Comparative Study made on Piano Timbre Perception

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40 piano professionals and musical acoustics experts have participated to this listening experiment. We compared results obtained with two different perceptual tasks: similarity judgment on a “same-different” evaluative scale and free categorization. Chromatic scales and melodies played by a single pianist on 9 different concert pianos and recorded under identical acoustic conditions constituted the two types of stimuli. Data extracted from subject’s descriptions suggest a distinct vocabulary linked to piano timbre. Similar statistics obtained with two different listening tests illustrated that piano players are able to describe precisely the feature of timbre through listening as well as playing. The classes of similarities organized by listeners gathered instruments with close spectrums. Even if the subjects had used different listening strategies, the classifications were the same for the majority of them. Preliminary sound analysis supports the semantics used for describing features of timbre.

1 Introduction

The first level to recognize sound is the source identity, but timbre has no precise definition because it refers to a quality more than to a dimension (i.e. quantity). Then, sounds timbre can be compared if they are produced by similar sources.

2 Problematic

Our research is focused mainly on the categorization aspects of the piano timbre. The aim is to find relations between timbre perception and the physical/acoustical variations responsible in perceptive categorization and quality preference. We expect significant correlations between verbal descriptors and piano groups characters. Differences between pianos, revealed through auditory categorization tasks could help in defining acoustical descriptors of subjects gathering. The comparative analysis of these vectors must bring information on timbre categorization and perception.

3 Test Setup

3.1 Experimental Methods

The method of timbre (dis)similarity judgment demands the subjects to listen to pairs of stimuli and to quantify their degree of (dis)similitude on a graded different-same perceptive scale (fig.1). This method develops a total listening and a spontaneous perceptive judgment, allowing subjects the possibility of answering what they really perceived. The interpretation of data is made through the tree analysis method.

The same method of analysis is used in the model of free categorization, which is a technique of experimentation elaborated according to the principle of prototypical categorization. Subjects can freely setup classes of stimuli by following the (dis)similarity criteria. All items must be classified. This task has two parts: the first requires the organization of the stimuli in classes following timbre characteristics; the second demands semantic qualification as well as the establishment of a prototype for each one of these classes.

3.2 Procedure

The instruments were chosen in order to create a homogeneous group in terms of manufacture and quality. Nine concerto pianos were used in this experiment; except a single “3/4 queue” (piano 9) all pianos were 1/2 queue. The pianos’ manufacture was hidden in order to avoid subjectivity in quality judgments. The sound was captured in the same position of microphones by rotating the 9 pianos. A single pianist played the same two musical sequences on each instrument.

3.3 Listening Test

Stimuli were presented stereo over professional speakers in a phono-isolated room at LAM by using a McIntosh computer interface. Generally, 50 min were enough for passing the entire test and all the subjects were able to finish it. More than 50% of participants had already participated to previous listening tests concerning musical or noise stimuli.
3.4 Participants

40 professional musicians, women and men between 17 and 62 years old, were tested. Several pianists had participated in a previous study in which the same instruments were used. The participants were in majority pianists and acousticians but there were also several luthiers and tuner craftsmen. The subject’s panel was split in two, in order to examine the influence of stimuli order.

3.5 Sound Stimuli

Two types of stimuli were used. The first was a chromatic scale descending from La 440 Hz to La 220 Hz and the second was a 7 seconds sequence from "The Obermann’s Valley" by Frantz Liszt, treated with a short ‘fade in’ and ‘fade out’. In task A, the chromatic scales couples were presented with a 4 sec. inter-trial interval, the interval between items of a pair being 1,5 sec. Subjects were previously familiarized with the nature of stimuli.

3.6 Tasks

Three auditory tasks (A, B1, B2) and one visual task (C) were presented to the participants.

Task A (16 min) required the subjects to listen to a long sequence of pairs of downward chromatic scales (LA3 440Hz to LA2 220Hz) played on 9 various pianos. Musicians had to estimate the degree of similitude on a different-same evaluative scale as shown in the next representation:

DIFFERENT   undecided   SAME

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Figure 1: different-same evaluative scale

There were 89 scales of this type, each one of them corresponding to a piano pair. Regarding the traditional method, I introduced an additional element, the possibility of answering "undecided" ("do not know"). The role of the "undecided" box was to divide the scale in two distinct perceptive sections: different – not different. However, if the subject chooses "undecided", that could also represent a behavioral "marker".

