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Research of perceptual descriptors discriminating clarinet reeds of identical stiffness

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ABSTRACT

From the musician's point of view, reeds considered as identical by the manufacturer (same cut, same strength and same brand) may exhibit large perceptual difference in terms of musical qualities. Past studies, carried out with clarinetists or saxophonists, have revealed that the reeds were mainly differentiated on the basis of their "ease of playing" which appears as the main perceptual descriptor of reed quality. This descriptor proved to be correlated with the reed stiffness measured at its tip in either static or dynamic conditions. The current study aims at discovering if other perceptual descriptors can be used to differentiate between reeds that would obtain similar "ease of playing" assessments (i.e. that exhibit the same stiffness). Firstly, the reeds are sorted on the basis of stiffness measurements carried out at the reed tip by using an artificial musician. Secondly, reeds of equivalent stiffness are selected for perceptual assessment by professional clarinet players. As this selection process might result in subtle differences between reeds, the musicians are asked to differentiate between them by using a comparison test. In addition to this perceptual assessment, the subjects are asked to verbally describe their criteria for reed differentiation.

1. INTRODUCTION

Woodwinds instruments such as the clarinet or the saxophone use a single reed mounted on a mouthpiece coupled to a resonator in order to produce sound using a constant pressure

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in the musician's mouth. After the resonator, the reed probably play the most important role in sound production but remains largely misunderstood. Most of the time, reeds are made of a grassy plant known in French as *Canne de Provence*. Manufacturers design reeds with varying cuts (i.e., surface geometry) and strength with respect to the mechanical stiffness, which is commonly expressed with a number ranging from 1 to 5 or with labels (Soft, Medium, Hard). According to musicians, two reeds sold as identical in strength and cut by the manufacturer may be perceived as very different in quality. A survey reported that 30 % of them are described as very bad, and only 30 % are of sufficient quality to be played in a concert [1, 2]. Additionally, a variety of perceptual investigations have been carried out and documented in academic publications. Some evaluate reed quality as an overall criterion [2, 3] or as a combination of descriptors related to timbre (such as brightness), intonation, or ease of playing [4, 5]. However, because it causes significant intra- and inter-musician discrepancies, overall quality does not appear to be a useful criterion for reed categorization [2, 6]. While researchers have only discovered that reed stiffness (in static or dynamic situations) predicts playing ease [3, 7] and opening at rest predicts intonation [7] for a single player, they are still attempting to create a physical measure to predict perceptual descriptors for various musicians.

Finally, it appears that scientists can quantify several physical indicators on reeds, but the primary challenge is identifying alternative perceptual indices of reed quality other than apparent strength. Some results from the literature review suggest indicators. Nevertheless, some of these new indicators appear to be also correlated with perceived ease of playing (like timbre) [1,2]. Some other indicators have been established by a single musician, who may not be representative of the entire musical community [7].

The purpose of this work is to present a novel experimental procedure for characterizing clarinet reeds. First, this technique tries to determine perceptive descriptors that are complementary to perceived strength. Second, based on Taillard's results [7], it should permit the evaluation of the mechanical properties of reeds installed on a mouthpiece. The final goal is to identify the features that are utilized by different musicians to distinguish reeds with identical stiffness characteristics, aside from "ease of playing" or "global quality".

Sections 2.1 and 2.3 deal with perceptual assessments of reeds. The musician is first asked to classify the reeds according to his own criterion. Reeds of equivalent classes will then be compared by pairs with the musician verbalizing how he perceived the difference. Section 2.2 presents the stiffness measurements carried out on the reeds between these two perceptual assessments. In this experiment, reeds are mounted on a mouthpiece and pressed with a synthetic lip to measure mechanical properties under static conditions.

2. EXPERIMENTAL SETUP

2.1. Reed classification

The design of this initial perceptual test is based on results obtained by Gaillard *et al.* [6]. The primary purpose is to determine whether the musician can provide consistent reed classifications across multiple tests. To facilitate the musician's task and to ensure that the results are reliable, the test is being carried out under ecological conditions.

