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# EFFECT OF WOOD ON THE SOUND OF OBOE AS SIMULATED BY THE CHANTER OF A 16-INCH FRENCH BAGPIPE

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## ABSTRACT

Many objective and subjective experiments on brass instruments, organs, flutes and clarinets have shown that the influence of material was weak. Yet, the influence of wood on the sound of oboes is still to be determined. In this study, short musical recordings of ten French 16" bagpipes made of 5 different woods (African Ebony, Santos Rosewood, Boxwood, African Blackwood and Service Tree) were presented to subjects (specialist and naïve), who had to give their feedback on several criteria (global quality, warmth, aggressiveness, brightness, volume and attack precision). The choice of a bagpipe rather than a simple oboe enables to minimize the influence of the musician, as he is not directly in contact with the reed. An influence of the reed material was found, but no influence of the wood. In a second experiment, a discrimination task allowed to confirm that the differences between chanters were not principally due to the wood. Several physical parameters calculated from recorded signals could also not reveal any large differences between woods.

*Keywords : wood, oboe, woodwind instrument*

## 1. INTRODUCTION

Very different opinions can be found among musicians, acousticians and musical instrument makers regarding the influence of materials on the sound of instruments. When the sound is generated by the body of the instrument (a violin for example), the choice of materials can be essential (see [1] for string instruments, [2] for drums). On the other hand, the sound of wind instruments is generated by the air column inside the instrument and depends on the mode of air column excitation, the shape of the air column (cylindrical or conical), and the air column's length, controlled by opening and closing the finger holes on the instrument. Material, as it is not directly involved in sound generation, is therefore less likely to have a significant impact on sound qualities.

## 1.1. Brass instruments

The effect of wall vibration has been studied with brass instruments [3]. Whitehouse et al. [4] have shown that mechanical wall resonances were excited when a simple wind instrument, consisting of a mouthpiece and section of metal piping, was artificially blown. The strength of those induced wall vibrations was dependent on how close in frequency the artificially blown resonances and the structural resonances were. The material of the pipe affected the position of the structural modes and hence its response to a particular note. In [5], one-third octave sound level measurements were recorded for four yellow brass and three nickel–silver French horn bell flares of varying hardness. The sound level associated with the unannealed brass flares was higher in the 1–3 kHz range than with the annealed brass bell flares, whereas the opposite relationship was observed for nickel–silver bell flares.

Organ is not part of the brass family, but some of the organ pipes are made of thin metal wall. In [6], the resonating air column in a thin-walled metal organ pipe was observed to interact with a wall resonance. Effects became audible when a wall resonance frequency was nearly the same as that of the air column. Level changes of 6 dB and frequency shifts of 20 cents were found. In [7], the influence of the wall vibrations on the timbre of flue organ pipes have been studied by measuring wall velocity and sound spectra of wooden and metallic pipes. While large differences have been found in vibration spectra, only slight changes have been observed in the sound signal.

## 1.2. Woodwind instruments: wall vibration

The wall vibration (and the possible influence of material upon this vibration) was also studied for woodwind instruments [8,9,10]. The main physical process at the origin of sounds produced by woodwinds is the radiation of the open end(s) of the waveguide [11]. The mechanical vibrations of the instrument wall may contribute to sound production by: i) structure/internal fluid interaction, ii) structure/external fluid interaction and iii) inter-modal coupling due to the radiation of the open end of the waveguide. In [12], a model for the vibroacoustic behaviour of an ersatz clarinet was presented, including the above-mentioned kinds of coupling. The radiated sound power from the lateral wall was found to be much lower than the sound power radiated from the open end. Backus [13] also showed that the wall vibrations of a woodwind instrument do not affect (or to a very low extent) its steady tone either by radiating sound themselves or by affecting the harmonic structure of the internal standing wave.

So it seems that the contribution of the wall vibration was quite negligible in pipes with no circularity default. However, the vibration of the air column could be altered by oval shaping of the wall and the state of the internal surface [14]. Moreover, an analysis of recordings of a transversal flute made from the dried stem of the *Heracleum laciniatum* (with an irregular circularity) was presented in [15] (Hanssen). While the lower octave exhibited conventional harmonic spectra, the upper octave surprisingly included subharmonic components. Authors believed that the subharmonic contributions were due to nonlinear oscillations of the flute material.

