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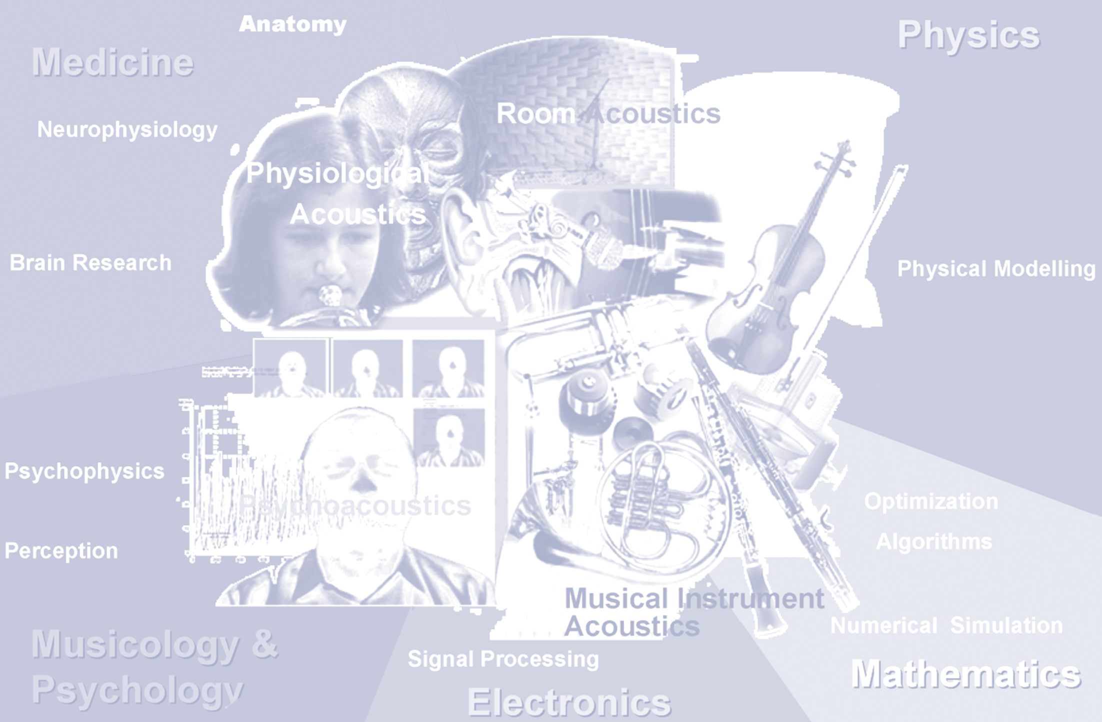
IWK

Collected Papers in Musical Acoustics 1995/2003

Matthias Bertsch



Reprint of articles from Matthias Bertsch published between 1995 - 2003

Nachdruck von Textbeiträgen von Matthias Bertsch aus den Jahren 1995 - 2003

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Collected Research Papers in Musical Acoustics (1995 - 2003)

Brass Instruments

Woodwind Instruments

Percussion Instruments

Viennese Sound & Playing Style

BRIDGING INSTRUMENT CONTROL ASPECTS OF BRASS INSTRUMENTS WITH PHYSICS-BASED PARAMETERS

Matthias Bertsch

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ABSTRACT

Is there a connection between what we feel when playing an instrument and what we can measure? Physical models and measuring tools have been developed to provide a better understanding of brass instruments and objective physical documentation of their acoustics.

Musicians and instrument makers still criticize the enormous gaps between the physics-based parameters and the empirically reported feelings of brass players on quality aspects of their instruments. Deviations between played and measured parameters like intonation and their variability have already been focused on in earlier studies. Attempts at finding a theoretical explanation of these deviations using physical modeling continue.

For musicians, one of the most important quality factors of a brass instrument is its response. A new series of playing tests has been designed to correlate empirical data with objective physical parameters (impedance measurements). International instrument makers provided special test instruments (modular trumpets). This paper will examine the difficulties in defining response and setting up suitable playing tests.

1. INTRODUCTION

Brass instrument makers produce and customize their brass instruments for players who have many different requirements and expectations of their ideal instrument. The manufacturing knowledge has developed through the centuries. Today, there are many good instruments on the market and the selection is large. One can choose between “rather similar” instruments built in large series by factories and custom-made smaller series or even handmade or adjusted “singular instruments”. So how can one find his optimal instrument without testing all of them? For beginners it is usually the advice of the teacher or the dealer, which narrows the choice. Those who start to test instruments usually quickly realize how difficult this procedure is. There are many criteria. On the one hand there is the sound quality and on the other hand there are the many aspects of instrument control parameters. The main criterion for the musician in choosing his instrument is the specific sound and timbre. Preferences about sound quality are individual and hard to describe with verbal attributes. It also depends on the specific interaction with the input of the player. Instrument makers’ descriptions of instrument parameters are for the most part very similar: perfect intonation, easy speaking, full sound, good response and more or less resistance. Of course, there are differences between those instruments, but there is little experience in labeling the parameters. You cannot simply look at a table and compare features as you do when you shop for a car or loudspeaker. Quality control of brass instruments is still chiefly done through subjective criteria of test players. Reproducibility is difficult to control.

1.1 Measurement tools and previous studies

Since the 1980s, acousticians have been asked to deliver objective quality control tools. Meanwhile there are hardware and software systems that can measure the input impedance of brass instruments, which are easy to use [1]. The impedance measurement data represents an acoustic fingerprint of the total behavior of an instrument. One curve corresponds to one physical geometry of an instrument. But what do these curves tell the musician?

One feature of the impedance curve had almost immediately been translated into musical terms. The positions of the peaks correspond with the intonation of the notes. The measurement allows the detection of deviations to a reference intonation. The Brass Instrument Analysis System (BIAS) developed at the Institute for Musical Acoustics (IWK) at the Music University in Vienna can accurately show the intonation of all playable notes of a brass instrument. Earlier studies by the author have been done to determine the intonation properties of trumpets [2]. Empirical data of played trumpets have been compared with different theoretical tuning systems and with the intonation, which was calculated by means of input impedance measurements. The results showed great differences amongst players even playing the same reference instrument. The arithmetic mean over all trials correlated best with the calculated objective intonation. This information is already a big help for both makers and players in evaluating instruments. Additionally, new optimization tools can already help to correct problems of existing instruments by bore profile modifications and they can be used in developing new instruments by calculating the intonation with computer models before the instrument is built.

1.2 More questions remain

So what about other instrument control aspects? Do they also correspond to physics-based parameters? Acousticians expect that they do. Thomas Moore wrote in his article for trumpet players: “the sound and feel of every horn is definitely determined by its impedance spectrum” [3]. But how can you measure the feel of the horn? The language of musicians describing instrument properties is not easily translated into physical terms. Even when they use the same words, the meaning can be different. So far, it is not clear that what all players label “good response”, “easy speaking” or “low resistance” are the same. Also, most players have little theoretical understanding about tone production. Our approach is to find a common language for players to report tone control parameters and to translate them into acoustical terms. The objective is to find an answer for a simple question: which factors make a trumpet speak well? What does the player, the mouthpiece, the bore, the shape or even the material have to do with it all? What can be changed to improve the response of a given instrument? The following example of practical relevance can show the need for these answers: While writing this introduction I received a phone call from an instrument maker. There is an almost perfect horn played by professional musician. The intonation is perfect; except that one note does not speak well if played piano. He asked what he should change on the instrument. I gave an answer, but I hope that we find a better answer as the ongoing project progresses.

1.3 Aims

The aims of the trumpet research project (TRP) are to define what 'response' can mean (there are many varying meanings), and to find physical parameters that can be used in further calculations and measurements. Preferences of different player types (classical, jazz, etc.) for these physical parameters are searched. This would allow computerized optimization of real instruments. Bridging the languages of musicians ("this trumpet feels good"), acousticians ("how much impedance is at this frequency") and instrument makers ("I could use a wider bore or different material") will help to create tools for developing better instruments.

2. METHODS

Several methods are used in this ongoing study. The planned methods include playing tests, input impedance measurements, bore reconstructions and finally the correlation of all data.

2.1 Playing tests setup

Blind performance tests and regular playing tests with outstanding professional trumpet players and with groups of musicians in Austria, Finland and the USA will deliver empirical data on specific test instruments. Different international instrument makers provide the test instruments. Playing tests are made with Bb trumpets with Périnet valves and German system trumpets with rotary valves. Some instruments are built modularly, such that the leadpipe, tuning slide and the bell can be changed. Information about makers is kept confidential during the playing tests so that players do not know what brand, model or setup of modular instrument they are playing. Tests are performed in a dark room (or with blindfold) and a questionnaire for each setup is answered. Information on the experience and preferences of the players are also requested. All data are organized in a database with search, sort and export functions.

2.2 Playing test questionnaire

Instrument control aspects are highly trained competence of musicians, but the knowledge is developing without unified verbal attributions. This is a well know problem of acoustician to deal with. Earlier tests by Wogram [4] have been taken into account. A new approach in this study is to proceed with the support of "images" and visualization. The player gives answers and the tester fills out the questionnaire. Sometime this includes translating expressed feelings. A typical difficulty is to quantify the value of a given aspect. In this questionnaire the player has five possible values ("-2","-1","0","+1","+2"), but he can use his own personal reference. The answer "0" corresponds to "neutral, normal" Answers of "+1" indicate more, "+2" much more of a given aspect (respectively "-1" is less and "-2" is much less). During testing the player develops his own scale.

Questions about the subjective sound preference and description of the sound quality:

- Dynamic range: small - normal - large
- Timbre: dark - neutral bright
- Timbre: dull - neutral - brilliant
- Small sound - normal - full sound
- Boring, hard to modulate, - normal - rich colors
- I don't like it - Don't know - I like it
- Sound volume: small - normal - large
- Sound projection: poor - normal - good
- Tendency to sound brassy: low - normal – high

Questions about the starting phase of a note: (The question focus specifically on g4 and g5 as open series and with valve 1 and 3 engaged):

- How fast is the attack (soft versus quick onset)
- Ease of staccato and repetitions, How quickly can you repeat very fast notes pp and ff
- Soft versus abrupt slurs (B4-C5, C5-Eb5)
- Easy to play ppp? How much effort do you need to play a note? How easy does it speak?

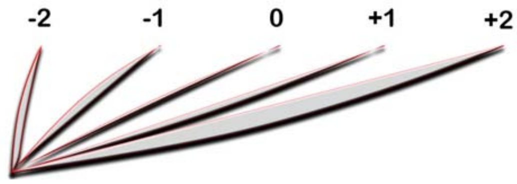

Figure 1: *Schematic representation to ask for the attack*: *"How fast do you get feedback when you start blowing"*

Question about the control aspects of a sustained note:

- Blowing resistance (forte)
- Air volume: Amount of energy (air) needed to sustain a note.
- Intonation of given notes
- Slotting pitch: enough or too much flexibility (how easy can you "lip up" and "lip down"?)

Figure 2*: Schematic diagram to ask for slotting pitch. The deepness and shape represents the flexibility of the pitch center.*

Classification of the instrument. The players are asked to judge about:

- Adequate user player level (beginner, student, pro),

- The type of music this instrument is best suited for (classical, jazz/pop or both)
- The applicability for all ranges, high or low register

Additional questions on mechanical and optical aspects (not in blind tests) are asked (Fast valve action... lightweight / heavyweight, Conception and assembly; finish) Finally the total preference is asked.

2.2 Measurements

All instruments and combinations of modular parts are measured with the BIAS system [2]. Several physics-based parameters are extracted from the input impedance measurement. Besides the peak frequencies, the shape of the peaks and the "0" phase position are taken into account. For each peak, the following values are calculated:

- **Offset**: Intonation given by the impedance peak center frequency. Intonation error related to the equal temperature in Cent. Tuning reference frequency is adjusted in order to minimize the overall intonation error of all playable notes.
- **Envelope**: Absolute peak height of impedance peak in MegOhm
- **Curvature**: Absolute value of the 2nd derivative of impedance curve at peak center in MegOhm/Hz^2. Calculated as parabolic fit using the Savitzky-Golay convolution.
- **Low3dbLimit**: Distance of left peak edge (-3dB) from peak center in Cent.
- **High3dbLimit**: Distance of right peak edge (-3dB) from peak center in Cent
- **Bandwidth**: Low3dbLimit plus High3dblimit. (Inverse Q factor in Cent)
- **Phase**: Phase value at peak center in Rad. Should be close to zero at least for prominent peaks.
- **Groupdelay**: Group delay, 1st derivative of impedance phase at peak center in Rad/Hz.
- **ZeroPhase:** Intonation given by zero phase frequency. Intonation error related to the equal temperature in Cent. Tuning reference frequency is adjusted in order to minimize the overall intonation error of all playable notes.

For a detailed analysis of input impedance peaks, the shift of the position and of the amplitudes of all higher peaks has to be taken into account. Weighting Functions in the BIAS system allow considering the sum function of the excitation spectra of the lip.

2.3 Bore reconstruction:

Different impedance curves correspond to different bore profiles. Recent studies of Kausel [5,6,7] in calculating the profile from input impedance measurements demonstrate a further development in this technique. To compare these data with special leadpipes used for playing tests, digital X-RAY measurements have been done to document their geometrical difference. Small changes in the bore and mouthpiece have strong impact on difference "response" parameters.

2.4 Correlation:

The main step is to correlate the data of the playing tests to those of the input impedance, and to the bore profiles. The questionnaire delivers values, which can be used for calculations. First, it will be necessary to find dependent and independent variables. As documented in earlier studies, reasons for variability in trumpet sounds are enormous [8].

3. PRELIMINARY STUDIES

3.1 Three leadpipes

Figure 3: Three different leadpipes for a rotary trumpet.

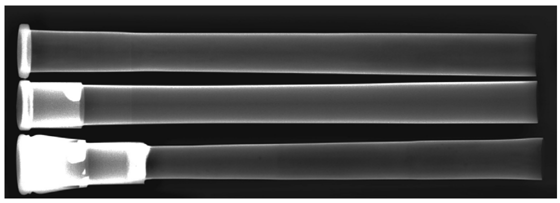

Figure 4: X-RAY images of above leadpipes

Different leadpipes can influence many aspects of a given instrument. Timbre, intonation, and several response factors are changed together with the input impedance. Figure 5 shows the impedance of trumpet #27 with the three leadpipes shown in Fig. 3 and 4. The absolute height and the shape of the peak that corresponds to the note g4 are different. This note can also be played with valve combination 1+3. The impedance peaks for this fingering is also plotted in Fig. 5. Musicians testing these instruments feel and hear differences, and more tests are necessary to find dependent and independent variables. A large number of tests repeated without knowledge of the players will determine the reproducibility of the tests.

3.2 Extra keys for response support

Some professional players and students in Vienna use rotary trumpets with additional keys (see Fig. 6) to support the response of tones in the high register. As can be seen in Fig. 7, the keys have a similar function to those on (non-original) historic trumpets. When the additional key is engaged, e.g. the "C" key, the impedance at this note is similar, while those at the neighbor's frequencies are much more changed. For this instrument, the peak height of the played note increased with two keys and decreased with two other keys. More tests should be done to find to what extent these keys help psychologically for the "high note syndrome", or if they actually improve the response. (The keys are pressed only to start a note and not to sustain it!)