Task B (20 min) required the subjects to freely set up groups of pianos by judging them trough timbre similarities. This categorization task had two sections: B1 and B2, each one representing the application of the same method on different stimuli. Stimuli used in B1 were individual chromatic scales from task A. In the B2 task, the piano items corresponded to a 7 sec. musical sequence from the "Obermann’s Valley" by F Liszt. Subjects were asked to define categorization criteria only after the classes were already formed. Stimuli were displayed on the computer screen. Participants had the opportunity to listen freely the piano items by activating the corresponding shortcuts. It is necessary to specify that we changed the items depending on tasks’ feature in order to avoid subjectivity in categorization preference.

In the visual task C the stimuli were the same chromatics scales as those used in tasks A and B1, this time presented like images (sonogram representations, fig. 2,3).

Figure 2: piano 1 & 2 (10 kHz, 4100 bands, 100% time window), hamming

Figure 3: piano 5 & 7 (10 kHz, 4100 bands, 100% time window, hamming)

The instructions of the visual task remained identical to those of the listening task B1, the subject having to gather the images through free criteria. The 9 images were simplified sonograms of the chromatic scales as shown in the previous example.

3.7 Analysis Method

Developed on contrast models, the tree analysis method transforms the average matrix of all individual answers (proximity matrix fig. 4) in a tree representation, as showed in the figure below. In our case, proximity matrix has 9 rows and columns corresponding to the 9 pianos we used. The number situated at the intersection between rows and columns indicates how different the pianos were inside the
couple (1=same, 10=different). Any possible pair and order configuration are included.

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Figure 4: Proximity matrix for subject 17 in task A

The tree structure (fig 6,7 etc.) is constructed through this proximity matrix and offers a bi-dimensionally image, the experimenter having no choice in choosing the representation. Each tree knot represents a category and each leaf represents an object included in this category. The distances between the group’s elements are interpreted in terms of distinctive traits and the distances between the groups as commons traits for the group’s elements. For example, by measuring distance through the shortest way between the end of two leafs we can determine how distant the corresponding stimuli were. In task A (fig.7) the largest perceptive distance was found between Piano 7 & 8 while the shortest corresponds to the Piano 1 & 2.

The coefficients related to branches’ knots represent the “taux d’arboricite” [arborescent rate (A.R.)] and the class’s knots symbolize “le taux de quadruplets bien representees (Q.B.R.)” [Well Represented Quadruplets Rate]. Tree structure requires several statistic conditions. Previous research showed that tree structure becomes pertinent when the values of these coefficients are greater than 0.75.

We considered this method is well adapted to our study since the nature of physical parameters involved in the perceptive organization was not preset.

4 Results and Discussions

In order to verify if the musicians were able to judge timbre similarity in a coherent way, we constituted in task A several behavioral markers. More precisely, specific pairs formed by repeating the same stimulus (Piano8 – Piano8, Piano2 - Piano2 etc) were positioned at equal distance in the sequence.

The next example illustrates the answers’ evolution for subjects 17 and 40 (fig 5) in case of the pairs formed by repetition of the same piano. The average answers are represented in blue and the individual answers in red.

Observations made on markers reveal that the great majority of participants were highly precise in their evaluations. However, isolated subjects (like subject 40) had difficulties in finding correctly the highest (1) degree of similarity for the pairs formed by the repetition of the same piano. Despite this, nobody was eliminated from the statistics by considering that all answers are pertinent. By studying subject’s trees, we found that interactions between subjects and tasks or between subjects and stimuli (fig 6) were not significant, fact which supports the solid musical formation of the participants. This validates similar results obtained through the marker method.

Figure 6: Subject trees for B1 and B2 tasks

An important global observation is that the perceptual distances between piano classes revealed the same configurations for both methods and stimuli conditions (fig. 7, 8)
Subjects didn’t encountered major difficulties regarding task A and nobody stopped during the stimuli series. Concentration as well as frequent changes in the listening strategy due to the repetition of stimuli, determined the subjects to consider the task A the most interesting but also the most difficult one. The statistics of the tree configuration had the A.R. 0.66 and Q.B.R 0.88 (fig. 7). This means the groups' structure did not have enough coherence, however the distances between elements in these classes are relevant.

Attention was paid to stimuli order effects inside series but no significant influences were found among the orders of presentation (fig. 9)

Musical formation of the participants was also taken into account and the results showed non-significant interactions between these categories. (Fig. 10&11)

However, it appears that piano classes organized by acousticians (fig. 10) are the most coherent (coefficient 1). Thus, they established in the task A a distinct group formed by pianos 9 & 4, configuration that is absent in classes gathered by the others. Interestingly, this configuration is very well defined in the visual task C (fig. 8). This could suggest that specific listening strategies as well as specific skills in analyzing visual representations of sounds, give acousticians more pertinence in their answers. The main classes constituted in all these tasks were piano 1 & 2 and piano 5 & 7. The tree configuration related to B1 task (fig. 7) had A.R. 0.74 and QBR 0.87. For B2 (fig. 8) the corresponding coefficients were 0.81 and 0.92.