### **1.3. Woodwind instruments: wall losses, state of the internal surface**

Beyond its impact on wall vibrations, materials can have an influence on the state of the internal surface. Some studies [16,17] indicated that wall losses (frictions and thermal energy transfer to the instrument walls) have a great effect on the eigenvalues. Benade [18] and Fletcher [19] also indicated that the viscous loss of energy to the pipe walls, along with the loss due to conduction of heat into and out of the air column from the walls during each cycle of the sound wave, both contribute to the dominant energy expenditure of most instruments. More precisely, Yin and Horoshenkov [20] indicated that porosity modified the high order modes. Wegst [21] indicated that the tube material influences the sound of the instrument and its playability by vibrational damping due to air friction at the tube walls (lower in tubes with a smooth finish) and by turbulences in the vibrating air at the edges (which are reduced when the extremity edges, as those of the finger holes, are cut precisely and finished slightly rounded). It explains why the woods from which the wind instruments of the Western symphony orchestra are made traditionally are dense, have a fine structure and a high dimensional stability, especially when exposed to high levels of moisture. They can be turned and drilled with great accuracy, and they are sufficiently dimensionally stable under the influence of moisture [22,23].

### **1.4. Woodwind instruments: perceptive effect of wood**

The above-mentioned studies have sometimes revealed an objective influence of materials (because of wall vibrations or the internal surface state). Nevertheless, this influence was not always audible: in [24], three keyless flutes of identical internal dimensions and made of thin silver, heavy copper, and wood, respectively were played out of sight to musically experienced observers, who had to indicate whether tones were alike or not. No significant correlation between the listeners' answers and the material of the instrument was found. In [25], 7 flutes with different materials were evaluated by 110 persons. Although the sound analysis pointed out objective differences, statistical analysis on perceptual results showed subjects could not differentiate between materials.

However, in [26], a nickel silver/copper alloy Bundy and a silver Muramatsu were used, and the Bundy was found to be more "reverberant," while MLS measurements revealed that the Muramatsu had more high frequency components. The authors indicated a large difference between the two flutes in tone quality. In [27], two flutes of the same maker and model, but with one being made of gold and the other one of silver, were played and slight differences in the radiated sound of the two flutes were found. Yet authors raised some questions: would those differences also be found in two "identical" flutes (of the same material), since no instrument can be exactly identical? Could two flutes of the same maker, model and material sound different, due to slight differences in manufacturing ?

## **1.5. Wood of oboes**

Studies on oboe quality as a function of the wood are rare. Pfeister [28] used an oboe made of Grenadilla wood and another one made of a plastic resin, and found that there were noticeable differences overall such as larger amplitudes of the higher harmonics present in the wooden oboe. Moreover the wooden oboe impedances had higher impedance levels at high frequencies but often lower levels for the fundamental frequency of each note. Higher impedance levels can indicate (i) that, at that frequency, more pressure waves are bouncing back to the top of the instrument (so at the mouthpiece), making the instrument easier to play, and (ii) that the higher harmonics have a greater impact on the sound output resulting in a more complex sound (this trend in the wooden oboe became even more apparent in the upper notes).

Moreover, oboes have conical bore, with a pipe radius that gets very low close to the double reed. At this point, as the thickness of the boundary layer (in which turbulences are important and gradients of particle velocity and temperature are high) is large compared to the pipe radius, wood could possibly have a significant influence.

## **1.6. The french 16" bagpipe**

The sound of a reed instrument is strongly dependent upon the player's lips position. If the pipe material has an effect, the player should be able to compensate for it with his lips. Bagpipes are worth being used for experiments on pipe perception because the player has no direct influence on the reed, since the reeds of chanter and drones are enclosed in stocks. The 16" bagpipe is a traditional instrument from the Centre of France. It consists of a bag, usually a blowpipe used to blow the bag, two drones with cylindrical bores and single reeds, and a quasi-chromatic chanter; the small drone plays a G3, whereas the big one plays a G2. The chanter, unlike the drones, is equipped with a double reed and has a conical bore. These instruments are exclusively homemade, and the most common wood species are Boxwood, African Blackwood, and Service Tree. Traditionally, the chanter double reeds have been made of cane, but nowadays more and more players use synthetic ones (plastic is interesting to make reeds because they are less dependent on moisture levels, high temperatures and ageing).

According to the unique study available on the perception of the materials of bagpipe chanters (which used a bagpipe close to the 16" French bagpipe of the present study) [29], sounds from chanters made of various wood species seem to be different. This perceptive observation was confirmed by several objective differences in measured spectra. However, differences between chanters could not be related to any physical property of the wood, such as density. Moreover, this study was limited because it relied on i) the assessment of chanter sounds by only one listener and ii) the use of only one reed and one chanter per wood species.

In this study, short musical sequences played on a 16"-bagpipe with chanters made of 5 different woods were recorded and presented through two tests to "piper-listeners" and "non piper"

listeners. They were asked to assess “the quality of sound” during a first session, then to report quantitative feedbacks on “brightness”, “aggressiveness”, “warmth”, “volume” and “attack precision” during a second session. In an additional experiment, subjects’ capacity of discrimination between chanters made of different wood were investigated.