The musician is asked to buy twenty reeds identical to those he usually uses and to number them. Then, he is asked to design his own assessment procedure, as he might naturally classify them according to a descriptor such as "ease of playing" or "global quality". The task is to classify the twenty new reeds according to his own categories by assessing each reed in a few seconds. He has to perform the same assessment procedure ten times on ten different days. Each ranking is independently reported.

The first and last classifications of the reeds are carried out at the laboratory with the experimenter. At the beginning, the experimenter helps the musician to define his categories and ensures that the musician is sufficiently aware of the task to carry it out autonomously at home.

At the end, the experimenter supervises the classification by the musician to check that the tests in autonomy were carried out according to the indicated protocol. The time required for the musicians is estimated at 3 hours and a half. The first session at the lab lasts an hour. Each of the autonomous classifications can be achieved in 15 minutes. The final lab session lasts 30 minutes. The first and last sessions are two or three weeks apart.

Finally, the twenty reeds and the ten classification results are collected to estimate the robustness of the clarinetist. The reeds with the highest agreement score are used for steps 2 and 3 of the experiment.

2.2. Stiffness measurement

In order to determine the objective properties of reeds, a device for measuring mechanical stiffness was designed. It allows measurements of the stiffness of the reed attached to the mouthpiece and pressed with a lip. This device is based on the artificial musician proposed by Gazengel *et al.* [8] and Munoz [1]. The test rig is presented in Figure 1. A clarinet mouthpiece (Vandoren BD4) is clamped with a reed on it and fixed with a ligature. A rectangular artificial lip made of silicone (30 mm \times 10 mm \times 7 mm) is designed to move along the z -axis (parallel to the height of the reed) and the x -axis (perpendicular to the height of the reed). The force produced by the lip on the reed is measured by placing the lip on a force sensor. A camera located above the system takes pictures of the reed channel (*i.e.* the opening between the mouthpiece tip and the reed tip). This measurement method is very close to the one proposed by Taillard [7] but instead of measuring the lip displacement, the lip force is measured here.

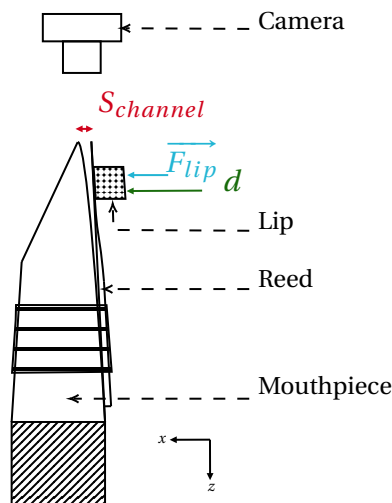


Figure 1: Setup for the reed static stiffness measurement designed for this experiment.

The lip was moved in 0.4 mm increments along the x -axis from the maximum channel opening (no lip force) until its complete closure. For each lip position, the force signal was recorded and a picture of the channel was taken. The surface area of the canal was then estimated using image processing tools adapted from previous works [9]. An example of the system characteristic is presented in Figure 2.

The characteristic could be divided in three sections [8]. Firstly, for low lip forces, the linear part of the curve could be approached by a line. Its slope and y -intercept, respectively, correspond to the reed compliance and opening surface of the channel at rest. Secondly, for intermediate forces, the curve shows non-linearity. It could be approximated by a second-degree equation and corresponds to the bending of the reed on the mouthpiece rails. Thirdly, for high forces, the whole reed is in contact with the mouthpiece, inducing the complete closure of the channel. It is

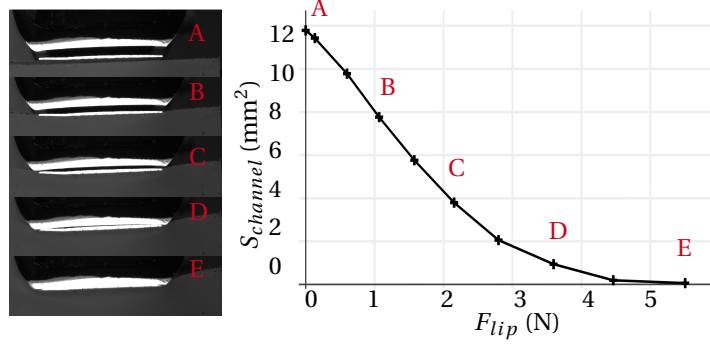


Figure 2: Surface of the reed channel for different lip forces applied on the reed. The lip force increases with the lip displacement on the reed. The left side presents pictures taken by the camera.