Task B2 (music) was considered the most pleasant and took more time than B1 (chromatic scales). Listening to a musical phrase requires superior cognitive functions because of the complex structure of the stimulus. Second part of these two tasks required correlations between piano sound and semantic descriptors.

The comparison between task correspondent trees reveals quite identical structures (fig. 7, 8).

Same configuration was obtained in task C (fig 8). More interesting is the fact that in this visual task the classes were highly homogeneous revealing very short perceptual distances between elements inside groups. That means classes of similarities were formed especially by inclusion rather by exclusion. This task was only 2 to 5 minutes long, constraining the subjects to apply a quick evaluation, through a holistic analysis.
of the images. We intended to establish if visual and auditory systems are managed in same manner through the categorization tasks. Results showed close tree configurations with those from the auditory tasks.

In order to examine connections between verbalization corpora and the acoustical structure of stimuli we chose the best represented piano classes which correspond to the same two couples in all tasks: Piano 1 & 2 and Piano 5 & 7. As previously mentioned, in the second part of tasks B1 and B2 subjects described the characteristics of the groups, which were already formed in the first part. For the first group we often met adjectives like: clair [clear], brillant, net [precise] (B1) as well as brillant, métallique [metallic], clair, ouvert [open] (B2). Considering the second group constituted by pianos 5 & 7, the verbalizations were: sourd [dull], doux [soft], feutré [felty] (B1) or feutré, doux, intérieur (B2). Interestingly, despite the same tree organization, the adjective sourd was mostly used for defining the chromatic scales, feutré being used in case of musical sequence. These two words are synonyms in the “piano language”; in spite of this, subjects had significant preferences in using these attributes depending on the type of stimuli.

The subjects were also asked to establish the best representative (prototype) for each class of pianos but they encountered difficulties for this requirement.

The detailed analysis of the acoustic descriptors will constitute the next aim of our study. The present research institutes only a global approach by observing in sound spectrum architecture possible connections with the piano classes and semantics. Thus, we found that the average spectrum concerning the same chromatic scale played on 4 different pianos supports the verbal descriptors as well as group’s configuration. Regarding the first piano couple, the spectrum structure shows a relatively equilibrate distribution of energy and reveals the presence of superior partials (fig. 12, 13).

For the first group, spectral envelope follows a quite straight slope, better observed in case of piano 2 (fig 13). The other couple presents a clear trimming between inferior and superior spectrum manifested around 5.2 / 5.5 kHz.
5 Conclusions

Preliminary observations in sound spectrums suggest that two main axes correspond to piano classes and their semantic descriptors. The most obvious was the Brilliant – Opaque (or synonyms) dimension. Another direction appears to be équilibré (balanced) / non équilibré (unbalanced) (or synonyms), and should correspond to the repartition of energy in sound spectrum.

Trees’ configuration revealed that coefficients of classes were quite powerful. Except several difficulties in establishing the prototypes all subjects responded to the tasks’ demands. The main gathering concerns two big classes, the most obvious being 3,5,7,9 and 1,2,4. The piano 6 & 8 were difficult to classify and appear in the same category, in this case formed by the exclusion of these two elements from the other categories. Inside these groups, the most significant classes were 1 & 2 (brilliant) and 5 & 7 (sourd) [dull]. From the perspective of quality and preference, they found piano 9 as being the most pleasant piano. This result is not surprising since piano 9 was the unique ¾ queue used in our experiment. We also noticed that, piano 4 was qualified as very “aggressive”, (B1 test), the sonogram revealing a higher energy that was unequally distributed in sound spectrum. Piano 8 was also difficult to classify which could come from the staccato manner of interpretation on this particular instrument.

Several musicians included in the present investigation had also participated in previous research made on semantic attributes used in piano timbre descriptions. The study was made on the same instruments. The difference consisted in the fact that the subjects had the possibility of a free playing on the instruments while in the present work they were constrained to listen only. Comparisons between these two tests revealed similar attributes and common timbre features as well as close tree configurations. This statement suggests that pianists were able to describe and categorize timbre in the same manner through listening as well as playing.

Order effects as well as interactions between stimuli, subjects and methods did not revealed significant influences in the final classification. Same results were obtained by studying musical formation or age and gender interactions. Data extracted from subject’s descriptions suggests a distinct vocabulary linked to piano timbre. Classes of similarities organized by listeners gathered Instruments with close spectrums. Even if the subjects had used different listening strategies, the classifications were the same for the majority of them. Also, preliminary sound analysis supports the semantics used by subjects for describing the features of piano timbre.

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