## 2. EXPERIMENT A

### 2.1. Material and methods

#### 2.1.1. Chanters and recordings

The chanters under test were made in duplicate from different species of wood: African Ebony, Santos Rosewood, Boxwood, African Grenadilla and Service Tree. The chanters were 44.5 cm long (the air column was actually 4.8 cm longer because of the additional duct of the double reed). As the internal bore was conical, the internal diameter of the chanter was 3.8 mm close to the reed and 19mm at the end of the pipe. The dimensions of the ten chanters were identical. When making the chanters, a rough cone was firstly dug inside a piece of wood using several drill bits of different diameters. Then, the internal shape was completed with conical reamers, which provide a very smoothed surface of the internal bore. Finally the tubes of the ten chanters were treated with bore-oil (a common practice with this type of instrument) several weeks before the recording. The diameter of the 9 fingerholes ranged from 4 mm to 6 mm.

The chanter reeds were either synthetic or made from cane. Since they were brand-new, they had to be used for a few hours before starting recordings. It is worth underlining that the aim of the experiment was not to observe the effects attributable to the reeds, but rather to extend the conditions of playing to make the experiments more realistic (indeed, some studies have shown that, with some bagpipes, the role of the reed could not always be negligible compared to the input impedance of the pipe [30,31]).

The chanters were successively mounted on a unique bagpipe, so that the recordings would be made with the same drones and the same bag. In some bagpipes, the musician has to blow in the bag. As the air from the lungs is moist, the working of reeds (especially cane reeds) is likely to be affected by the progressive increase of humidity. In order to free from this problem, a 16'' « Bechonnet » bagpipe was used, as it allows the player to send some dry air in the bag by moving a swell. The two drones were made of African Blackwood and were equipped with common synthetic single reeds. All chanters and bagpipe components were made by a professional maker.

For each chanter, a traditional tune from France played on the chanter with the two drones was recorded in a recording studio with a single DPA 4006 microphone, placed 1.20 m from the piper and 1.60 m above the floor, and connected to a Presonus Firestudio soundcard (the sampling frequency and quantization were 48 kHz and 16 bits respectively). The tuning pitch was controlled with an electronic tuner. With 5 woods, 2 duplicates per wood and 2 reeds, a total of 20 sequences was recorded. Each sequence was 20 seconds long.

### 2.1.2. Test protocol

Subjects were asked to assess global quality in a first test, then the five criteria in a second test. They were placed in front of a computer screen and equipped with Sony CDR2000 headphones, that they were instructed not to move during the entire test period [32].

After each presentation, the words “global quality of sound” were displayed on the PC screen with 5 boxes, from “1” (low) to “5” (high). The listener was requested to tick the box that matched at best his feeling (the test interface was implemented in Matlab). For the second test, the protocol was the same, except that there were 5 criteria to evaluate: “brightness”, “aggressiveness”, “warmth”, “volume” (refers to the volume of the sound by the chanter with respect to the sound by the drones) and “detached precision”. These terms were determined on the basis of a pre-study, during which pipers and non-pipers had been asked to express at best how they qualified and differentiated sounds from bagpipes. Once a subject was satisfied with his answers, he had to press a button to go to the next stimulus.

Each listener was successively given the two tests. The first one lasted about 15 minutes, and the second one 25 minutes. Each test was preceded by a pre-test of about 5 minutes to familiarize the listener with the proposed range of sounds and the different criteria. The aim of the experiment was to assess the sound produced by the chanter played under normal conditions, that is with drones. Yet subjects were reminded that drones were not the subject of the assessment, and that they should focus on chanter sound. The sound volume of the sequences played in the headphones was about 85dB SPL to correspond to the true volume of a 16” bagpipe (at 1 meter).

Among the 18 listeners involved in the study, 9 were non-piper musicians. The other ones were all trained pipers with a high practice level. This diversity in the population under test was made on purpose to determine whether both populations of listeners had similar quality criteria to assess chanter sounds.

## 2.2. Results

As the scale could not be considered continuous, data were analyzed with non-parametric procedures, and ranks were rather used than means [33].

### 2.2.1. Global quality of sound

*Wood effect:* according to the listeners, wood had no direct effect on the sound produced by chanters ( $p=0.103$  according to the Friedman test [33]).

*Reed effect:* the listeners gave significantly higher marks to chanters equipped with synthetic reed than to those with cane reed ( $p<0.0001$  according to Wilcoxon test [33]).