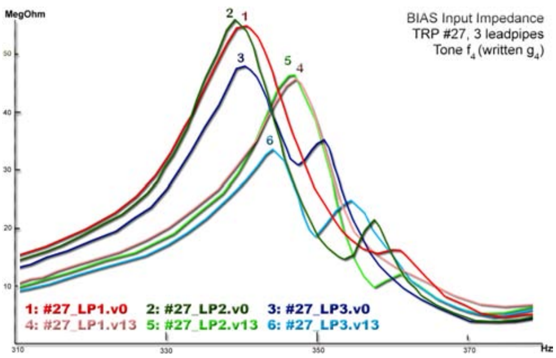

Figure 5: *Impedance peaks for g4 (written f3) at 340 Hz. of one trumpet with three leadpipes. The peaks 1-3 are without valves and peaks 4-6 are with valve 1+3 engaged.*

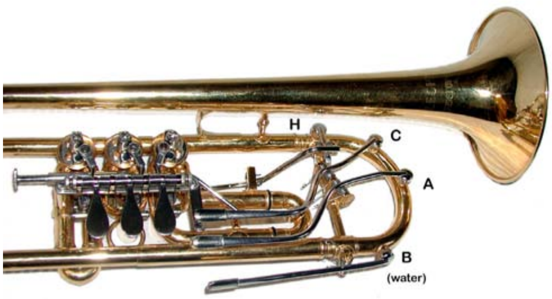

Figure 6: *rotary trumpet with additional keys to support the response of higher tones. The regular water key is used for "Bb5" and "D6", additional ones for "A5" "C6" and "H5".*

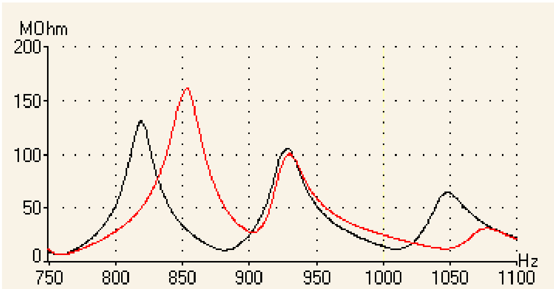

Figure 7: *Impedance for the written c5 (sounding Bb4) at 930Hz with (red) without (black) the addition C-key engaged. The peak at this frequency changes slightly compared to dramatically changes of the total curve. The shift of the position and amplitude of all higher peaks has a significant influence on the played note.*

4 SUMMARY

Preliminary studies have been done in 2002 for setting up the large-scale tests. The playing tests are being performed from March to June 2003 in Vienna and further tests with the same instruments are planned in other countries (Finland, USA,) to evaluate regional preferences and variations of schools. Playing tests are very difficult sensory evaluation tests, which depend on many aspects. Several psychological aspects have to be taken into account. Therefore, the tests will be performed without seeing the instrument and knowing about brand names; otherwise the expectations about brands and visual impressions can easily dominate the "feeling" of the musician. The expected results will help musicians to find their individual ideal instrument and deliver new tools for instrument makers.

5 REFERENCES

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Further information can be found through the website of the Institute for Musical Acoustics:

http://www.bias.at/TRP

BRIDGING INSTRUMENT CONTROL ASPECTS OF BRASS INSTRUMENTS WITH PHYSICS-BASED PARAMETERS

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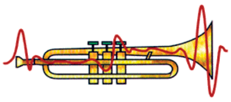
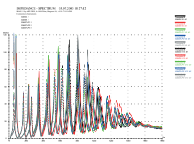
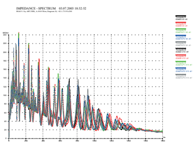


Input impedance data of test instruments

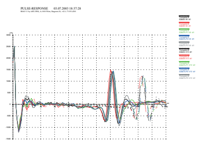
BIAS analysis of all Instruments (#24, #38 and #27 with three different leaadpipes) and for both valve positions (v0 and v13)



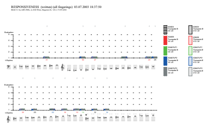
input impedance unweighted



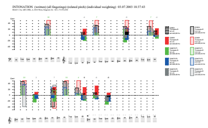
input impedance weighted



pulse response (calculated)

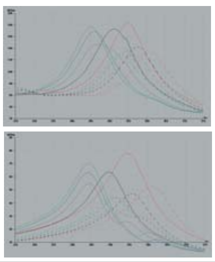


responsiveness



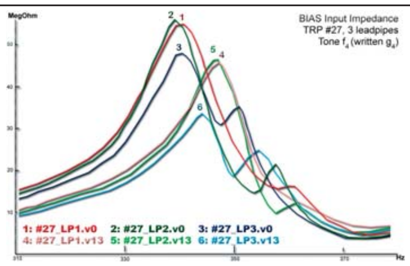
intonation

Impedance plot zoom to the written note „g4“



All Instruments, both valve positions

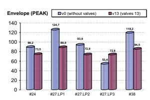
One trumpet, 3 leadpipes (both valve positions)



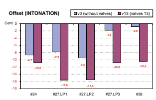
Picture of the 3 leadpipes TRP #27

XRAY images of above leadpipes

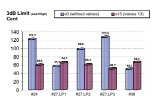
New BIAS 6.0 analysis export features: Example figures for note „g4“ of the all Instruments. Values should correlate to impedance curves. (Do they?)



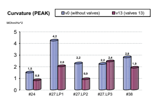
Envelope: Absolute peak height of impedance peak in MegOhm



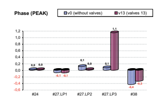
Offset: Intonation given by the impedance peak center frequency. Intonation error related to the equal temperature in Cent. Tuning reference frequency is adjusted in order to minimize the overall intonation error of all playable notes.



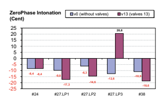
Bandwidth: Low3dbLimit plus High3dblimit. (Inverse Q factor in Cent)



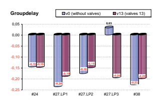
Curvature: Absolute value of the 2nd derivative of impedance curve at peak center in MegOhm/Hz^2. Calculated as parabolic fit using the Savitzky-Golay convolution.



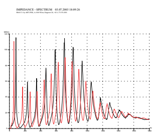
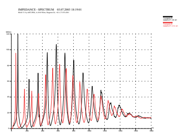
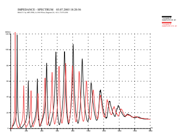
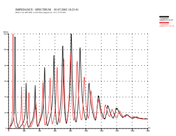
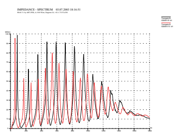
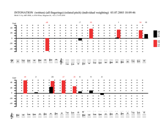
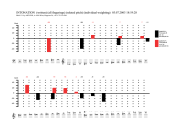
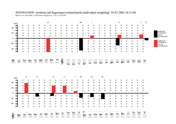
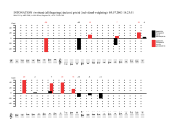
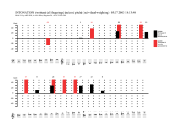
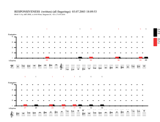
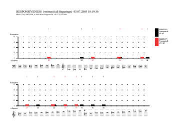
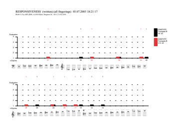
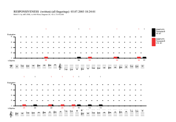
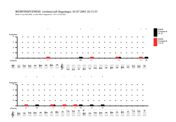
Phase: Phase value at peak center in Rad. Should be close to zero at least for prominent peaks.



ZeroPhase: Intonation given by zero phase frequency. Intonation error related to the equal temperature in Cent. Tuning reference frequency is adjusted in order to minimize the overall intonation error of all playable notes.



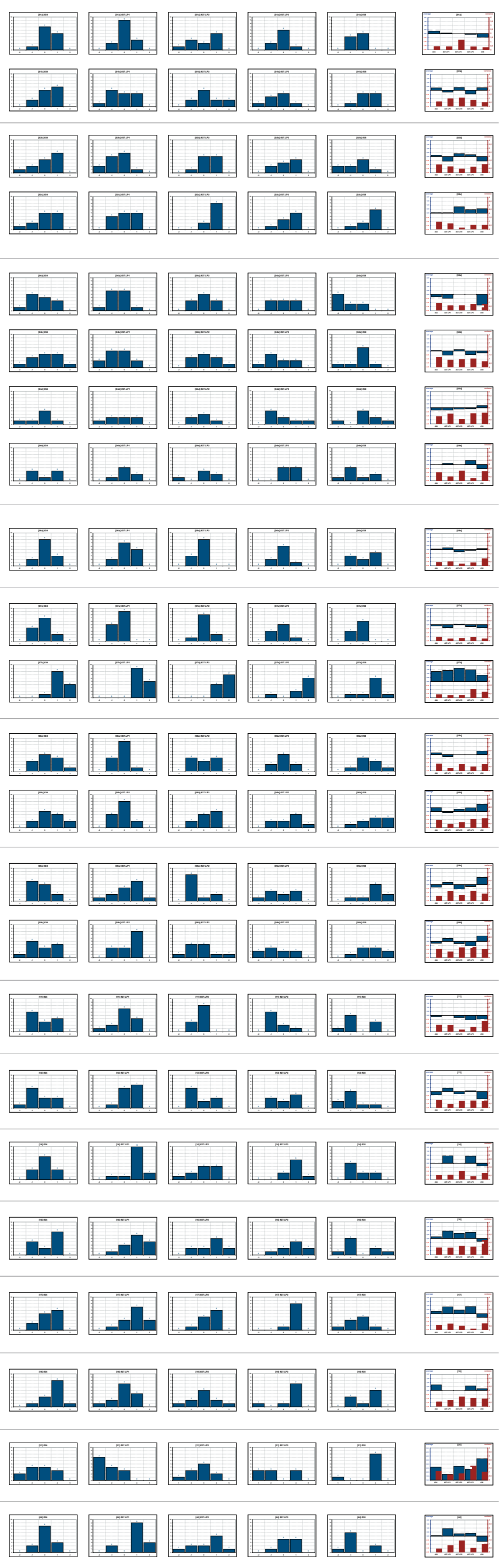
Groupdelay: Group delay, 1st derivative of impedance phase at peak center in Rad/Hz.

-> trumpet:	#24	#27.LP1	#27.LP2	#27.LP3	#38
BIAS impedance *v0 - black* *v13 - red*					
BIAS intonation *v0 - black* *v13 - red*					
BIAS response *v0 - black* *v13 - red*					

Results of blind performing tests

Questions asked during the playing tests and answers given by players in Vienna (student and professional players) for five rotary trumpets.

trumpet #24 | **trumpet #27 leadpipe 1** | **trumpet #27 leadpipe 2** | **trumpet #27 leadpipe 3** | **trumpet #38** | **statistic (mean & variances)**



start — **Question 01: „How fast is the feedback at the start of the note?“ „How quickly does the note speak?“**
Answers: [-2] very quickly /[-1] /[-0] ok /[+1] /[+2] not quickly, slow

g4 no valves (v0)
g4 valves 13 (v13)

32nd — **Question 02: „How quickly can the note be repeated? Play 32nd notes staccato!“**
Answers: [-2] fast /[-1] /[-0] ok, normally /[+1] /[+2] not so fast

g4 no valves (v0) forte
g4 valves 13 (v13) forte

ppp — **Question 04: „How quietly can the note be played? How easily does it speak at ppp?“**
Answers: [-2] very easily /[-1] /[-0] ok, normally /[+1] /[+2] not easily

g4 no valves (v0)
g4 valves 13 (v13)
g3 valves 13 (v13) pianissimo
c6 no valves (v0) piano

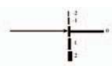
air — **Question 06: „Required air (energy) for maintaining a forte note?“**
Answers: [-2] very low, not much air /[-1] /[-0] ok /[+1] /[+2] very high, alot of air

g4 no valves (v0)

tuning — **Question 07: „How is the intonation of single notes?“**
Answers: [-2] very flat /[-1] /[-0] ok /[+1] /[+2] very sharp

g4 no valves (v0
g4 valves 13 (v13)

resis-tance — **Question 08: „Blowing resistance (maintaining a forte note)“**
Answers: [-2] very low /[-1] /[-0] ok /[+1] /[+2] very high



g4 no valves (v0)
g4 valves 13 (v13)

Question 09: „How easily are the notes lipped, or how centered are they?“ Answers: [-2] lick up or down difficult, note is extremly centered /[-1] /[-0] ok, normally /[+1] /[+2] lick up or down easy, note is not so centered

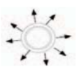
g4 no valves (v0)
g4 valves 13 (v13)

Question 11: „Tone quality (bright- dark)“
Answers: [-2] very dark /[-1] dark /[-0] ok, neutral /[+1] bright /[+2] very bright

Question 13: „Tone color quality (colorless- brilliant)“
Answers: [-2] very colorless /[-1] /[-0] ok, neutral /[+1] /[+2] very brilliant

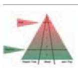
full round — **Question 14: „Tone qualilty (thin- full, round, open)“**
Answers: [-2] very thin, flat /[-1] /[-0] ok /[+1] /[+2] very full and round

sound pref — **Question 16: „Tonal preference, Sound preference“**
Answers: [-2] don't like it /[-1] /[-0] ok, neutral /[+1] /[+2] like it alot



Question 17: „Tonal power, Radiation (weak- strong)“
Answers: [-2] very weak /[-1] /[-0] ok /[+1] /[+2] very strong

brassi-ness — **Question 19: „Tendency to split notes, or to „scream“; (brassiness)“**
Answers: [-2] very little /[-1] /[-0] normal, ok /[+1] /[+2] very much



Question 31: „This instrument is appropriate for which player level?“
Answers: [1=prof.], /[2=semi-prof.], /[3=student], /[4=advanced], /[5=beginner]

good? bad? — **Question 44: „How do you like the instrument on the whole?“**
Answers:[-2] very bad /[-1] rather bad /[-0] neutral /[+1] rather good /[+2] very good

ANSWER SCALE	-2 minimal -- worst	-1 - worse	0 standard neutral OK	1 + better	2 maximal ++ best

trumpet #24 | **trumpet #27 leadpipe 1** | **trumpet #27 leadpipe 2** | **trumpet #27 leadpipe 3** | **trumpet #38** | **statistic (mean & variances)**

VISUALIZATION OF TRUMPET PLAYERS' WARM UP BY INFRARED THERMOGRAPHY

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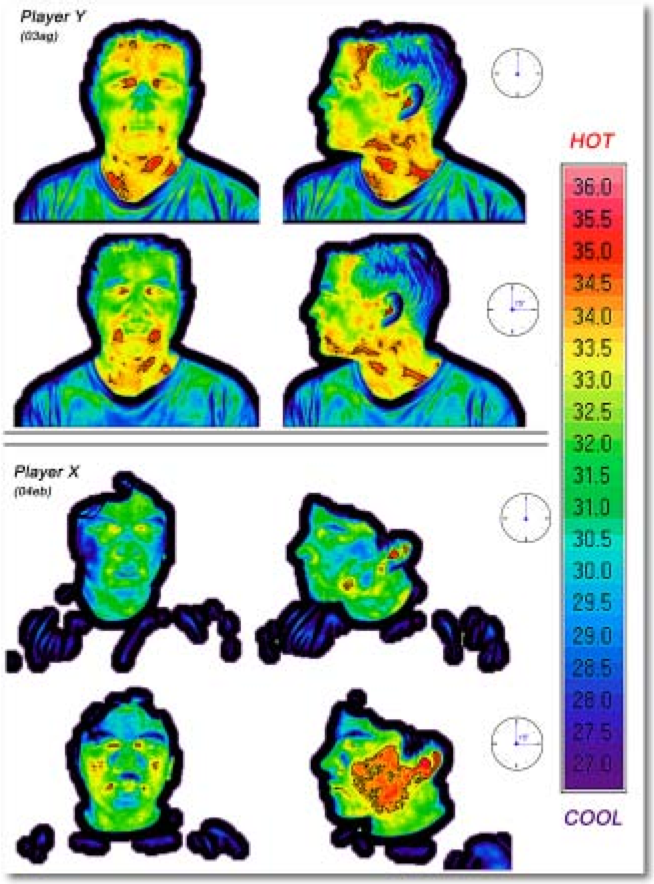
Dr. Thomas MACA
Department of Medical Angiology, AKH Vienna; Austria



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Visualization of Trumpet Players' Warm up by Infrared Thermography

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Thomas MACA, M.D / Department of Medical Angiology, AKH Vienna; Austria

Abstract

During the warm up of trumpet players, face muscle contractions with increased blood flow result in a higher temperature of the overlying skin. This effect can be visualized and quantified by infrared-thermography. The analysis demonstrates that the main facial muscle activity during warm up is restricted to only a few muscle groups (M.orbicularis oris, M.depressor anguli oris). The "trumpeter's muscle" (M.buccinator) proved to be of minor importance. Less trained players expressed a more inhomogenous thermographic pattern compared to well-trained musicians. Infrared thermography could become a useful tool for documentation of musicians playing technique.