modelled by a constant value. Finally, each characteristic is defined by 4 coefficients, illustrated in Figure 3 :

- The reed opening surface at rest S_{00} .
- The maximum force F_M exerted by the lip on the reed assuming a linear behavior of the reed (constant stiffness).
- The range of force C on which the stiffness is nonlinear. The parabola is estimated from this coefficient.
- The value of the constant part L of the characteristic corresponding to an eventual leak if $L \neq 0$.

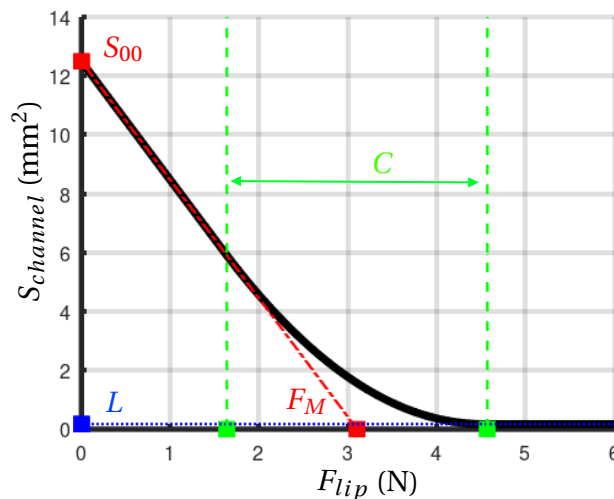


Figure 3: Four coefficients used to model the stiffness characteristic of reeds.

This nonlinear stiffness measurement was repeated 10 times with the same reed. Each time, the system is mounted and unmounted. The uncertainties for the 4 coefficients are given in Table

1. The absolute standard deviations of S_{00} , F_M and C are small enough to be confident in this measuring bench. This indicator is higher for the leak value L . In fact, it is most of the time caused by a lack of precision in the reed positioning, which results in shadow over the mouthpiece tip. It is recognized as a small channel opening by the image processing tool, which makes its interpretation highly hypothetical.

Parameter	Mean	Standard Deviation	std/M
S_{00} (mm ²)	12.21	0.18	1.5%
F_M (N)	3.05	0.06	2%
C	1.52	0.06	3.7%
L (mm ²)	0.15	0.01	6.9%

Table 1: Uncertainty (mean (M) and standard deviation (std)) for the 4 coefficients.

2.3. Reed comparisons

The main goal of this step of the protocol is twofold. The idea is to check whether it is possible to determine a reed differentiation threshold according to the stiffness measurement conducted on the assessed reeds. In addition, verbalization would enable to determine which perceptual indicators seem the most important in terms of reed quality.

The reeds are here compared according to a *AB* paradigm: the musician successively assesses two reeds provided by the experimenter. The two reeds may be different or not. The musician's first task is to indicate whether or not the two reeds are different. The time required to change the reed between the two tests is about 15 seconds. About 6 or possibly 7 reeds could be included in the paired comparisons test. In addition to the differentiation task, the musician has to describe in a few words the criteria that enabled him to identify the differences between the two reeds.

3. PRELIMINARY RESULTS

3.1. Physical measurements

The measurement setup was characterized with 50 identical (Vandoren V12 - strength 3) reeds that were measured according to the protocol described previously. The variability of the four coefficient extracted from the nonlinear stiffness is presented in Table 2. The absolute standard deviation of all these coefficients is higher than the experimental uncertainty. As a consequence, this measurement setup appears suitable for reed comparison. It should be noted anyway that it provided too much uncertainty for the leak measurements L , that were not kept for further analysis.