*Listener’s background effect:* Globally, the set of stimuli received higher ratings with piper listeners than with “non piper” listeners ( $p<0.0001$  according to Mann Whitney test [33]).



*Effect by chanter items:* despite the lack of a direct effect of wood species on the assessment of sound quality, listeners showed some significant preferences for certain chanters, independently of their wood. The figure 1 indicates the ranks for each chanter. A chanter with a rank  $n$  means that the concerned chanter was, on average, sorted at the  $n^{\text{th}}$  rank with respect to other chanters (the first chanter being the *least* preferred instrument). The figure indicates that the ranks for chanters made from the same wood can be more distant than ranks obtained for chanters from different woods. For example, the two chanters in African Ebony have very different ranks, whereas the second item of chanter made from African Ebony obtained a rank close to those of the two chanters made from Service Tree. This example supports the absence of a significant global influence of wood.

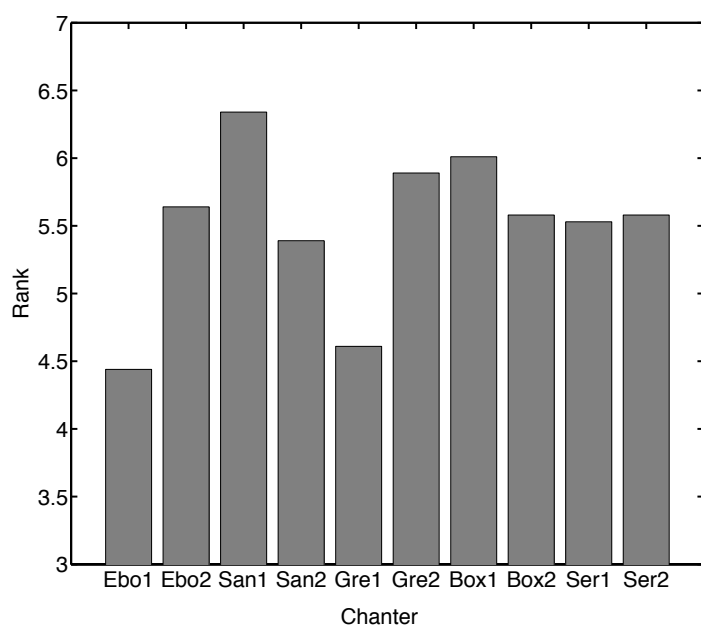


Figure 1. Global quality: ranks for the two chanters from the five different woods (namely African Ebony, Santos rosewood, African Grenadilla, Boxwood, and Service Tree)

### 2.2.2. Other criteria

Concerning the criteria “brightness”, “aggressiveness”, “warmth”, “volume”, and “detached precision”, the Friedman test indicated no effect of wood.

*Brightness criterion:* the reed and the listeners background were found to have some significant effects: indeed, the chanters with the cane reed were judged as brighter than those with the synthetic reed ( $p < 0.0001$ , Wilcoxon test), and the “non piper” listeners gave higher brightness marks than the “piper” listeners to the whole set of sounds ( $p < 0.0001$ , Mann Whitney test).

*Aggressiveness criterion:* the reed and the listeners background were found to have some significant effects: indeed, the chanters with the cane reed were considered as more aggressive than those with the synthetic reed ( $p < 0.0001$ , Wilcoxon test), and for all sounds the “aggressiveness” marks given by the

“non piper” listeners were always higher than those by the “piper” listeners ( $p < 0.0001$ , Mann Whitney test).

Warmth criterion: the reed was found to have some significant effects: the chanters with the cane reed were judged as warmer than those with the synthetic reed ( $p < 0.0001$ , Wilcoxon test).

Volume criterion: the reed and the listeners background were found to have some significant effects: the chanters with the cane reed were considered as louder than those with the synthetic reed ( $p < 0.0001$ , Wilcoxon test); moreover, with respect to the “piper” population, the “non piper” one assessed all of the chanters as louder ( $p < 0.0001$ , Mann Whitney test).

Detached precision criterion: the reed and the listeners background were found to have some significant effects: the chanters with the cane reed were considered as providing a better degree of detached precision than those with the synthetic reed ( $p = 0.002$ , Wilcoxon test); moreover, the degree of detached precision found by the “non piper” population was higher than by the “piper” population ( $p < 0.0001$ , Mann Whitney test).

### **2.3. Discussion**

The main result of this experiment is that wood seems to have no significant influence on global sound quality.

The quality of sounds seems to be strongly dependent on the reed material: in this study, the synthetic reed was preferred by most of the subjects. This preference can be related to the results of the second test where the sounds produced by the cane reed were felt to be brighter, warmer, more aggressive and louder than those by the synthetic one, and providing a better degree of detached precision. Moreover, this preference (at least for “piper” listeners) may be due to the fact that most of pipers plays with synthetic reeds nowadays, and may be more familiar with their sound.