Introduction

Just as in athletics, trumpet playing induces activation of certain muscle groups which are optimised after a warm up phase. For that reason this warming up is the first part of a brass player's daily routine to enhance muscle coordination of the complex setup of the embouchure. The warm up includes body and brain work; it "refreshes" the trained lip and muscle control mechanism. During the warm up, muscle contractions and increased blood flow result in a higher temperature of the overlying skin due to generation of heat. This effect can be visualized and quantified by infrared-thermography.

Aims

This study is a new approach to reflect physiological aspects of musicians' playing-technique by means of infrared thermography. The purpose of this study is to observe the individual reactions of different facial muscle groups during warm up and to compare playing patterns of professional trumpet players (n=5) with students (n=5) and beginners (n=6).

Method

16 Trumpet players were invited to the Vienna General Hospital (AKH). Five professional trumpet players (with an average 22 years of routine, standard deviation [SD] ±8 years), five students (13 years routine, SD ±4 years) and six beginners (4 years of routine, SD ±2 years). In order to meet the international standards for thermography they were instructed not to eat or smoke four hours before the test and to acclimate for 30 minutes in the lab (where they completed a questionnaire form). The time schedule is sketched in figure 1.

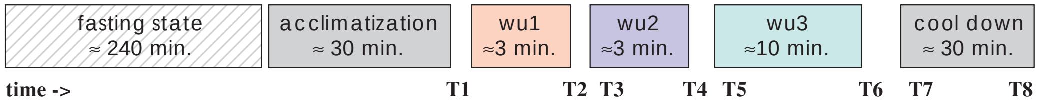


Figure 1: time-schedule and time-slots for measurements

Then, all trumpet players were instructed to play easy exercises for three minutes (given music tasks "wu1") then an exercise of medium difficulty (given music tasks "wu2") and, finally, about 10 minutes of playing whatever they play usually for warming up (individual music "wu3"). Frontal and lateral infrared images were taken before the very first warm up (T1) and after each part of the warm up (T2, T4, T6). This was realized with a Thermo Tracer TH1100 System (San-ei Inc.), and processed, using IRIS-software (nbn-Elektronik Inc.). The temperature resolution is 0,1°C; the frame time for one image is 1s and was taken about 30 seconds after each task. Additionally, axillary and finger temperatures were measured together with blood pressure and pulse rate before and after they finished playing (T1, T6).

Regions of interest

For determing the temperature at the selected points, the following 13 square sections with an area of 1cm x 1 cm have been used. Besides the forehead, which is measured in one point in the center only, all other locations have been measured on the left side *{sinistrer, s}* and on the right side *{dextrer, d}:*

1 • corner of the mouth *{anguli oris inferior}*
2 • inner corner of the eye *{anguli oculi}*
3 • forehead *{frontal}*
4 • side of nose *{perinasal}*
5 • inner cheek *{buccal rostral}*
6 • center of the cheek *{buccal central}*
7 • outer cheek *{buccal auriculaer}*

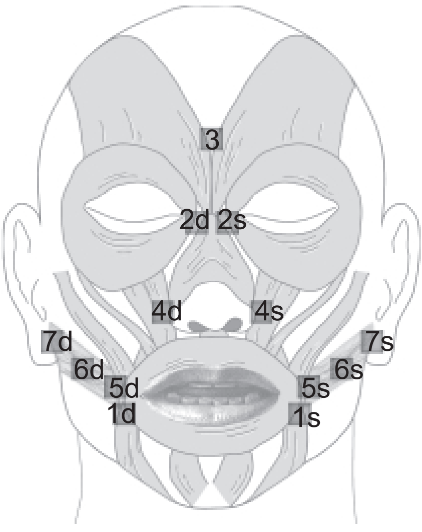


Figure 2: Areas of measured temperature

Questionnaire

The question "how long do you warm up daily and how long before a concert" has been answered in a rather wide range of 0 minutes (not at all) to 90 minutes. Regarding duration of warm up and the playing level there was no significant correlation. The duration seems to depend on the individual type only and not on level of skill. The mean duration of all groups was 30 minutes. Professionals are used to warm up for about 50 minutes before concerts, which is much higher than average.

By Infrared Thermography the main changes can be seen in the embouchure region with increased temperatures during brass playing The blood supply seems to be redistributed from lateral to central parts. Therefore, the main facial muscle activity seems to be restricted to only a few muscle groups in this area (M.orbicularis oris, M.depressor anguli oris, M.levator anguli oris).

Variation between the three groups of players can be observed in Figure 5 . The first player, a professional musician, shows a very symmetric and compact warm region in the embouchure area. In comparison, player two, a beginner, shows a more asymmetric warm up, while player three, a trumpet student, demonstrates a much greater area of warming. For all players, the inner corner of the eyes seems to be a hot spot before and after playing.

For almost all players the "Trumpeter's muscle" (M.buccinator) proved to be of minor importance since the area of the cheeks are not warming up.

One exemption can be found in example 4. Figure 6 shows the hot cheeks of a trumpet student on the lateral infrared images. This is obviously caused by a buccal playing technique (like Dizzy Gilespie or the baroque angels who gave the "trumpeter's muscle it´s name).

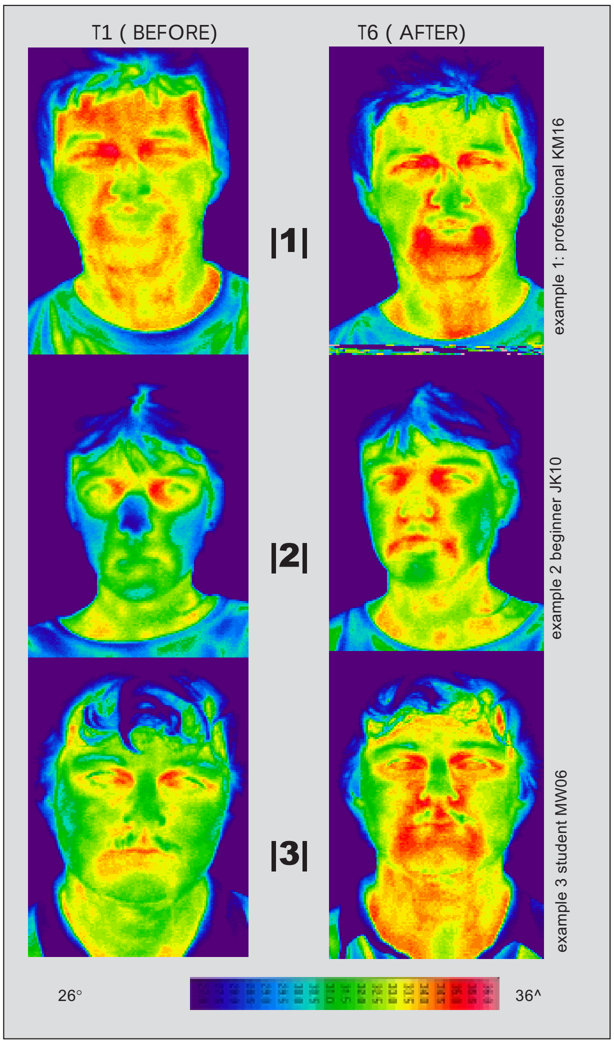
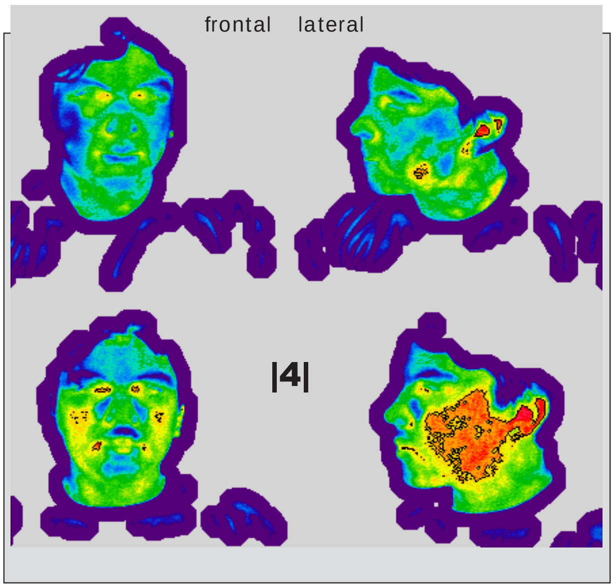


Figure 5 (above): Frontal infrared images from three different trumpet players before (left) and after the third warm up (right). Figure 6 (below): Frontal and lateral images of a players as example for a buccal type (hot cheeks).



The increase in temperature at the corner of the mouth was found for all players. Figure 7 demonstrates the values for the right side (anguli oris inferior, dextrum). The graphic shows the changes for all players from "before playing" (T1) to "after the first warm up" (ΔT2) and to "after the third warm up" (ΔT6). Values corresponding to professional player are plotted with a red line, those of students in blue and for beginners in green. The black line refers to the mean value.

The average temperature increase "after the third warm up" (T6) is one degree Celsius at the corner of the mouth. Some players even are 2 degrees warmer at the mouthcorner.

Figure 8 and 9 represent the same type of graph. In figure 8 you can see that the temperature at the eyecorner (point 2d; anguli oculi) remains very similar before and after both warm up rounds.

Figure 9 corresponds to the measured temperature at the outer cheeks (point 7d; buccal auriculaer). The average change is very small except for one beginner. The reason for this exemption could be explained by his different playing technique, whose thermo- pattern is shown in figure 5.

These three examples for temperature changes on the right hand side of the face are similar but not identical for the left side.

In figure 10, where the temperature changes after third warm up have been compared at all points of measurements between the

Figure 7: temperature changes at the right mouthcorner (Point 1d: anguli oris inferior)

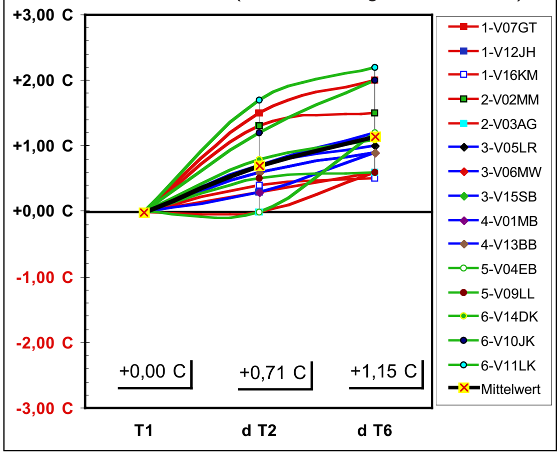


Figure 8: temperature changes at the right eyecorner (Point 2d: anguli oculi)

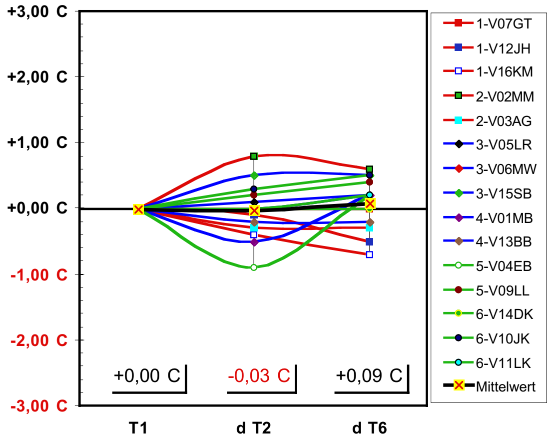
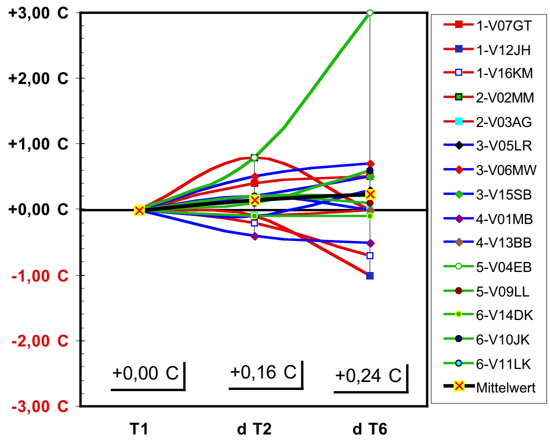
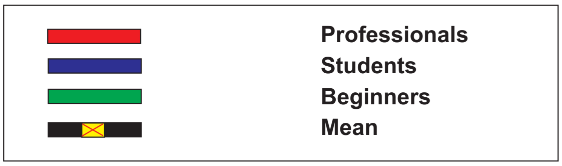


Figure 9: temperature changes at the right outer cheek (Point 7d: buccal auriculaer)





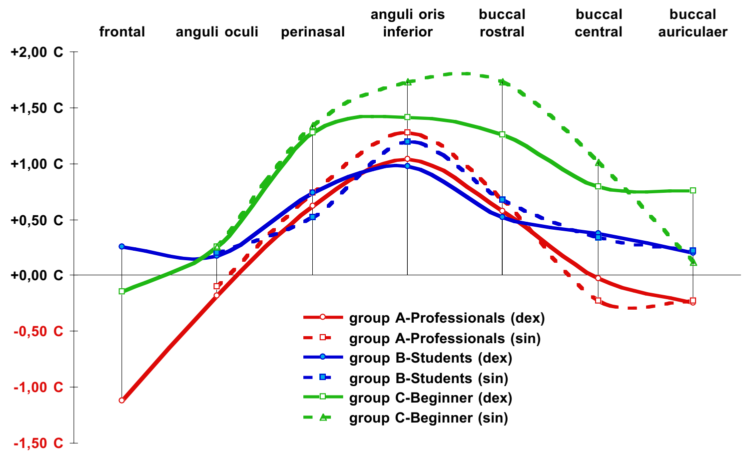


Figure 10: Changes of skin temperature in the face of trumpet players after the third warm up (ΔC t6-t1)
symmetry comparison by level of skill.

solid line: right side; dotted: left side.

three groups, significant differences may be seen: Professionals warm up much more symmetrically than beginners. Not only the symmetry, but also the intensity of the warm up is much more focused towards the embouchure area when the players are more experienced. Players with less experience expressed an inhomogeneous thermographic pattern compared to well-trained musicians. Professional trumpet players show a more compact, economic and homogenous embouchure.

