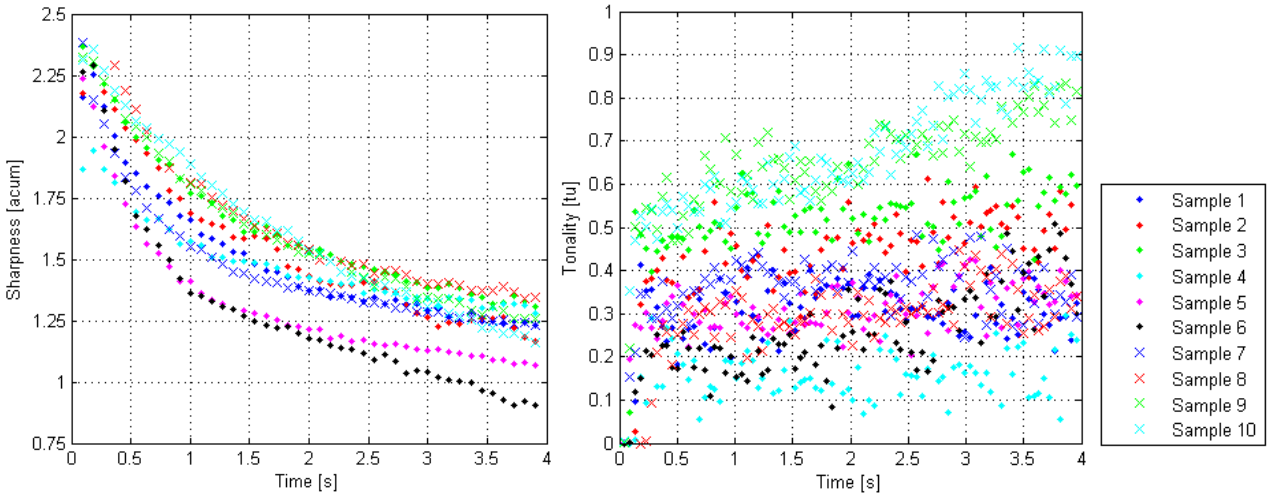


Figure 1 – Sound sample recording scheme in the semi-anechoic chamber.

All cymbals were struck by the same trained professional percussion musician, with the same drumstick model (*Liverpool Classic Series Marfim 5B*), at a point on the top surface at half of the radius, and with a musical dynamic level referenced as *forte*. An accelerometer was fixed on the drumstick body to be used as a trigger for the recordings. Duration of all recordings was $T = 4$s.

In order to exclude loudness as a primary aspect in timbre, and taking into account that all samples are transients, the 5th percentile loudness N_5 [11, 12, 13] was normalized to 16 sones (soneGF), a value that according to [14] describes a musical dynamic level *forte*. This was achieved by an iterative procedure wherein the pressure signal was multiplied by a varying coefficient in steps, until it reached the desired N_5 of 16 sones. This iterative procedure was realized for both channels of the recorded samples: left and right. The software used for the normalization algorithm were *MATLAB* and *ArtemiS 10.000* (from *HEAD Acoustics*)[7]. After normalization, Sharpness and Tonality were calculated using *ArtemiS*.

Figures 2a and 2b show, respectively, the mean channel (left and right) results of Sharpness and Tonality (both Aures models) over time, for all recorded and loudness normalized samples. Table 2 show the mean values over time of Sharpness and Tonality, for each sample.



(a) (b)

Figure 2 – Aures Sharpness(a) and Aures Tonality(b) over time for 10 recorded samples.

Table 2 – Temporal mean of Sharpness and Tonality for each sample.

Sample number	1	2	3	4	5	6	7	8	9	10
Sharpness [acum]	1.50	1.54	1.63	1.48	1.32	1.28	1.47	1.59	1.61	1.61
Tonality [tu]	0.30	0.44	0.52	0.16	0.31	0.26	0.36	0.29	0.65	0.67

3 Subjective evaluation

In the subjective evaluation, the sound samples were evaluated by means of two discrete rating scales for sound coloration, one evaluating brightness and the other darkness. All sounds were randomly grouped into two groups of five samples, and each one was evaluated on the *Bright* and the *Dark* scaling rate, without sample repetition. Figure 3 shows an example of the questionnaire applied using the *Labview* GUI.