The listener background had a significant effect on the test results: the ratings of the sound quality by the “non piper” listeners were globally worse than those by the “piper” population; the former also considered all of the sounds as brighter, more aggressive and louder. Moreover, the detached precision on the whole set of chanter sounds was assessed by the “non piper” listeners as more precise than by the “piper” listeners. It is worth noting that “non piper” listeners reported that they had trouble assessing this criterion.

The correlation between global quality and the other criteria was very low, and, surprisingly, lower for piper listeners. The maximum correlation was reached with global quality and warmth, yet the coefficient was low (0.33 for naive listeners, 0.29 for expert listeners, with  $p < 0.0001$  according to Spearman test). Those very low correlations are surprising, especially from expert listeners, who had determined during the pre-study the choice of criteria.

In this first experiment, subjects did not perceive significant differences of sound quality between wood species. Yet they reported that the task was difficult. It is therefore impossible at this point to determine whether wood was found to have a negligible impact on sound quality because

subjects could not hear any differences between the woods, or because the difficulty of the task hid potential differences, or simply because subjects could hear differences between woods, but did not have any preferences. Moreover, the fact that the differences between two chanters from the same wood are sometimes larger than the differences between chanters from different woods is surprising, and suggests that the variability in instrument manufacturing is more important than the choice of the wood.

A second experiment was therefore carried out to verify whether subjects could truly differentiate between the different wood species.

### 3. EXPERIMENT B

#### 3.1. Material and methods

In this discrimination experiment, a 3 Interval 3 Alternative Forced Choice (3I3AFC) response paradigm was chosen. During a trial, three intervals were successively presented. Each of the three intervals was a 5-s extract from the musical sequences used in experiment A. The three sequences were distinct recordings: two with a same chanter, and one with a different chanter (from identical or different wood). The order of the three sequences was randomized, and subjects had to identify which one of the three was the oddball stimulus (that is the chanter that was only presented once).

As experiment A had shown that the influence of reed was very pronounced, chanters with plastic reeds were never compared to chanters with cane reeds. The number of pairs to be compared was therefore  $[10 \cdot (10-1)]/2 = 45$  for the chanters with synthetic reeds and also 45 for the chanters with cane reeds. With a total of 90 pairs, the test was about 30 minutes, with a 5-minute pre-test to familiarize subjects with the task.

Among the 22 listeners involved in the study, 11 were non-piper musicians. The other ones were all trained pipers with a high practice level. The test conditions (room, hardware...) were the same as those used in experiment A.

#### 3.2. Results

Firstly, results of experiment B were similar for naive and expert listeners ( $p=0.84$  according to the Mann Whitney test).

Then, the influence of chanters and woods on the detection rate was quite close between synthetic and cane reeds (it did not affect the order of ranks significantly). Yet the detection rate was globally higher with synthetic reeds (55,25% on average) than with cane reeds (44,8% on average). This difference was significant according to a Wilcoxon test ( $p=0.001$ ).

Figure 2 indicates the detection rate of the oddball stimulus (the chanter played one time only), for each of the chanter pairs (pooled across all reeds and listeners). The stars above bars indicate pairs of chanters coming from the same wood, and reveal that chanters from the same wood are sometimes distinguished more easily than chanters from different woods. For example, the two chanters in Santos Rosewood were distinguished at 72% (it is even the most distinguished couple). On the other hand, many couples of chanters from different woods were distinguished with a detection rate inferior to 50%.

Figure 3 presents the same results as figure 2, but it enables to compare rates obtained with two chanters made from the same wood more easily. A lighter case corresponds to a higher detection rate. The diagonal is black because listeners were never proposed the same chanter in the three intervals. In most cases, the two items of a same wood (consecutive odd/even columns on the figure) gave quite different results. This is particularly clear between Ebony item 1 and Ebony item2: those two chanters were not differentiated from the other ones in the same way.