Summary

The main facial muscle activity during warm up seems to be restricted to only a few muscle groups (M.orbicularis oris, M.depressor anguli oris,) while the “Trumpeter’s muscle” (M.buccinator) proved to be of minor importance. Less experienced players expressed an inhomogeneous thermographic facial pattern compared to well-trained musicians. Professional trumpet players (with more experience) seemed to be mentally “cooler” after warm up. Their pulse rate tends to decrease probably due to their well-trained condition. Thermography shows a more economic, compact and symmetrical warm up of the embouchure in these players.

This first study gives reason to suppose that infrared thermography could become a useful tool for documentation of brass players playing technique. The technique could for example be used to test the effect of embouchure trainers, or could be expanded to physiological studies of different instrument playing. Perhaps this method could be used to identify areas of unnecessary muscle tensions in string players, either.

Reference
Bertsch Matthias. “Studien zur Tonerzeugung auf der Trompete”. Dissertation at the University of Vienna 1998.

Intonation on trumpets

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Abstract: The purpose of this study was to determine the intonation properties of trumpets and to compare empirical data of played trumpets with a.) theoretical tuning systems like equally tempered, Pythagorean tuning or just intonation and b.) with the "objective intonation" which has been calculated by means of input impedance measurements. Another aim of this study was to evaluate the size of inter- and intra-individual variability in performances. Results show that there are great differences amongst players even playing the same reference instrument. The arithmetic mean over all trials correlates best with the equally tempered system. In the middle register, the calculated "objective intonation" matched played intonation even better.

INTRODUCTION

Tone generation on trumpets is influenced by many parameters. Variation of the played intonation are caused by either the instrument, the player, or both. The intonation of the instrument is determined by the mechanical dimensions of the instrument and the mouthpiece. The position of resonance frequencies, the so called "objective intonation", can be calculated using the input impedance method. Statistical data taken from 35 trumpets will be presented and compared with the pitch of notes blown by the player (so called "subjective intonation"). The "subjective intonation" can vary for many reasons. It can be caused by the physiological condition of the lips of a player or the increasing participation of higher harmonics in a crescendo. The desired timbre of the sound can cause variations as well. These variations can be more than 50 cent with the same instrument as shown in a previous study (BERTSCH 1997). The main objective of this study was to find out if players follow the tuning of the instrument or if rather they are trying to perform one of the musical scale models as equally tempered, Pythagorean tuning and just intonation.

METHODS

Measurement of the "objective" Intonation of trumpets : 36 trumpets in B-flat have been measured using the "Brass Instrument Analysing System" BIAS, a Hard and Software system developed at the *Institut für Wiener Klangstil* (IWK). [Widholm, 1995]. BIAS measures the input impedance of brass instruments. Frequencies of impedance peaks are detected and set into relationship with the equally tempered scale. The reference frequency for A4 is calculated in a way that the mean deviation of the impedance peaks 2-6 and 8 (which correspond to the natural tones Bb3, F4, Bb4, D5, F5, Bb5) is a minimum. Then the departure of all notes from their ideal location is calculated taking all valve combinations of the instrument as well as the refrence frequency - usually about 440 Hz …445 Hz, - into account. This calculation method (the so called „without weighting" method; WGT=0) assumes that the excitation signal is a sinusoidal signal. In reality the excitation signal of a real player will instead have a sound spectrum containing many harmonics with different amplitudes. Therefore not only the impedance peak at one frequency (the fundamental of the particular note) has to be taken into consideration, but all multiple frequencies of the fundamental of the virtually played note. The contribution of each partial of the excitation spectrum to the „over all“ impedance of a particular note has to be weighted according to the relative amplitude of the excitation spectral line. BIAS allows different weightings to simulate different dynamic conditions resp. sound spectra of the excitation signal. Usually a “standard weighting” (WGT=2) is used, where the magnitude of the impedance of higher partials is weighted by $\frac{1}{\sqrt{x}}$ (x being the index of the harmonic). This relationship has been found in preliminary studies to correspond well with mezzoforte dynamic. The present study is another approach to find an appropriate formula.

Analysis of performed intonation of players: trumpet players have been recorded in the anechoic chamber of our institute playing several tasks in two sessions. The first trial was played on their own instrument, while in the second trial, a reference trumpet in Bb (Romeo ADACI, Referenz 2001) together with a reference mouthpiece (BRESLMAIR G1) had to be used. Only the rim of the mouthpiece could be chosen by the player. The detailed set up was already described at ISMA 97 [Bertsch, 1997]

The subjects were 35 musicians having 18.5 years of experience in average. 20 of them were highly trained professionals and members in established Vienna orchestras. The other 15 were advanced trumpet students or amateurs with a wide range of experiences. 24 were playing a trumpet with rotary valves in the first trial, 11 one with Perinét valves. The reference trumpet has Perinét valves, too.

The musicians were asked to play the given music as if they would perform on stage. No special instructions were given to concentrate on the intonation in order to receive realistic samples. Two scales in F major have been analysed. Note that this corresponds to G major when the notation is for a trumpet in Bb (fig. 1). Task F3-4 starts at F3 in the lower register of the instrument and ends in the middle register one octave above. Task F4-5 covers the next octave from F4 to the beginning of the high register of the trumpet at F5. One note, the F4 (written as g4) is played and analysed twice.

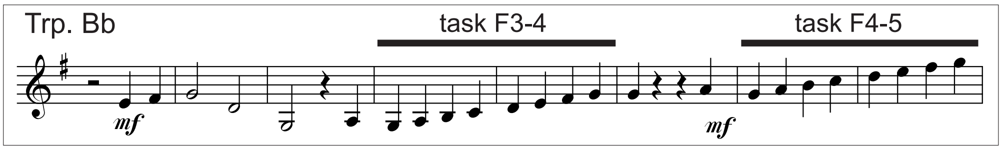


FIGURE 1 Musical context of task F3-4 and F4-5 played on trumpets in B-flat.

Duration and articulation was not defined more precisely. The dynamic should be *mezzoforte*. The growing tension of the ascending scales and the influence of the different dynamic range of the instrument in lower and upper registers caused all players to perform a crescendo. In average, the F5 was played 13dB louder than F3. i.e. an increase of 6 dB per octave. The inter individual variability was remarkably more than 14 dB in each register which demonstrates a different interpretation of mezzoforte. Correlation between intonation and dynamic was part of the previous study.

Each single note played on a brass instrument varies in pitch, even without any vibrato. Most notes in a ascending scale also ascend from their beginning to their end. To receive only one fundamental frequency (f0) for each blown note, digital signal analysis has been applied. Fundamental frequencies have been detected (fs: 44,1 resp. 48kHz; window lengths: 2048 Samples) when at least four partials were fitting into a harmonic grid. Additionally the RMS was plotted. As relevant frequency (in this study referred to as the oberseved mean frequency) the frequency at the moment with maximum amplitude (RMS) has been considered. (Only in some cases a more constantly played frequency was chosen.) The upper part of figure 2 shows the f_0 played by one player as the note C5. Each data point indicates the fundamental frequency as a result of a harmonic grid analysis. The first and last 50ms of each tone, - one FFT window length -have been omitted. Absolute frequencies have been transformed into relative intervals corresponding to an individual tuning. (A4 between 438 Hz and 445 Hz.) For the determination of A4, the minimum departure of all natural tones (no valve engaged) have been taken into consideration. The arithmetic mean, 443 Hz (SD: 2 Hz), illustrates the actual custom to tune to a higher frequency than the current international standard tuning frequency for western music, 440 Hz. Additionally the minimum and maximum frequencies have been tracked to determine the variation of one note.

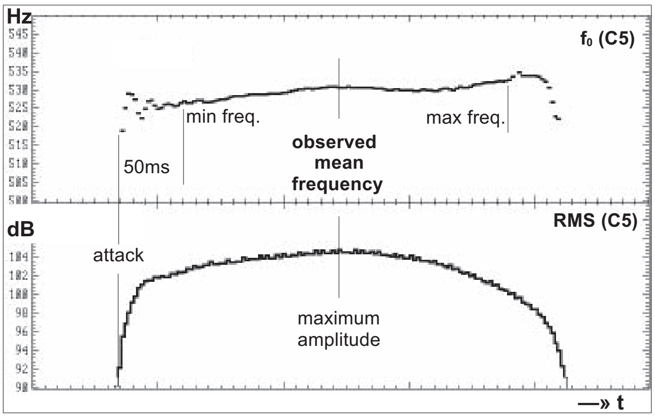


Figure 2. Detection of the played fundamental frequency.

RESULTS

Measured intonation: BIAS measurements of 35 trumpets in B-flat have been made and the average departure of the calculated intonation from the equally tempered system is shown in Fig.3. In the lower register there is a great difference between a graph without weighting (WGT=0) - where notes are very flat,

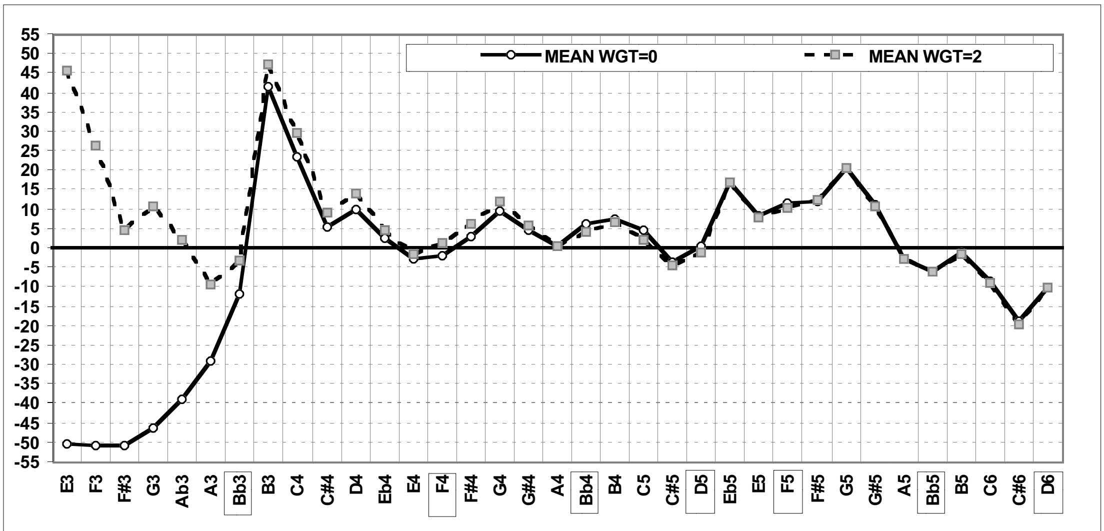


Figure 3. Departure from equally tempered scale in cent (arithmetic mean of all BIAS measurements)

and one with standard weighting (WGT=2) - where notes in the 3rd octave are rather sharp. In the middle and high register, variations between weightings are very small. For most values (except 3rd octave of WGT=0) the analysis shows that if more than one valve is engaged t he effective length of the additional tube is too short. The resulting tone is sharp. In fig. 4, the values (for WGT=2) for each valve combination which are used in standard fingering are shown separately. This well known fact can on almost all instruments be corrected manually using a trigger. Especially for B3 and C4 the use of a trigger is always recommended.

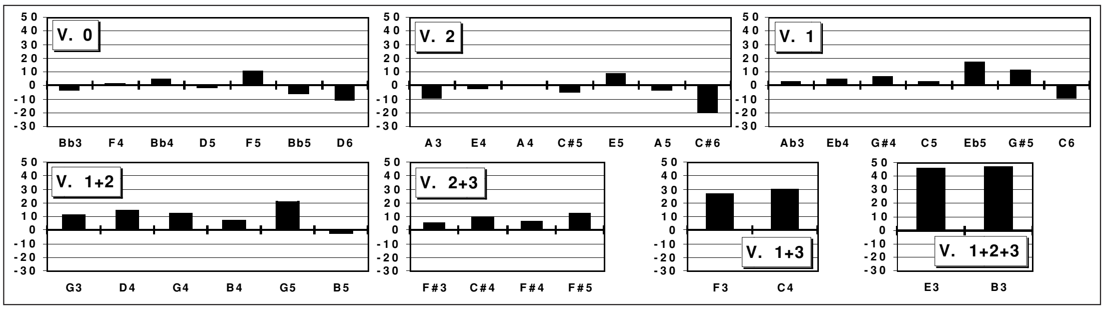


Figure 4. Intonation error in cent for each valve combination (BIAS WGT=2)

Besides this characteristic, which is connected to the valve combination, it is remarkable that all notes blown using valve 1 are sharp (except C6). Furthermore, notes blown at the 6th resonance frequency tend to be very sharp (Eb5: +17 cent; F5: +10 cent)

Played intonation: Recordings of 35 trumpet players have been analysed regarding of their intonation performance within two F major scales. In Fig. 5 a huge inter-individual variation of the observed mean frequencies can be seen. The overall distance between maximum and minimum is about 30-40 cent, and in the lowest register even more. Astonishing is the variety of played intonation on the reference trumpet.

Compared to the equally tempered system, the arithmetic mean of all played intonations fluctuates between sharp and flat. (See table 1) Remarkable is the note A3, which is more than 16 cent flat and the notes C4, G4 and F5 which are played more than 10 cent higher than the equally tempered scale. The associated

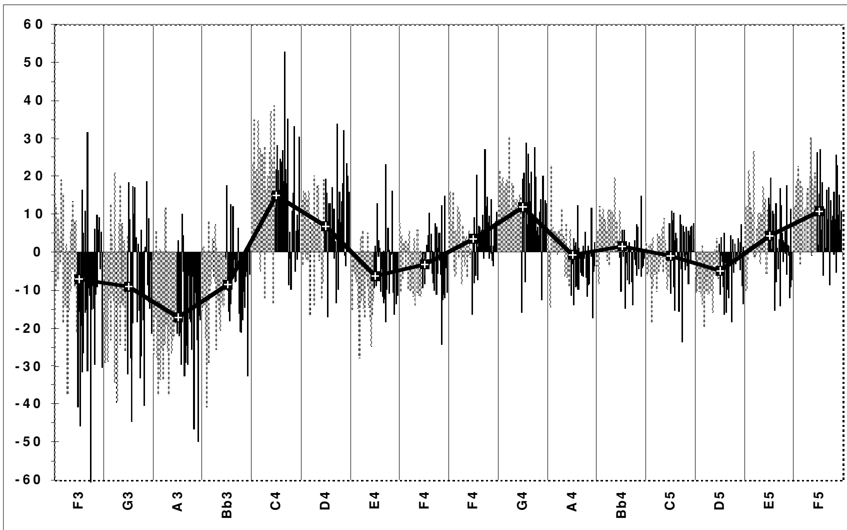


Figure 5. The actually played intonation of all trumpeters (departure from the equally tempered scale in cent). The black curve indicates the arithmetic mean over all sessions. The individual values are shown as black narrow bars for values played with their own individual instrument and grey bars for the session played on the reference trumpet.

standard deviation (SD) for tones in the lower register is about 15 cent, in the middle and upper register approxamately 7 cent. The SD for trials on the reference trumpet (R) is only slightly higher (1 cent) than for the trials played with individual instruments (I).