Figure 3 – Questionnaire GUI used for *Bright* rating.

The subjects should choose 10 for the brightest (or darkest) in a group, 0 for the less *Bright* (or *Dark*)

and rate the others between these two. The random presentation order was used to check if these adjectives can be used or not as a pair in a semantic differential for these type of sounds. The equipment used for this evaluation was: a notebook with *Labview*, to run the questionnaires and acquire all data from the subjects; a PEQ V audio interface, from *HEAD Acoustics*; and *Sennheiser HD600* headphones to present the normalized sound aurally correct and calibrated. The evaluation was realized in a quiet meeting room (background noise around 35 dBA), at common ambient temperature and lightning.

The subjects that took part of the experiment were 13 musicians (drummers and percussionists), some of them professionals and others that were hobby drummers. The shortest previous music experience was 5 years, and all of them were aware of the meaning of the adjectives *Bright* and *Dark*.

After the subjective evaluation, a statistical analysis was carried out in order to check if there is agreement between the evaluation of the participants (inter-subject correlation). It was found that the rating given for group 2 samples (both for *Bright* and *Dark* rating), show a better agreement between the subjects. This is confirmed by the intraclass correlation coefficient (ICC) of 0.76 and 0.79, respectively for each group. An ICC higher than 0.75 was considered as a feasible agreement [15, 16]. The results are shown as boxplot diagrams in Figure 4.