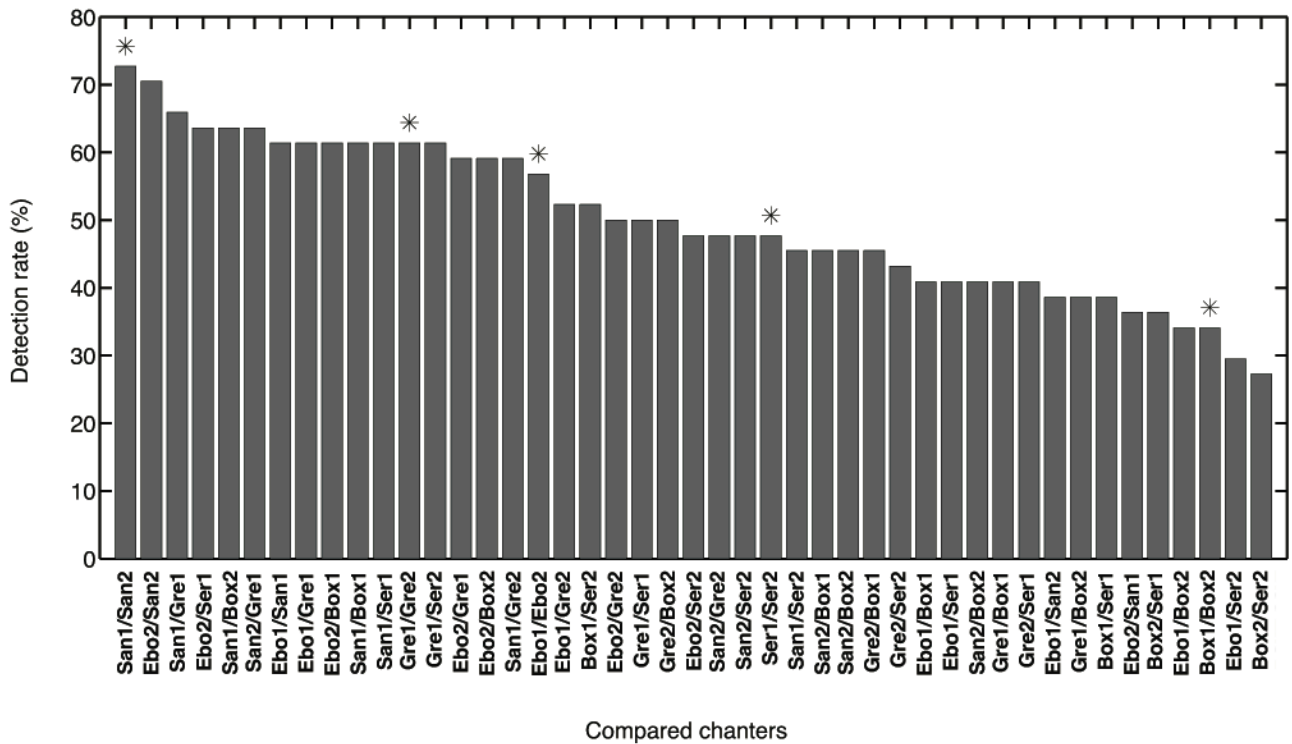


Figure 2. Detection rate of the oddball stimulus (the chanter played one time only), for each of the chanter pairs. Stars above bars indicate pairs of chanters that come from the same wood.