Intonation differences between I and R exist for some particular tones, which are caused by the type of the trumpet. On instruments with Perinét valves (like R), the A4 and Bb4 are about 6 cent sharper, C5 and D5 are about 7 cent more flat as on instruments with rotary valves (like most of I).

The fact that the second F4 is in average 7 cent higher than the first shows the importance of musical context. In this case the second F4 is played right after the G4, which is very sharp.

If the intonation of both tasks is compared, (see fig. 6) almost no common trend concerning interval relationship can be found. This makes an underlying general "theoretical system" unlikely. Remarkable is that both keynote octaves are larger than 1200 cent. Moreover, 7 of 9 occurring octaves are stretched. In order to compare the played intonation with theoretical tuning systems like equally tempered, Pythagorean and just intonation, the departures have been calculated and plotted in Fig. 7. In general, trumpet performance most closely conforms with equally tempered intonation. Departures from each model are much greater than differential threshold (about 3 cent).

Table 1. arithmetic mean, in cent of departure from the equally tempered intonation over both trials (I+R) together with standard deviation and for each trial seperatly.

	I+R MEAN	I+R SD	R MEAN	I MEAN
F3	-7,1	17,3	-2,9	-11,7
G3	-9,2	15,8	-10,6	-8,3
A3	-16,9	12,4	-18,4	-16,0
Bb3	-8,4	10,4	-10,2	-7,2
C4	15,0	13,0	16,0	13,5
D4	6,9	10,5	5,6	8,4
E4	-6,1	8,8	-8,2	-3,7
F4	-3,1	7,2	-3,6	-2,1
F4	3,7	7,2	3,0	4,5
G4	12,0	8,3	13,5	10,4
A4	-0,6	7,0	2,2	-3,1
Bb4	1,6	6,8	4,9	-1,8
C5	-0,8	7,1	-2,2	0,5
D5	-4,7	6,3	-6,3	-3,0
E5	4,5	8,6	6,6	2,6
F5	10,9	8,0	12,2	9,7

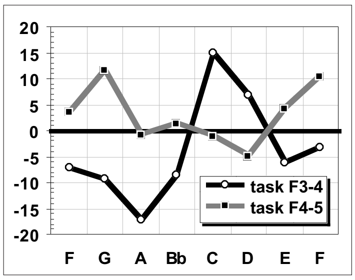


Figure 6. upper / lower octave (Δ ET)

Additionally, the played intonation of certain groups of players selected from all players has been statistically analysed. As a result, little significant difference was found between professional and student players, between younger and older players, or between male and female musicians. Diversity was found to exist only on notes with extreme deviation. For example professionals played the C4 and G4 five cent less sharp than amateurs and students. Especially the C4 was played very sharp by players with less experience.

The examination of the played tones reveals further a great difference between minimum and maximum for each note within the scale. 26 cent in average among all players for the trials on their own instrument, and 28 cent for trials with the reference trumpet. In the lower register the average variation of some notes was even more than 50 cent. Of course, during the ascending scale, most slurs have been upwards.

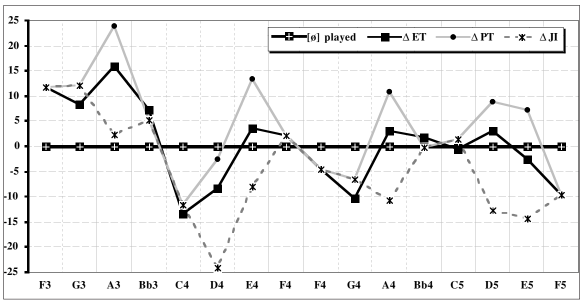


Figure 7. Departures from theoretical intonations in cent. Ordinate corresponds to played intonation on indiv. instruments

MEASURED VERSUS PLAYED INTONATION:

A comparison of the arithmetic mean of the variety of subjective intonations of an instrument as played by a player and the “objetive intonation” as measured using BIAS shows a good matching in the middle register. In Fig. 8 a disagreement can be only found in the lower register, where weighting influences the result to a great extent. The standard weighted intonation measurement approaches the played intonation more closely which can be taken as an indication that an improvement of the weighting algorithm could be a good way to further improve correlation between played and measured intonation.

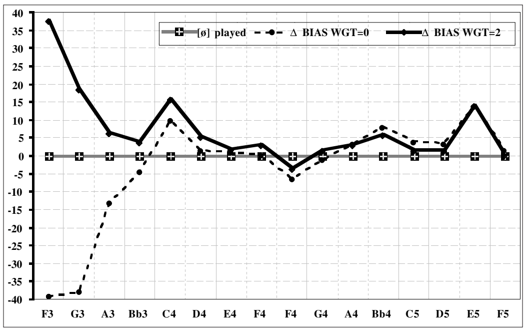
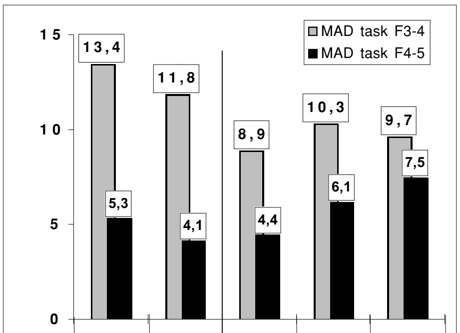


Figure 8. Departures of BIAS measurements from the played intonation in cent. Ordinate corresponds to played intonation on indiv. instruments.



	Δ BIAS WGT=0	Δ BIAS WGT=2	Δ ET	Δ PT	Δ JI
F 3-4	**13,44**	**11,84**	**8,87**	**10,33**	**9,65**
SD	*16,13*	*12,21*	*4,73*	*7,11*	*7,10*
F4-5	**5,31**	**4,11**	**4,45**	**6,15**	**7,47**
SD	*4,24*	*4,44*	*3,62*	*3,86*	*5,18*

Table 2. Mean absolute difference (MAD) in cent between observed played intonation on players own instruments and BIAS measurements without (WGT=0) and with standard weighting (WGT=2). Further MAD and theoretical musical systems: equal tuning (ET), Pythagorean tuning (PT) and just intonation (JI). **Figure 9.** shows MAD for each task seperately.

SUMMARY

The main results of the present study are summarized in table 2 in which the arithmetic mean of the MAD values and the associated standard deviations are tabulated. Visual inspection of Figure 9 shows: a.) that trumpet performance in regard to theroretical tunings most closely conforms to equally tempered intonation and b.) that the standard weighted “objective intonation” model matches played intonation especially well in middle register. Therefore, it can be concluded that trumpeters follow the tuning asserted by the instrument rather than trying to match a theoretical scale.

For the player, a perfect „objective intonation“ that matches his „intended intonation“ could free him to concentrate on other aspects. Since technical tools are able to optimise the „objective intonation“ of brass instruments (Anglmayer and Kausel 1998), the question arises which ideal intonation a musician expects from his instrument. Usually only extreme departures are considered as a real problem, because much energy is needed for correction.

ACKNOWLEDGMENTS

I am grateful to all trumpet players who have participated in this study.

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VARIABILITIES IN TRUMPET SOUNDS

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1.INTRODUCTION

Although the sound of a trumpet is very distinctive within an orchestra, there are many nuances if the tones are played isolated. The same instrument can sound very different even played by the same person, and two different instruments can sound very similar. It is often said that a good player can play what he likes with any instrument. This leads to the central questions of this study. To what extent does the player or the instrument dominate the sound and how large are the variables? How does the sound - played by many professional and student trumpet players using the same instrument - differ? Since tone generation is very complex, the synthesis and simulation of the sound in a model is quite unsatisfactory. The development of theories and models from physicians and computer scientists is encouraging. However, there are many variables that will be included in future work. This paper first offers a description of sound-influencing variables. Then, the first results of a substantial audio-visual research study on trumpet playing are presented. Finally, a comparison of particular playing-techniques worked out by means of optical analysis is presented.

2. AIM

The aim of the study is to demonstrate how different trumpets can sound. The attempt has been made to find parameters that influences the tone generation. The main purpose of the study is to provide more empirical data to support models of synthesis and simulation.

3. METHODS

3.1 Players and Instruments

Professional, amateur and student trumpet players are invited (and still are, for further studies) to play 10 different tasks two times in the anechoic chamber of the ”Institut für Wiener Klangstil” (n=35 in May, 97). First they played their own instruments (in Bb). The second time they all played on a reference instrument (Referenz 2001 made by Adaci), which is also in Bb, with a mouthpiece (G1, made by Breslmair) where throat and cup were given and the rim could be chosen.
To reduce the strange and unpleasant acoustic of the anechoic chamber, all players could choose the amount of reverberation they preferred to hear through their headphones (realized with ”Zoom 9120” advanced sound environment processing).

3.2 Tasks

a.), b.) two phrases from the classical Hummel concerto in Eb major. c.) a signal from Beethoven‘s *inst = f (qp (int, rsp, mcp (bor, shp, mat)), sq (bn, ow, ol)) {2}*

The player (ply) can be defined through his intention (itt) (what he wants to play), his ability (aby), (what he could play) and how he realizes it (rlz) (playing technique). All factors includes cognitive, physiological and psychological aspects.

ply = f (itt, aby, rlz) {3}

The environment is defined by time (time) and room (room). While the physical room acoustics (pra) such as air temperature (atmp), reverberation time (rvt) or air quality (aqty) have an overall impact, the optical appearance (opa) and the haptic quality (hap) can influence the players' psyche.

evi = f (time, room (pra (atmp, rvt, aqty), opa, hap) {4}

Each of the variables given above are determined by additional parameters. For example, the variables of the players could be divided in the following subcategories.

The intention (itt) of the player describes what he wants to play. This depends on his musical background (mbg) from parents and his environment (such as tone system, scales or sound imagination), the general music style (gms) (baroque, classic, jazz, funk, folkmusic) and the specific context of the next tone (sctx) (such as the register, dynamic, articulation or interval).

itt = f (mbg, gms, sctx) {5}

The ability (aby) of the player, (what he could play) is affected by the amount of talent (tal), the age (age), the IQ (IQ), the education level (elv), the educational style of the teacher (tea), experience (exp), the regional influence of other performed music (reg), his or her familiarity with the instrument (fami) and the physiological constitution (phyp) of the player. This includes, for example, gender (gnd), the teeth constellation (teth), the constitutions of lips and mucous membranes (lips), lung capacity (lung) the auditory hearing system (hear), endurance ability, (endu) and the constitution of participating muscle groups (musc).

aby = f (tal, age, IQ, elv, tea, exp, reg, fami, phyp (gnd, teht, lips, lung, hear, endu, musc)) {6}

The realizations (rlz) of the actual played tone depends on the motivation (motv), the concentration (conc), the situation (sit) (if relaxed or at a concert or participating in a contest) and the psychological constitution (psyc), the frame of mind (fom), health (hlth) (blood pressure, pulse and other vital functions) and last, but not least, the playing technique (pltq). It can be described as a function of the air flow (aflw), the lip oscillation (osci), the embouchure pressure (epre), the tongue position (tngp), the instrument placement (iplc), the actual muscle control (amct), (eg if he is warmed up or not), and the fingering (fing).

rlz = f (motv, conc, sit, psyc, fom, hltl pltq (aflw, osci, epre, tngp, iplc, amct,fing)) {7}

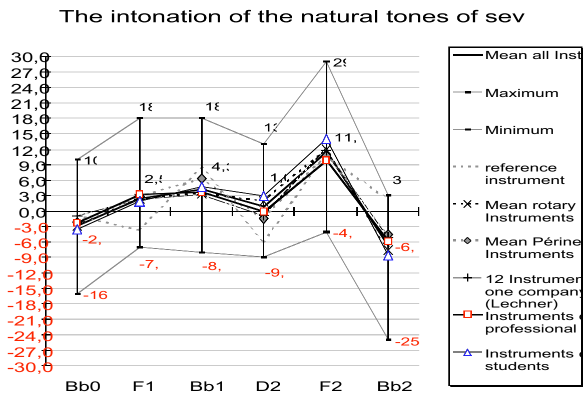
These 58 variables mentioned demonstrate the complexity of the generation of one single trumpet sound:

ts = f (inst(qp (int, rsp, mcp (bor, shp, mat)), sq (bn, ow, ol)), ply (itt (mbg, gms, sctx), aby (tal, age, IQ, elv, tea, exp, reg, fami, phyp (gnd, teht, lips, lung, hear, endu, musc)), rlz (motv, conc, sit, psyc, fom, hltl pltq (aflw, osci, epre, tngp, iplc, amct,fing))), evi(time, room (pra (atmp, rvt, aqty), opa, hap)) {8}

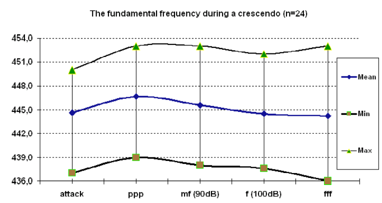
5. FIRST RESULTS ON SOME VARIABLES

5.1 Intonation [int]

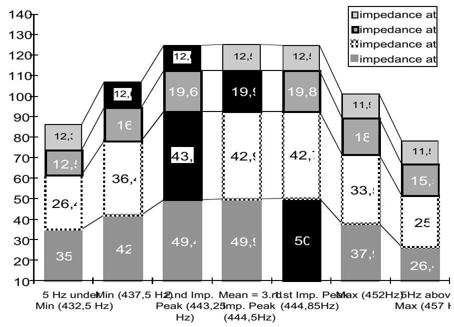
5.1.1 Intonation characteristic of multiple trumpets (n=33). Each trumpet of the participating musician is measured with the BIASsystem. It calculates the intonation error and the deviations of each tone in cent. [illustration: all instruments have a common tendency to be out of tune. The mean of the groups of one valve type or one manufacturer or the instruments blown from professional or student musicians do not differ signicicantly from the average of all instruments. The single measurement of the reference instruments also follows this trend.]



5.1.2 Intonation of the reference trumpet. The fundamental frequency of the a1 blown on the reference instrument depends on the dynamic and varies greatly between players. [illustration: the mean, maximal and minimal values played during a crescendo of the a1; (moment of attack; sustained ppp, the individual minimal amplitude; mf (measured 90 dB); forte (measured 100 dB) and at fff, the individual maximal amplitude).]



Since the generation spectrum of the trumpet player includes lots of harmonics, the impedance at the corresponding frequency has to be taken into account. The position und intensity of all peaks can explain the blown fundamental frequency. The mean value corresponds with player tuning on the first peak. The sum of the acoustic MOhm of 4 harmonics justify the range of all fundamental frequencies played by 24 different persons. [illustration: addition of the impedance values of the harmonics coresponding to the blown fundamental frequency]

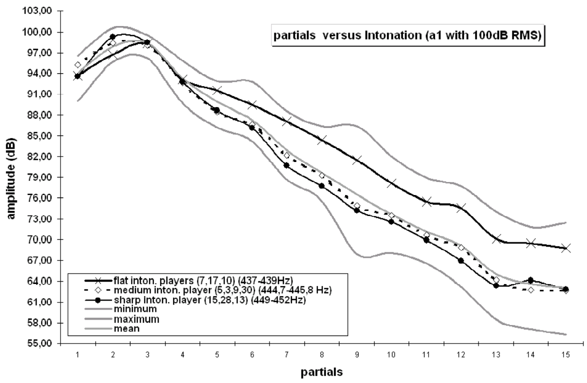


5.1.4 Variations between players. The intonation difference at mf (measured 90 dB) is 58 cent (min.=438 Hz; max.=453 Hz) and at f (measured 100 dB) is still 56 cent (min.=437, 6 Hz; max.=452 Hz)! The influence of different temperatures (18°C-23°C) during the recording cannot be the reason for the variations, since it alters the intonation to a maximum of 15 cent. The differences are caused by the player [ply].