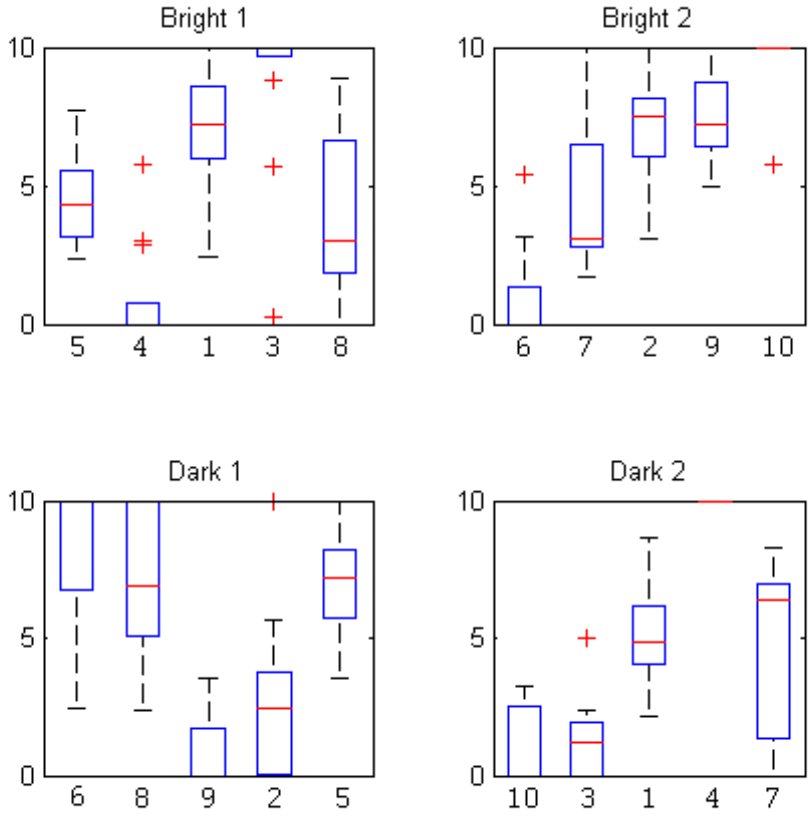


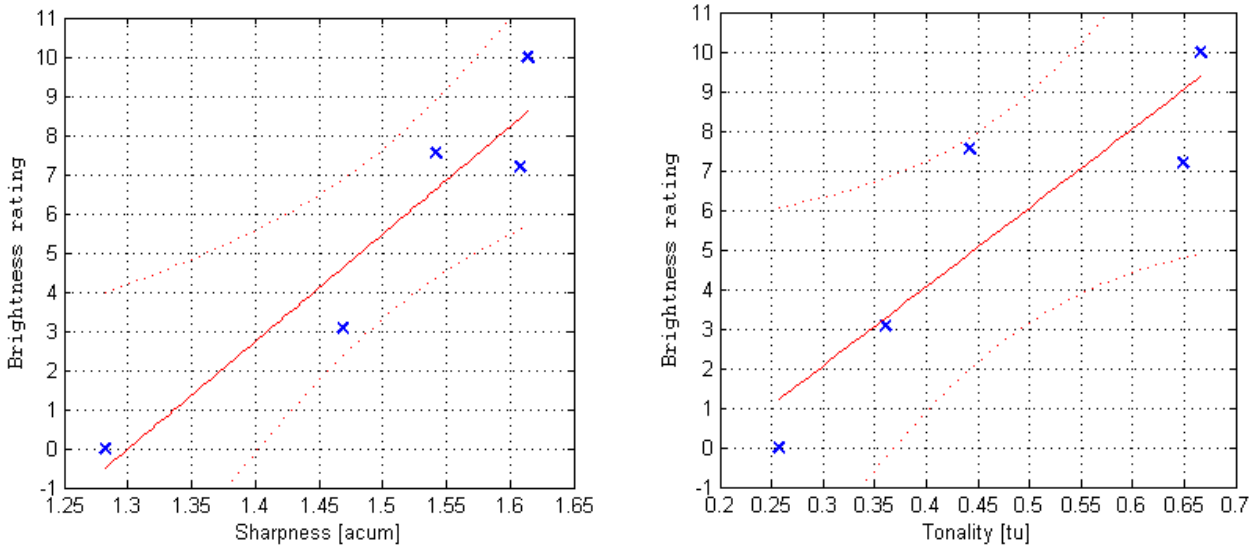
Figure 4 – Boxplot diagrams for the evaluation on the *Bright* and *Dark* scales of different groups of samples. X-axis: sound sample number; Y-axis: subjective scaling rate. *Bright* sample group 1: ICC $= 0.52$; *Bright* sample group 2: ICC $= 0.76$; *Dark* sample group 1: ICC $= 0.64$; *Dark* sample group 2: ICC $= 0.79$.

4 Correlation analysis and linear regression

In the last part of this work, correlation analysis and linear regressions were made between the mean magnitudes of Sharpness and Tonality sensations determined with psychoacoustic models (as independent variables) and subjective ratings (as dependent variables). The presented results are related only with *Bright* sample group 2 and *Dark* sample group 2, which achieved the highest ICC values of the evaluation between subjects.

For the *Bright* perception, the mean value of the subjective rating of each sample from group 2 highly correlates with the temporal mean of Aures Sharpness, showing a Pearson correlation coefficient of $r = 0.943$. A linear regression (Figure 5a), being the temporal mean of Sharpness the independent variable and the subjective level of brightness the dependent variable shows a coefficient of determination of $R^2 = 0.89$.

The temporal mean of the Tonality of the samples, shows a Pearson correlation coefficient of $r = 0.898$ with the *Bright* rating. In a linear regression (Figure 5b) a coefficient of determination of $R^2 = 0.807$ was found being the temporal mean of the Tonality of the samples the dependent variable. For this particularly group of random samples of ride cymbals, the brightness can be seen as being directly related to Sharpness and Tonality.