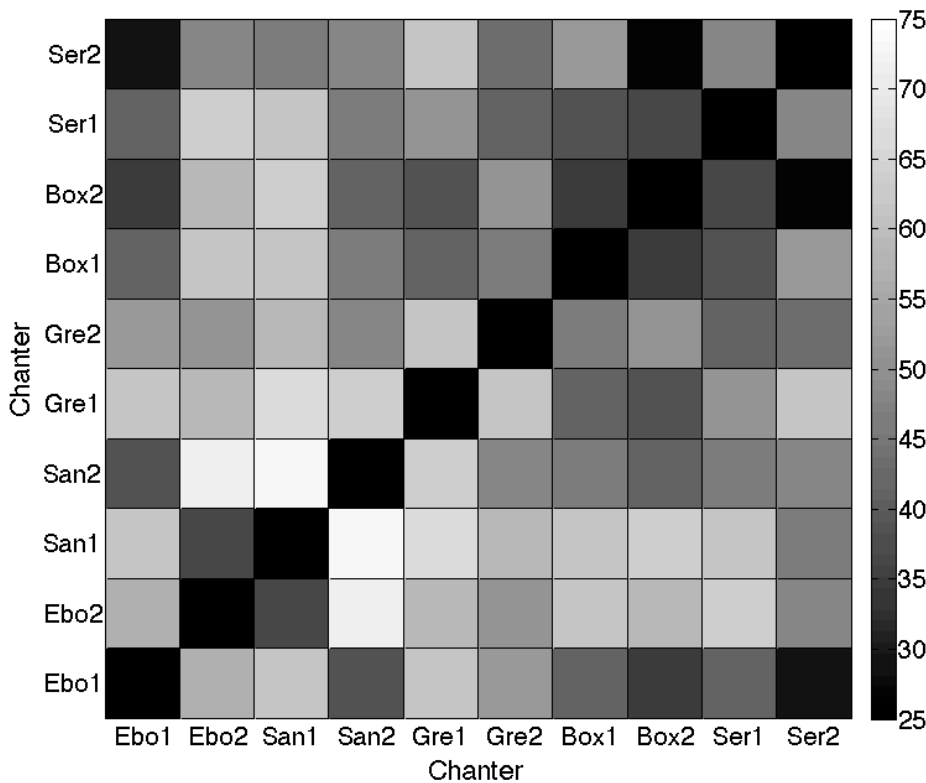


Figure 3. Detection rate of the oddball stimulus (the chanter played one time only), for each of the chanter pairs, on a gray scale. For example, the gray color of the square at the intersection of row Ebo1 and column Gre1 indicates that the differentiation rate between the first chanter item in African Ebony and the first chanter item in African Grenadilla was 61%.

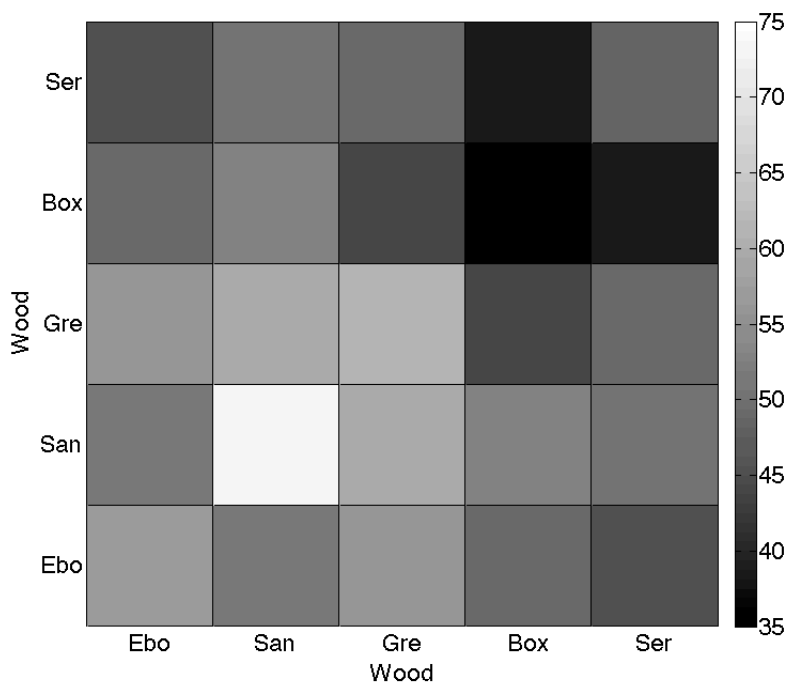


Figure 4. Detection rate of the chanter played one time only, for each wood (pooled across items), on a gray scale. For example, the gray color of the square at the intersection of row San and column Box indicates that the differentiation rate between chanters (pooled across items) in Santos Rosewood and chanters in Boxwood was 53%.

Figure 4 indicates the detection rate for each wood, pooled across items. The diagonal indicates the discrimination rates for two chanters from the same wood. It can be seen that the detection rate was the higher when the two duplicates of Santos Rosewood were compared between each other, and when the two duplicates of Grenadilla were compared between each other. It confirms that differences between chanters from the same wood can be larger than differences between chanters from different woods. On the other hand, the two Boxwood duplicates seem to be very close. Though results cannot be legitimately generalized (as there were only two duplicates per wood), they suggest that some wood species (boxwood for example) may have a more « constant » structure, and/or may provide a more constant manufacture than other wood species. Constancy does not seem to be related to density: for example, the two Grenadilla duplicates were better differentiated than the two Boxwood duplicates, when Grenadilla density is far superior to Boxwood density (1270 kg/m<sup>3</sup> and 975 kg/m<sup>3</sup> respectively [34]).

It is worth noticing that the reputation of the Service Tree (a particularly different sound compared to other woods, with a “warmer” and “sweeter” tone) was not verified in experiment A. Actually, this wood was rarely differentiated from other ones in experiment B (the column associated to Service Tree is the darkest in Fig. 4).

Two groups can be distinguished: (i) African Ebony, Santos Rosewood, and Grenadilla, which seem quite different between them and with for chanters from the same wood, (ii) Boxwood and Service Tree, which seem closer between them and with for chanters from the same wood. In experiment A (figure 1), the two chanters in African Ebony were very differently assessed. The same observation was done, to a lesser degree, for Santos rosewood and Grenadilla. On the contrary, the two chanters in Boxwood and the two chanters of Service Tree were close. So the two experiments are in agreement: the chanters which was found to have similar quality ratings in experiment A were also the chanters which were less discriminated in Experiment B (and the absence of large quality differences in Experiment A seems to be not due to the difficulty of the task).