5.2 Spectral analysis of the a1 blown forte (100 dB)

5.2.1 Overall [inst]. The formant of the trumpet dominates the spectrum of all 24 players (800 Hz - 1400 Hz) The third partial has the highest amplitude (Mean=98,3 dB) followed from the second (97,9). The fundamental frequency is about 4 dB weaker than the third partial. The amplitude of the higher partials descends continuously (4. =93,3; 5.=89,9; 6.=87,3; 7=82,8; 8.=79,7; 9=76,5; 10=73,6; 11=71,1; 12=69,1; 13=64,9; 14=63,6; 15=63,1)The values of higher partials differ 7-16 dB !

5.2.2. Variations between players. For those players who play the a1 very flat (a1= 437 - 439 Hz) the first and second partial were weak but the 5. to 15. partials are significantly stronger than those of the other players. If higher partials have a higher intensity, the first and second partials are weaker than the averages. Those players playing the a1 between 444,7 Hz and 445,8 Hz have a stronger fundamental frequency but the higher partials are about or under average. Players tuning the a1 very sharp (449-452 Hz) have more intensity on the second partials than others but the amplitudes of the fundamental and the higher partials are about or under the average. [illustration: the spectrum of the minimal, maximal, mean values and the average of low, medium, and sharp intonating players.]



5.3 Dynamic range (a1 crescendo from ppp to fff)

5.3.1 Overall. The dynamic range general depends on the register. The measured mean value of the RMS for the a1 (which is in the middle register) on the reference instrument increases 27 dB from 81,3 dB at ppp (individual minimum amplitude) to 108,5 dB at fff (individual maximum amplitude). About 100 dB correlates with forte, 94 dB mezzoforte, 87 dB piano, 106 dB with fortissimo, 110 dB with fortefortissimo) Above 110 dB dramatic changes in the sound quality can be heard. The dynamic range is larger in the lower register (at b0 about 30 dB) and in the higher register less (at c3 about 13 dB). It is remarkable that the mean value of the intensity at the moment of attack is with 83,8 dB about 2,5 dB over the ppp (individual minimum amplitude).

5.3.2. Variations between players and types. Compared are the differences between [ELV]: player status (professional (n=14) versus student or amateur players (n=10)); [gnd]: gender (male (n=17) versus female (n=7)); [mbe]: types (rather classical (n=14) versus jazz players or all-rounders (n=10)); [exp]: experience (more than 20 years (n=11) versus less (n=13)).

5.3.2.1 Attack. Some players could begin very softly without a somewhat louder attack, some started up to 7 dB louder. There are no significant differences within one group of pairs in [elv], [gnd], [mbe], or [exp].

5.3.2.2 Dynamic range. There are no significant differences within one group of pairs in [elv], [gnd], [mbe], or [exp].

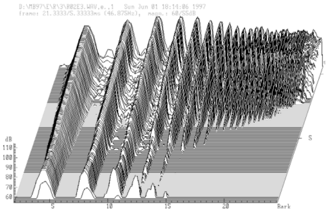
5.3.2.3 RMS minima (ppp). From the 24 players, four of the classical musicians played the slightest ppp and 3 jazz or all-round players played the ppp significantly louder. There are no significant differences within one group of pairs in [elv], [gnd] or [exp].

5.3.2.4 RMS maxima. 3 men and 2 females reached 110 dB. Only 3 males played even louder with 113 dB, where the sound becomes more penetrating. There are no significant differences within one group of pairs in [elv], [mbe], or [exp].

5.4 Other parameters

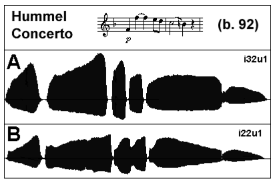
5.4.1 The influence of the microphone positions affects the recorded sound to a large extent. [room, evi] Behind the instrument, at the players ear, the sound is much duller, caused by the sound radiation characteristic of the trumpet (radiation focus to the front increases with the frequency). The nuances of several instruments will be studied at a later time.

5.4.2. The changes of the spectrum during a crescendo are very great. The formant always dominates the spectrum, but the increase of high partials determines the characteristic of the sound. At very high amplitudes (above 110 dB) high partials are intensive until the end of the analyzed frequency range at 24 kHz. [illustration: 3D FFT of a crescendo; frequencies in Bark (0-20 kHz). 100 dB RMS are reached at 4.2 s]



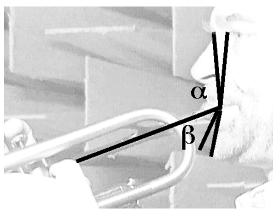
5.5 interpretation [rlz]

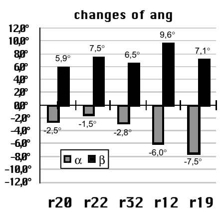
Of course, music does not only vary in dynamic or the spectrum of the quasistationary oscillation. It is often said that a trumpet player can be identified by his sound. This can only be justified if you take the changes versus time into account, which includes, for example, his articulation or interpretation. What is heard first are differences in articulation and such parameters as the attack or rhythmic variations. [illustration: differences in interpretation can already be seen in the wave form of two players. A plays more staccato while B plays in a very soft legato style.]



5.6 OPTICAL ANALYSIS [pltq]

Comparing the playing position in the lower and higher registers, similarities and variations between players can be observed. Some players move their heads, and some move their instrument. In both cases, the angle a changes. At the same time, the jaws moves forward and angle b changes. Following table shows the range of the angle changes. [illustration: measuring angle a and b] The variation is determined by the individual playing technique. [illustration: values of a and b for a slur two octaves downward (f2 - f0).]





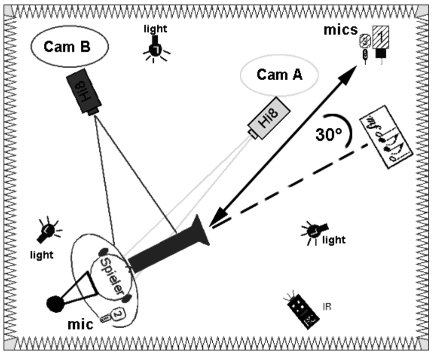
Annotation. This study will be continued; more participants and more variables will be taken into account.

6. REFERENCES

Since there are so many studies on several variables, a list of references can only be fragmentary. A list of studies is available on the World Wide Web. The URL is: http://unet.univie.ac.at/~a8708253/trumpet/literature.html

”Leonoren Overture”. d.) five single notes with p-f crescendo (fis0, b0, f1, e2, a2). e.) one single note (a1) with ppp - fff crescendo. f.) a G-major scale and a slurred f2-f1-f0-f1-f2. g.) two lip trills. h.) one 8-bar swing phrase.

3.3 Audio and video recording



The sessions were recorded with 3 microphones at two different positions. An AKG C515 and an AKGC577 were in front of the bell in a 30° angle to the playing direction with a distance of 2,2 m. Another AKG C577 microphone is placed close to the player‘s right ear. The signals of the three microphones are recorded on Audio Digital Tape (RD8 Fostex), digitally recorded on a PowerMac harddisk (Kork 1212 interface), preselected and stored as .wav files on CDR. To assure the possibility of comparing the dynamics of all players (the recording process is still in progress) a siren signal with measured 100 dB is always recorded with the tasks. Additionally, two Hi8 Camcorders are installed and focused on the player. Camera A records the embouchure area frontally and Camera B focuses laterally on the instrument and the player‘s head. To ensure that the player remains in the range of the picture he is instructed to remain close to an occiput support. [illustration: the set up of the player, the microphones and cameras in the anechoic chamber]

3.4 Analysis Software

Sound analysis: S_Tools 5.x (FFT, RMS, sonagram, f0 extraction) ; Deck II 2.6 . Acoustic measurements: BIAS 4.0 hard and software system (impedance, intonation). Optical video analysis: Adobe Photoshop 3.0 and Premiere 2.0; NIH Image 1.6

4. VARIABLES IN TONE GENERATION

Variables have been collected in order to explain differences. Some of them have already been investigated, some are not suitable for scientific approaches (psychological influences are almost impossible to investigate). It is necessary to mention some very unusual aspects, since, if you ask a musician what affects his embouchure, the range of answers is unbelievable: ”It depends how much I slept”; or ”Alone at home I played it wonderfully; now its much worse”. The next step must be to study the amount and quality of each variable. This may help to bring models closer to simulating the actual variety of tones.

Trumpet sound (ts) is generated by the two coupled vibrating systems of the instrument (inst) and the player (ply) in a unique environment (evi). Each component affects the other in a control loop.

$$ts = f(inst, ply, evi) \quad \{1\}$$

The instrument is determined by its objective quality parameters (qp) (such as the intonation (int), the responsiveness (rsp), which are caused by mechanical parameters (mcp) (such as the bore (bor), shape (shp), and material (mat)), and by subjective assigned qualities (sq) (such as brand name (bn), owner (ow), outlook (ol)).

Matthias Bertsch
IWK - University for Music, Vienna, Austria

Variabilities in Trumpet Sounds

A lot of variables and aspects makes trumpets sounding different.