Parameter	Mean	Standard Deviation	std/M
S_{00} (mm ²)	12.18	0.71	5.8%
F_M (N)	3.36	0.26	7.9%
C	1.55	0.29	19%
L (mm ²)	0.21	0.13	64.9%

Table 2: Variability of the 4 coefficients for the measurement of 50 identical clarinet reeds.

A Principal Component Analysis (PCA) was computed with *Jamovi* [10] to determine how many dimensions are needed to explain the variance in the results. Three variables were input,

S_{00} , C and $K = \frac{FM}{S_{00}}$, which is the reed stiffness (in $\text{N}\cdot\text{mm}^{-2}$). Each variable is standardized. Figure 4a shows that the system can be described thanks to two dimensions explaining 89.2 % of the whole variance. One of the dimension is mainly due to the stiffness K and the other one to the opening at rest S_{00} . Using the K-means method, reeds can be separated in clusters. Figure 4b shows that two groups are identified and separated on the basis of S_{00} . Cluster 1 in blue contains reeds with the largest opening at rest and cluster 2 in yellow, with the smallest. Each group contains reeds with a large stiffness range. This outcome is consistent with Taillard's observation [7], which emphasizes that reeds are mainly characterized by two parameters: stiffness and opening at rest (which are connected to "ease of playing" and "intonation," respectively).

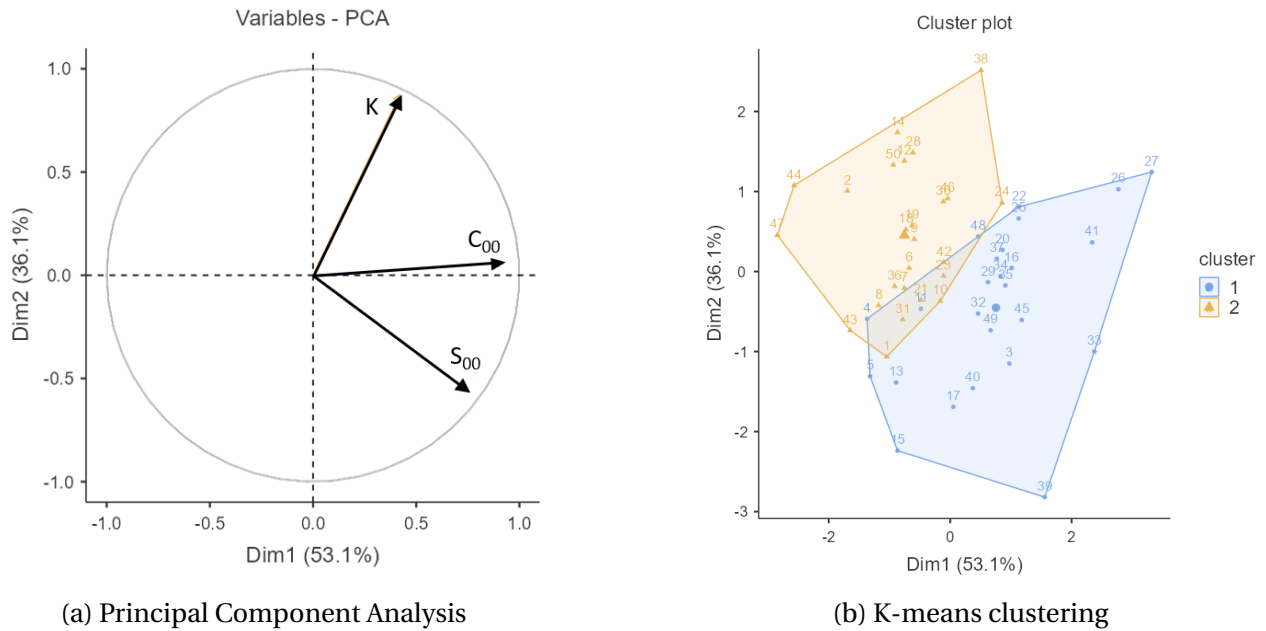


Figure 4: Classifications of the 50 reeds into 2 dimensional groups.