#### 4. SIGNAL ANALYSIS

Experiments A and B suggest that the perceptual effect of wood is negligible. Objective measurements were also carried out on recordings of isolated notes (from G3 to C4), with the same chanters as in experiments A and B: Sound Pressure Level (In Pascal and in dB), OE cue (The logarithm of the ratio between the sum of amplitudes of odd harmonics and the sum of amplitudes of the fundamental frequency and the even harmonics), spectral centroid (average and temporal evolution), irregularity cue (which indicates to what extent energy is constant through consecutive spectral bands), skewness (which measures how far a distribution is asymmetric), kurtosis (measures whether the peak is higher or lower than that of a normal distribution), ratio  $A_i/A_1$  (between the energy of the harmonic  $i$  and the energy of the fundamental frequency), ratio  $A_i/\sum A_i$  (between the energy of the harmonic  $i$  and the total energy of the  $n$  harmonics), tristimulus 1, 2 and 3 cues, which respectively indicates the relative importance of the fundamental frequency, of the low harmonics (from  $i = 2$  to 5) and of the harmonics of range superior to 5 [35, 36].

Only two physical parameters were significantly different between synthetic and cane reeds: The OE cue (-10,8 for synthetic reeds, -14.4 for cane reeds,  $p=0.002$  according to the MANOVA), and the spectral centroid (6710 for synthetic reeds, 6405 for cane reeds,  $p=0.005$  according to the MANOVA).

Only one physical parameter was significantly different between the woods: the spectral centroid (figure 5,  $p=0.04$  according to the MANOVA [33]), which was lower for chanters from Santos Rosewood, than for chanters from African Ebony (significantly different according to Bonferroni post-hoc test [33]:  $p=0.025$ ). This result is not really related to the perceptive results of previous experiments. However, the global absence of large objective differences between signals from different woods is in agreement with experiences A and B, which had not highlighted perceptive differences between woods.

It is worth noting that no physical parameter was significantly different between chanters, independently of their wood. Perceptive results have shown differences between chanters, independently of their wood. However, differences in quality assessments (in experiment A) were

globally low, and all these results indicate that the differences between chanters, independently of their wood or not, are weak (perceptively and objectively). This result is in agreement with several studies about other woodwind instruments [12,13,24,25].

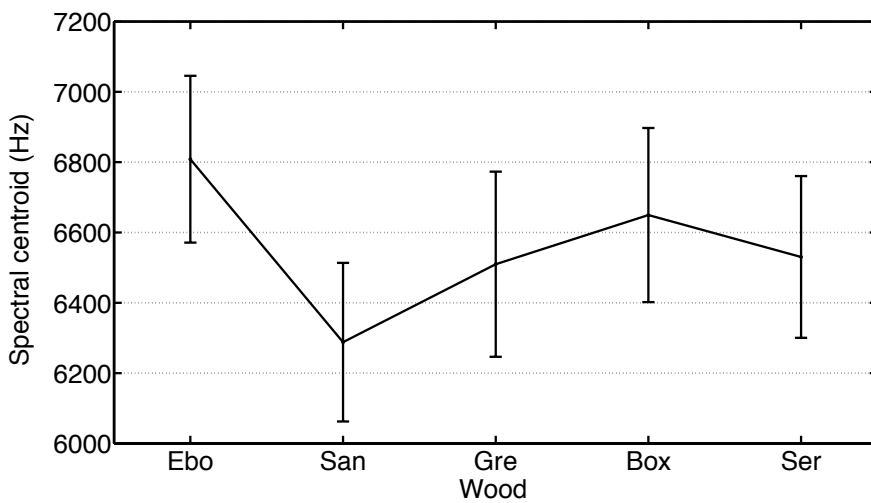


Figure 5. Spectral centroid for the five woods (namely African Ebony, Santos rosewood, African Grenadilla, Boxwood, and Service Tree)

## 5. CONCLUSION

Experiment A has not revealed any influence of wood on the sound quality assessment of chanters from bagpipes. Yet synthetic reeds were more appreciated than cane reeds, and ratings were globally higher with experts than with naïve subjects. “Warmth” was the most correlated criteria to global quality, yet the coefficient remains low. Independently of their wood, some chanters were preferred to others.

Experiment B showed that chanters from the same wood could sometimes be distinguished more easily than chanters from different woods.

The analysis of signals revealed that there was also little objective difference between wood species. Only the spectral centroid was significantly lower with the Santos Rosewood than with the African Ebony.

The influence of wood on the sound of chanters from french 16” bagpipes is therefore limited, and appears to be less important than micro-differences in manufacturing.

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