–

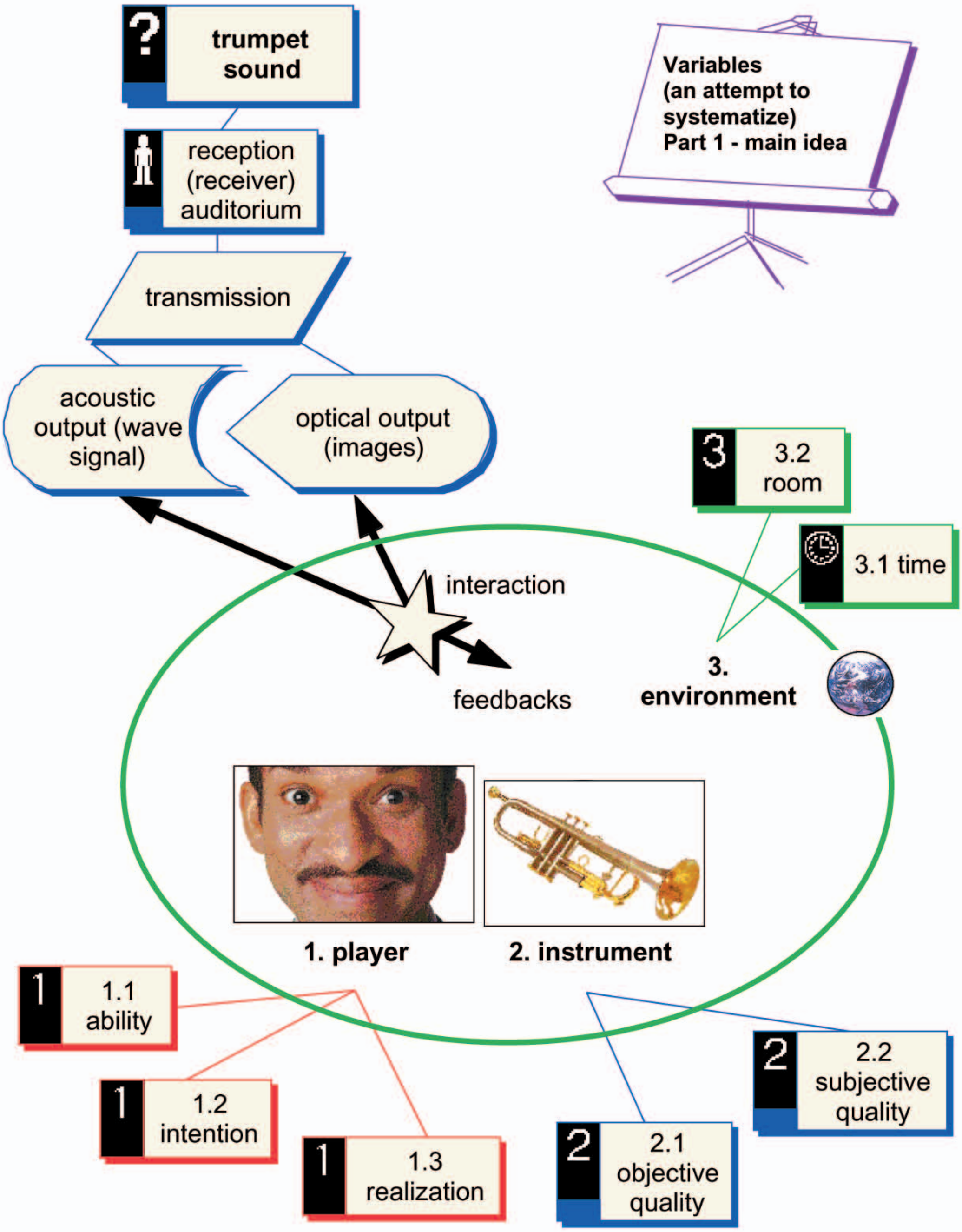
An attempt to systematize

overview

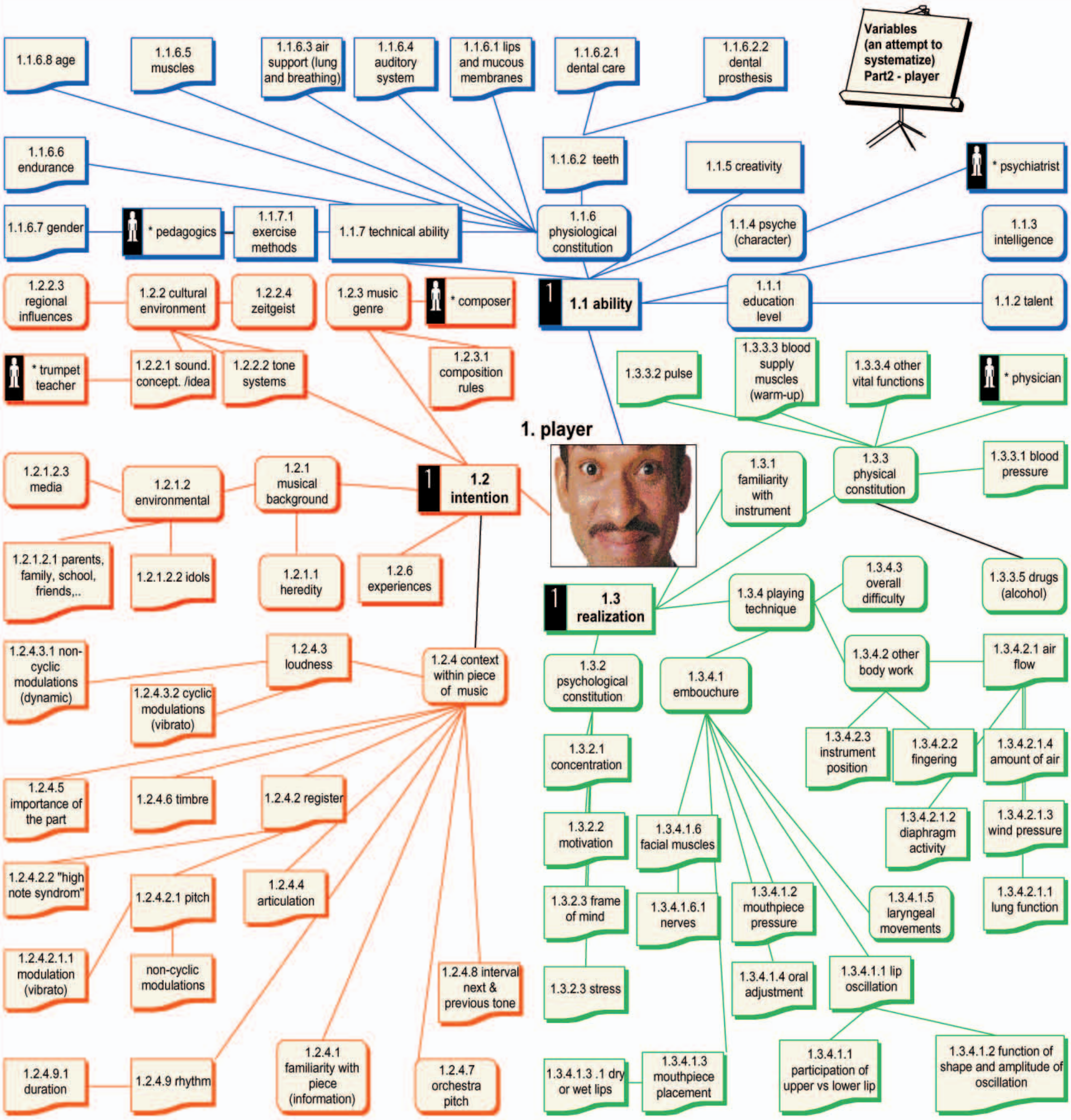
aspects concerning the player

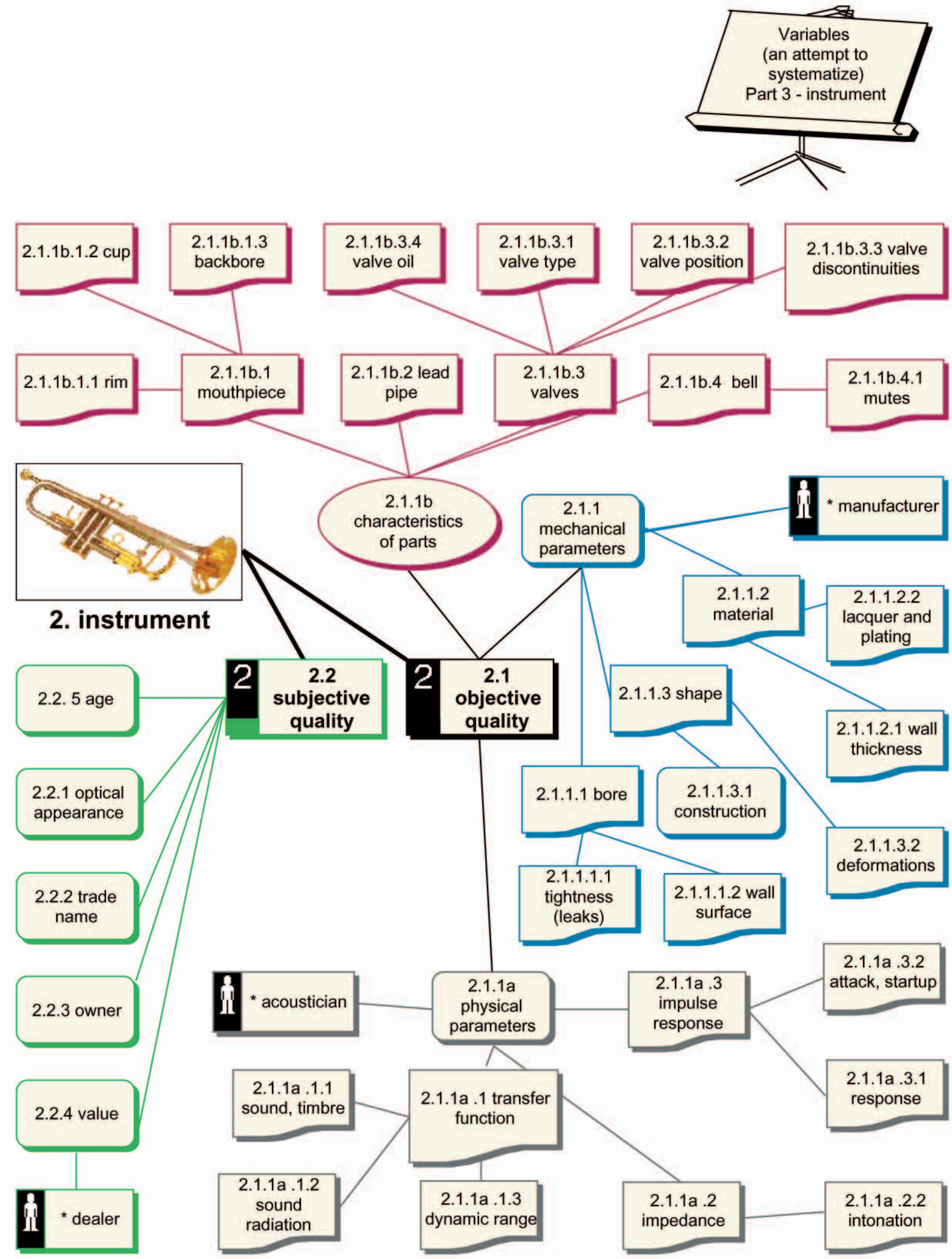
the instrument - variables of the trumpet

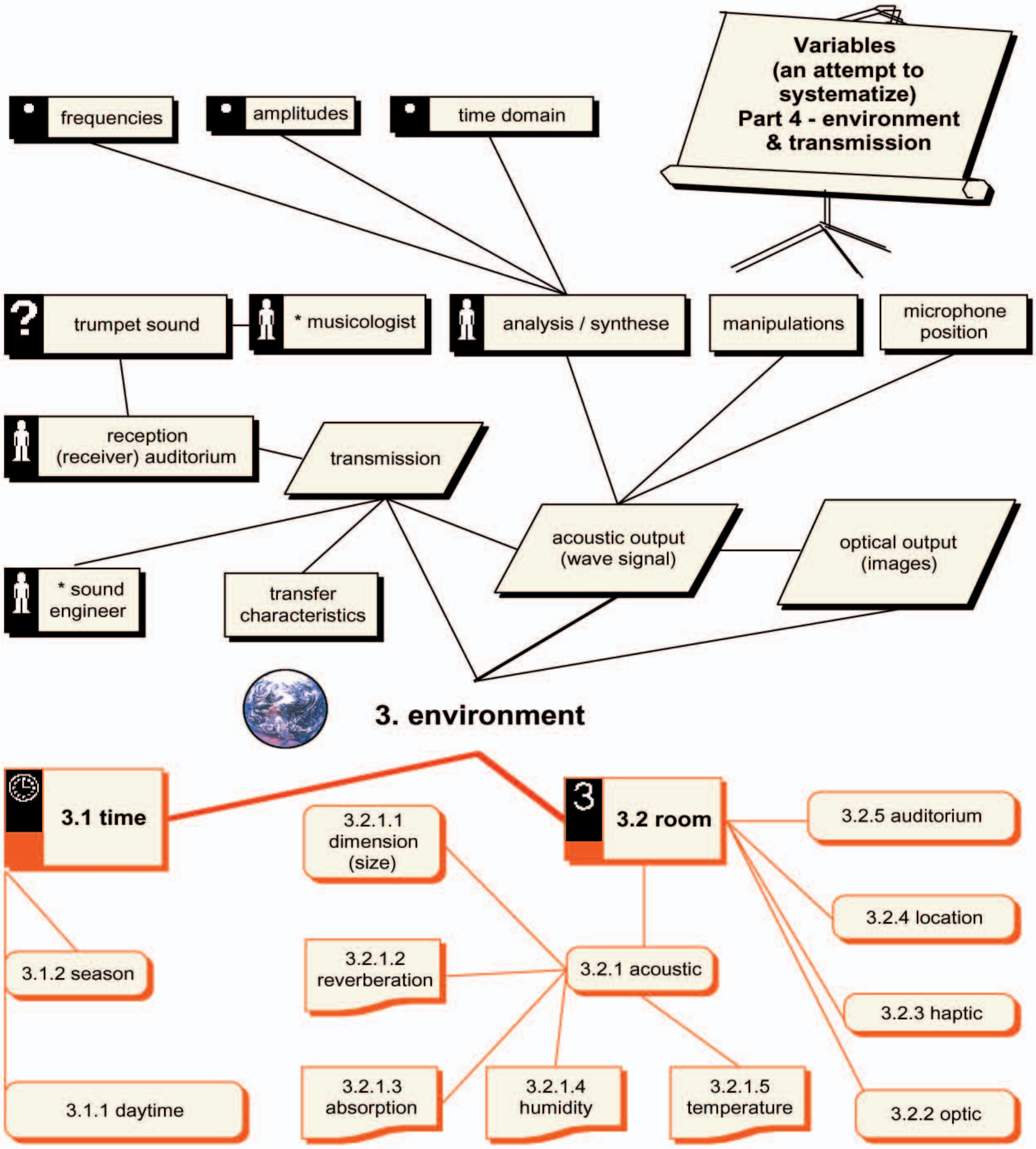
influence of the environment



trumpet sound
reception (receiver) auditorium
transmission
acoustic output (wave signal)
optical output (images)
Variables (an attempt to systematize) Part 1 - main idea
3.2 room
3.1 time
interaction
feedbacks
3. environment
1. player
2. instrument
1.1 ability
1.2 intention
1.3 realization
2.1 objective quality
2.2 subjective quality


Variables (an attempt to systematize) Part2 - player
1. player
1.1 ability
1.1.1 education level
1.1.2 talent
1.1.3 intelligence
1.1.4 psyche (character)
* psychiatrist
1.1.5 creativity
1.1.6 physiological constitution
1.1.6.1 lips and mucous membranes
1.1.6.2 teeth
1.1.6.2.1 dental care
1.1.6.2.2 dental prosthesis
1.1.6.3 air support (lung and breathing)
1.1.6.4 auditory system
1.1.6.5 muscles
1.1.6.6 endurance
1.1.6.7 gender
1.1.6.8 age
1.1.7 technical ability
1.1.7.1 exercise methods
* pedagogics
1.2 intention
1.2.1 musical background
1.2.1.1 heredity
1.2.1.2 environmental
1.2.1.2.1 parents, family, school, friends,..
1.2.1.2.2 idols
1.2.1.2.3 media
1.2.2 cultural environment
1.2.2.1 sound. concept. /idea
1.2.2.2 tone systems
1.2.2.3 regional influences
1.2.2.4 zeitgeist
* trumpet teacher
1.2.3 music genre
1.2.3.1 composition rules
* composer
1.2.4 context within piece of music
1.2.4.1 familiarity with piece (information)
1.2.4.2 register
1.2.4.2.1 pitch
1.2.4.2.1.1 modulation (vibrato)
non-cyclic modulations
1.2.4.2.2 "high note syndrom"
1.2.4.3 loudness
1.2.4.3.1 non-cyclic modulations (dynamic)
1.2.4.3.2 cyclic modulations (vibrato)
1.2.4.4 articulation
1.2.4.5 importance of the part
1.2.4.6 timbre
1.2.4.7 orchestra pitch
1.2.4.8 interval next & previous tone
1.2.4.9 rhythm
1.2.4.9.1 duration
1.2.6 experiences
1.3 realization
1.3.1 familiarity with instrument
1.3.2 psychological constitution
1.3.2.1 concentration
1.3.2.2 motivation
1.3.2.3 frame of mind
1.3.2.3 stress
1.3.3 physical constitution
1.3.3.1 blood pressure
1.3.3.2 pulse
1.3.3.3 blood supply muscles (warm-up)
1.3.3.4 other vital functions
1.3.3.5 drugs (alcohol)
* physician
1.3.4 playing technique
1.3.4.1 embouchure
1.3.4.1.1 lip oscillation
1.3.4.1.1.1 participation of upper vs lower lip
1.3.4.1.2 function of shape and amplitude of oscillation
1.3.4.1.2 mouthpiece pressure
1.3.4.1.3 mouthpiece placement
1.3.4.1.3 .1 dry or wet lips
1.3.4.1.4 oral adjustment
1.3.4.1.5 laryngeal movements
1.3.4.1.6 facial muscles
1.3.4.1.6.1 nerves
1.3.4.2 other body work
1.3.4.2.1 air flow
1.3.4.2.1.1 lung function
1.3.4.2.1.2 diaphragm activity
1.3.4.2.1.3 wind pressure
1.3.4.2.1.4 amount of air
1.3.4.2.2 fingering
1.3.4.2.3 instrument position
1.3.4.3 overall difficulty


Variables
(an attempt to
systematize)
Part 3 - instrument
2.1.1b.1.2 cup
2.1.1b.1.3 backbore
2.1.1b.3.4 valve oil
2.1.1b.3.1 valve type
2.1.1b.3.2 valve position
2.1.1b.3.3 valve discontinuities
2.1.1b.1.1 rim
2.1.1b.1 mouthpiece
2.1.1b.2 lead pipe
2.1.1b.3 valves
2.1.1b.4 bell
2.1.1b.4.1 mutes
2.1.1b characteristics of parts
2.1.1 mechanical parameters
* manufacturer
2. instrument
2.1.1.2 material
2.1.1.2.2 lacquer and plating
2.2. 5 age
2 2.2 subjective quality
2 2.1 objective quality
2.1.1.3 shape
2.1.1.2.1 wall thickness
2.2.1 optical appearance
2.1.1.1 bore
2.1.1.3.1 construction
2.1.1.3.2 deformations
2.2.2 trade name
2.1.1.1.1 tightness (leaks)
2.1.1.1.2 wall surface
2.2.3 owner
* acoustician
2.1.1a physical parameters
2.1.1a .3 impulse response
2.1.1a .3.2 attack, startup
2.2.4 value
2.1.1a .1.1 sound, timbre
2.1.1a .1 transfer function
2.1.1a .3.1 response
2.1.1a .1.2 sound radiation
2.1.1a .1.3 dynamic range
2.1.1a .2 impedance
2.1.1a .2.2 intonation
* dealer


Variables
(an attempt to systematize)
Part 4 - environment & transmission
frequencies
amplitudes
time domain
trumpet sound
* musicologist
analysis / synthese
manipulations
microphone position
reception (receiver) auditorium
transmission
acoustic output (wave signal)
optical output (images)
* sound engineer
transfer characteristics
3. environment
3.1 time
3.2 room
3.2.5 auditorium
3.2.1.1 dimension (size)
3.2.4 location
3.1.2 season
3.2.1.2 reverberation
3.2.1 acoustic
3.2.3 haptic
3.1.1 daytime
3.2.1.3 absorption
3.2.1.4 humidity
3.2.1.5 temperature
3.2.2 optic

TWO ASPECTS OF TRUMPET-PLAYING

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ABSTRACT

In the first part the results of an investigation of trumpet mutes are presented. The author demonstrates the influence of several trumpet mutes on the timbre, intonation, sound radiation and responsiveness of trumpets. The second part deals with a recently started approach in Vienna to get new information about the embouchure of brass players: the "human sound generator" is subject of uncommon cinematic studies. The factors influencing the lip action are so numerous that no quantitative theory can be formulated without further experiments.