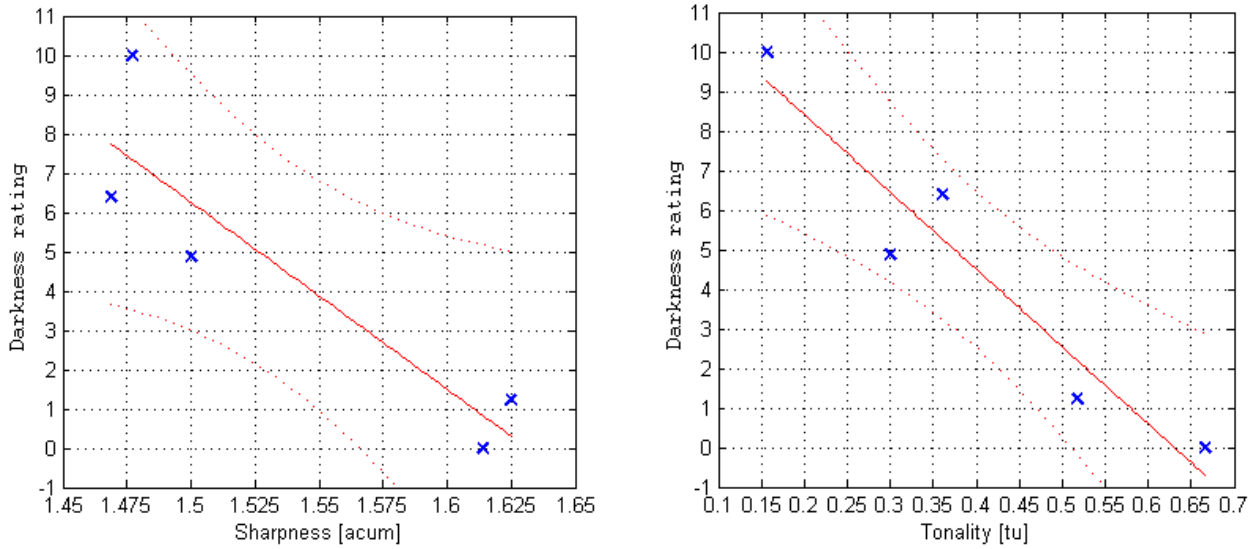


(a) (b)

Figure 5 – Linear regression for subjective *brightness* evaluation (dependent variable) and mean psychoacoustic models (independent variable) of *Bright* sample group 2. (a) Aures' model for Sharpness; (b) Aures' model for Tonality. Blue dots: acquired data; Red solid line: regression fit; Red dotted line: 95% confidence bounds.

The same was made for the adjective *dark* and the samples from group 2. The temporal mean of the sample Sharpness shows a Pearson correlation coefficient of $r = -0.901$ with the *darkness* scaling level. For the linear regression model, the coefficient of determination achieved was $R^2 = 0.812$ (Figure 6a).

For the temporal mean of Tonality Pearson correlation coefficient was $r = 0.8$ and in a linear regression the coefficient of determination was $R^2 = 0.91$ (Figure 6b). For this particularly group of random samples of ride cymbals, the darkness can be seen as being inversely proportional to Sharpness and Tonality.



(a) (b)

Figure 6 – Linear regression for subjective *darkness* evaluation (dependent variable) and mean psychoacoustic models (independent variable) of *Dark* sample group 2. (a) Aures' model for Sharpness; (b) Aures' model for Tonality. Blue dots: acquired data; Red solid line: regression fit; Red dotted line: 95% confidence bounds.

5 Conclusions

The analysis of timbre aspects of percussion instruments using psychoacoustic models was never presented in the literature regarding ride cymbals. The aspect of sound coloration, frequently used to describe sound differences between ride cymbals, was analyzed using sharpness and tonality measurements determined by means of psychoacoustic models

After the results of linear regression, the two main terms used to represent sound coloration (*Bright* and *Dark*), seemed to correlate with one another for two of the sample groups analyzed that obtained the highest agreement between subjects, showing ICC values around 0.75. Even for a small number of participants, there was a considerable agreement in the scaling of two important perceptions: brightness and darkness.

For the evaluation of the *Bright* term, the results have shown a proportional relation with the sharpness sensation, represented by the psychoacoustic model. The opposite was true for the term *Dark*, that presented an inversely proportional relationship with the sharpness sensation. Regarding the characteristics of spectral density, specifically the sensation of tonal components represented by the Tonality model, samples with higher mean values were considered *brighter*. Samples with less prominent tonal components, or "noisy", were considered as being darker.

So, it can be seen for the analyzed groups of samples, that *Bright* and *Dark* have presented an inversely proportional relation between each other, even for different samples and random orders. It is possible to fit them into a semantic differential sound coloration analysis regarding these type of ride cymbal sounds. The results can be used as an initial approach to cymbal sound objective analysis.

An important characteristic of cymbal sounds is the transient behavior in both spectral and temporal domains. In this work, as the mean values of the psychoacoustic models (Sharpness and Tonality) were considered, spectral and temporal variation differences between samples were ignored. In future work, these kinds of behavior should be considered and analyzed for different timbre aspects. For this kind of analysis, one should consider psychoacoustic models that incorporate transient behavior, for example the

loudness model proposed by Moore [17].

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