3.2. Perceptual evaluation

Based on the work of Prins *et al.* [11], various comparison tests have been experienced before to concentrated on the *AB* paradigm. Firstly, the 3-Interval 3-Alternative Forced Choice (3I3AFC) method has been tested. It involves comparing two reeds : a reference reed and a test reed. For this purpose, the experimenter presents the reference reed to the musician twice and the test reed once, in random order. The musician has to identify in which position the test reed was presented by playing a few notes each time. In this case, the task proved to be far too difficult for the musicians. The time between the assessment of the first reed and the third one is very long (much more than 1 minute). The musician's memory related to tactile sensation and musical sounds is not long enough for this task (under 10 seconds) [12, 13]. Secondly, an *ABX* paradigm has been tested. This involves presenting the musician a reed *A*, then a reed *B* and finally a reed *X* identical to reed *A* or reed *B*. The musician has to identify whether reed *X* corresponds to reed *A* or reed *B*. Preliminary tests with clarinet players have shown that it is easier than the 3I3AFC test, but the problem of sensory memory between reeds *A* and *X* remains the same. In addition, the musician's fatigue, occurring after 10 pairs (50 minutes), does not permit him to carry the test any longer. It means that only 5 reeds could be involved in this paired comparison protocol.

Finally, the *AB* paradigm appeared as the most suited one. As only two reeds are tested in each comparison, this protocol is less demanding for the musician's sensitive memory. Besides facilitating the musician's task, it also enables to test a larger number of pairs and thus increasing the number of perceptual observations. Before setting up the experiment with a

dozen of musicians, a preliminary test was conducted with one experienced musician. Ten reeds were considered and were classified in the categories only one time. Not all the comparisons combinations were tested, only ten of them. The results are presented in Tables 3 and 4.

Criteria	Too hard	Good	Too weak
Reed number	6, 3, 4	8, 7, 1, 2	5, 10, 9

Table 3: Assessment of reeds in categories chosen by the musician

Test	A	B	Answer	Self-confidence	Criteria
1	6	9	D	90%	Timbre + ease of playing
2	4	5	D	90%	Timbre + ease of playing + blowing noise
3	1	1	D*	50%	blowing noise
4	3	8	I*	10%	
5	10	9	D	40%	Blowing noise
6	2	2	I	70%	Timber
7	7	5	D	90%	Timbre + ease of playing + blowing noise
8	6	3	D	70%	Ease of playing
9	4	4	I	30%	Blowing noise
10	8	7	D	10%	Ease of playing

Table 4: Results of the preliminary comparison test. The colors in the *A* and *B* columns are related to the colors of the categories in Table 3. The * in the column *Answer* indicates a wrong answer.

As Table 4 shows, the difficulty of the test seems to be adapted to the task but other preliminary test should be conducted to get other musicians' feedback on it. As a result, the musician gave a wrong answer only two times over ten. The clarinetist also had to indicate her confidence in her answer. It clearly appeared that the less different the reeds, the smaller the confidence rate. Even if the answer is correct, the musician could hesitate before giving it. This variable provides an estimate of the degree of randomness in the musicians' responses.

The tester reported that the verbalization task should be improved since it was very difficult for her to express her perception. Two solutions are under consideration. Firstly, the criteria could be proposed in the form of a list and the musician could choose those that best suit him. The list could be based on the tester's vocabulary. Secondly, the tester could express himself as he wishes while the experimenter records what he says. To make this verbalization easier to analyze later, the number of sentences would be limited. In all cases, the musician will be offered a significant training phase with comparisons of increasing difficulty.

4. CONCLUSION

In this paper, protocols of both perceptual and physical measurements are presented. Each step of the experiment have been tested and preliminary results are shown in this article. The experimental conditions of the perceptual test need to be improved by a first musician who will give us feedback. If necessary, the number of repetitions of the classification and the method chosen for verbalization can be changed to be more adapted to the other musicians. The physical measurements of reeds were proven reliable and interesting conclusions are raised. Reeds can be classified according to their opening at rest and stiffness. The procedure is likely to be efficient if

the twenty reeds chosen by the musicians are taken into account. The main perspective for further conclusions is to make correlations between perceptual evaluations and physical measurements.

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