PART I : TRUMPET MUTES

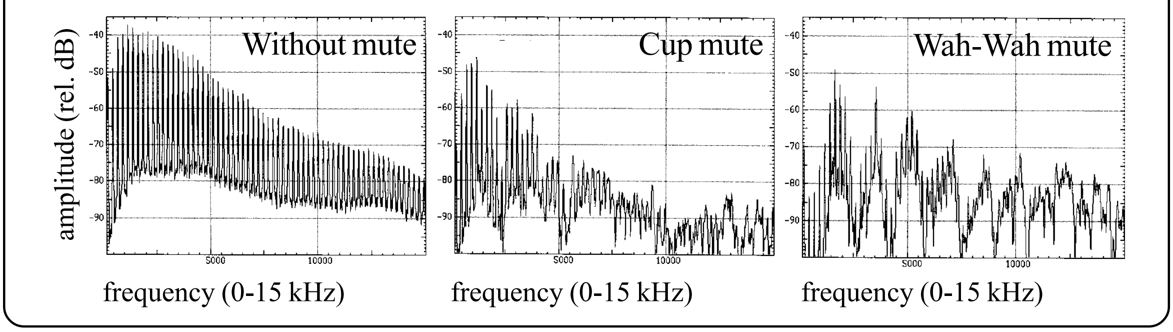
types - dynamics - timbre- response - intonation - sound radation

Types: brochures reveal many types of mutes. Surveys of the author result in a ranking list of types which are in use. **1. Cup** (93 % of using); **2. Straight** (92%); **3. Harmon** (75%); **4. Plunger** or anything alike (44%); **5. Wah-Wah** (40%); **6. Velvet** or Bucket (22%); **7. Whisper** (8%); **8. Hat** or Derby) (6,%); **9. Mega-Clear-Tone** (3,%); **10. Buzz WOW** (3%); **11. Mel-O-Wah** (2%); **12. Pixie** or Snubtone (2%) *[The Practicemute (47 %) is out of ranking, because different types are used as Practicemute].* The six most-used mutes have been subject of an acoustical investigation.

Dynamics: The dynamic range of the trumpet without mute depends on the register: about 30 phone in the lower and about 13 phone in the upper register (Meyer/1980). Measurements of a crescendo-tone in the anechoic chamber of the IWK reveal dynamic range values for the lower-register (written c1). The reference-amplitude 0 dB corresponds with the ppp (as soft as possible) on the trumpet without mute. The dynamic range of the trumpet without mute and with the plunger almost opened is about 30 dB. The Cup, Wah-Wah, Straight and Velvet Mutes have reduced dynamic ranges of about 24 dB. The Plunger has 21 dB at the almost-closed position and the Harmon reduces the dynamic range to 17 dB. The ability to play softer with a mute is only valid for the Cup, Wah-Wah, Straight and Velvet and Harmon mute. The ppp (as soft as possible) sounds -5/-8 dB lower than with without mute. The chance to play fff (as loud as possible) is extremly reduced with the Harmon. A fff is 20 dB weaker than without mute. This explains why the Harmon mute is usually amplified when it is in use. The fff played with Cup, Wah-Wah, Straight or Velvet mute is 12 dB softer than without. The dynamic level of the Plunger depends very much on the gap size. Almost closed (1cm gap) the fff is about 6dB lower than without mute.

Timbre: The sounds produced by some mutes are very characteristic, others sound similar. Physical reasons for a particular timbre are changes in the spectrum. Mutes cause typical formants and above all antiformants. The FFT-Spectrum of the Trumpet without mute is shown in the graph (tone written “c1”, blown fortis-

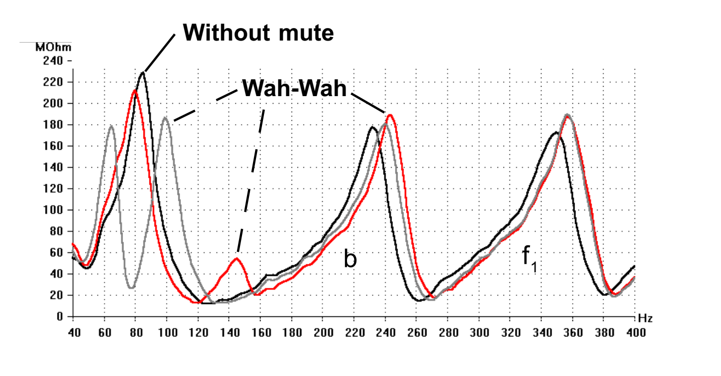
FFT -Spectrum of a fortissimo “c1” (0° direction)



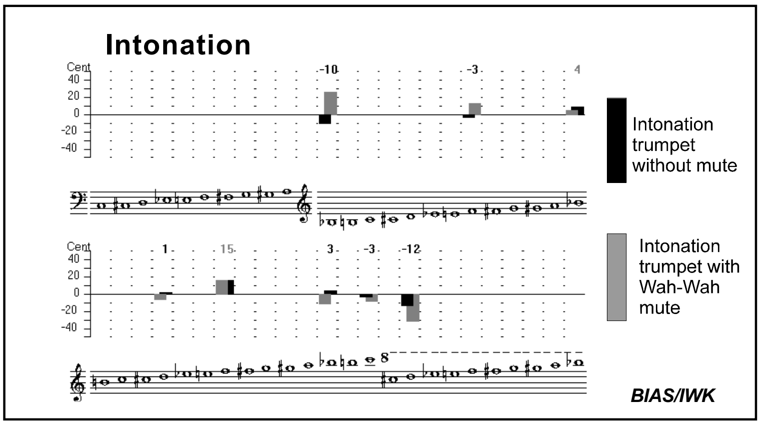
simo). The formant area is around 1.2-1.5 kHz. The intensity of higher partials diminish gradually. The FFT of the Cup mute indicates antiformants at 2.5 and 5 kHz. Also to be seen are the weakened partials over 10 kHz. The Cup prevents the radiation of wavelenghts shorter than the dimension of the mute. Very characteristic is the "Donald Duck" sound of the Wah-Wah mute. The FFT shows the alternating formants and antiformants. The foundamental is very faint. The strong partials around 1.5 kHz entail the nasal timbe. Some more examples for particular characteristics of other types: The "classical" Straight mute has weak low partials, a formant around 2 kHz and an antiformant at 4 kHz. The Velvet produces no antiformant or formant. It darkens the sound by attenuating generally high frequencies. (Frequencies with small wavelengths disappear in the cotton wool bucket). The Formants of some mutes correspond with vocal formants. E.g. the Harmon sounds like"ee"(it nickname is bee) and the Plunger sounds in the closed positition like "oo" (doo-wah discribes the closed-open onomatapoeicly).

Response: Impedance-measurements display the influence of mutes on acoustical behaviour. All investigated mutes - except the Velvet - add an additional resonance peak to the curve. This peak causes a shift-effect on further resonance peaks. The dimension of the shift depends on the positon and magnitude of this additional peak. Good specimens of the Cup-, Straight-, Harmon,- Wah-

Impedance graph: mutes can cause additional peaks

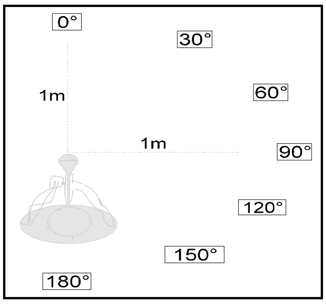


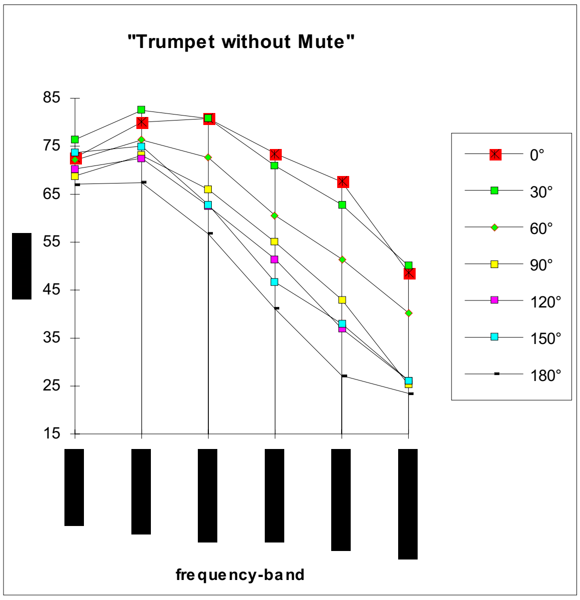
Wah,- mute push the peak below the playing range of the trumpet, and the unwanted shift is less disturbing. Bad specimens shift, and even suppress resonance peaks of the lower register considerable. The additional peak caused by the Plunger (closed position) is located within the playing range and prevents the sound generation of a "correct" musical pitch. That doesn´t matter, because the Plunger is mostly used for special effects like the "growl-technique".

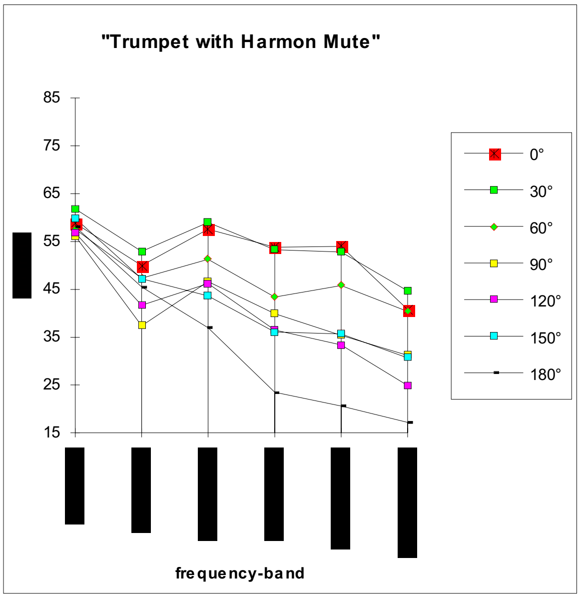


Intonation: The shifts of the resonance-peaks described above influence the intonation. The graph shows one example. In the lower register the trumpet with Wah-Wah mute is much sharper than the trumpet without mute (28 Cent above the values of the equal temperature scale instead of 10 Cent below).

Sound Radiation: The radiaton of the trumpet is more or less affected by the use of different trumpet mutes. Measurements with seven mikrophones *(see illustration)* in the anechoic chamber at our Institute allow the analysis of the radiated signal energy in different frequency bands. The two diagramms below show the RMS recorded at the seven positions in 6 bands for the trumpet without mute and the trumpet with Harmon mute.



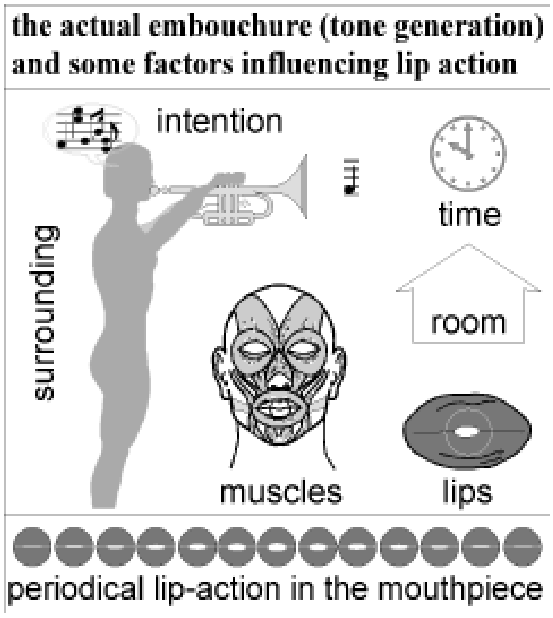




PART II: ON EMBOUCHURES

General

It is obvious that a note of a defined intensity sounds different on various musical instruments. Nor does one trumpet sound like another. But why does one and the same trumpet not always sound the same? This depends on the different sound generation and individual embouchure set-up of the player. It is caused by the complexity of embouchure. In the first *and last(?)* cinematical study *"Lip Vibrations in a Cornet Mouthpiece",* Daniel W. MARTIN wrote: "*The factors influencing lip action are so numerous that no quantitative theory can be formulated without further experiments.*" Thats the starting point for a new approach in Vienna.



Two definitions

The embouchure is the interface between the musician and the brass instrument. The term „embouchure" is used in two different ways: On the one hand, this term stands for the on-set of the mouthpiece on the lips and the actual tone generation of the lips. On the other hand there is the meaning of the word in its wider sense: phrases like *"I have no good embouchure today"* or *"Soft-drinks are not good for your embouchure"* indicate two aspects of parameters which affect the player. There exists quite a lot of parameters which influence the "human-part" of the linked system "player-instrument". Scientific approaches on this subject have been made from pedagogical side and from the instrumental-acoustic side. The bridge is missing. In fact, the tone generation is determined by the air flow and the lip action. This principle has been known for many years. What makes the differences between the same note, played on the same instrument (and even by the same player)? Brass player are no determinable machines who can repeat the same MIDI sample every time. Recent investigations in Vienna - using new means to work out more detailed information about the embouchure- will try to explain the phenomenon. First some examples of parameters which influence the sound generation of a brass player:

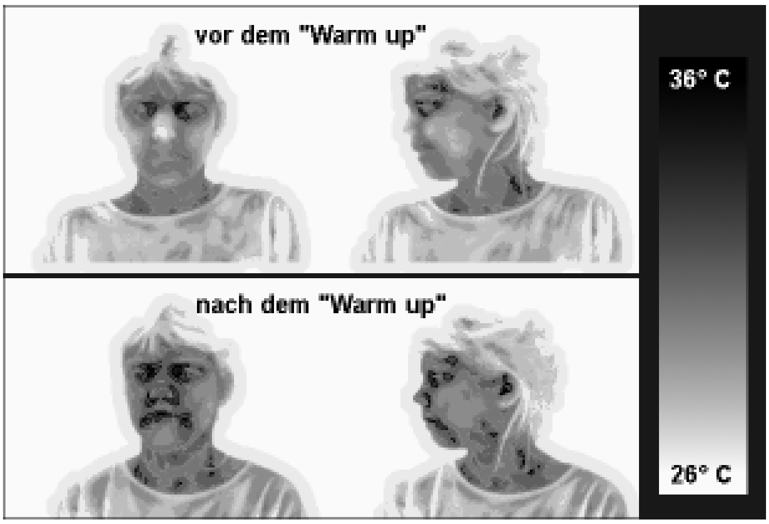
general conditions (social and cultural background; environment): - ability (*more talented / less talented)* - age - education level (*pupil / student / professional*) characteristics of school and teacher (*Vienna / French / German)* - room *(outside / inside; room acoustics)* - environment *(alone / in front of orchestra)* - Instrument (*response; intonation*; *quality)*

physiological conditions: - teeth constellation. - lung capacity - temperature - auditory-system (*hearing-ability*) - constitution of lips and mucous membranes (*"warmed-up / not "warmed-up")* - endurance (*more pressure / less pressure*) - muscles *(relaxed / forced)* - breathing (air-flow) -dynamic - register *(upper / lower)*
psychological conditions: - condition, frame of mind *(day / night; morning / evening; hungry / not hungry)* - intention (*music-context; classic / jazz / else*) - motivation (*sympathy / antipathy*) - cognitive processes - feeling *(familiar with mouthpiece and instrument?)*

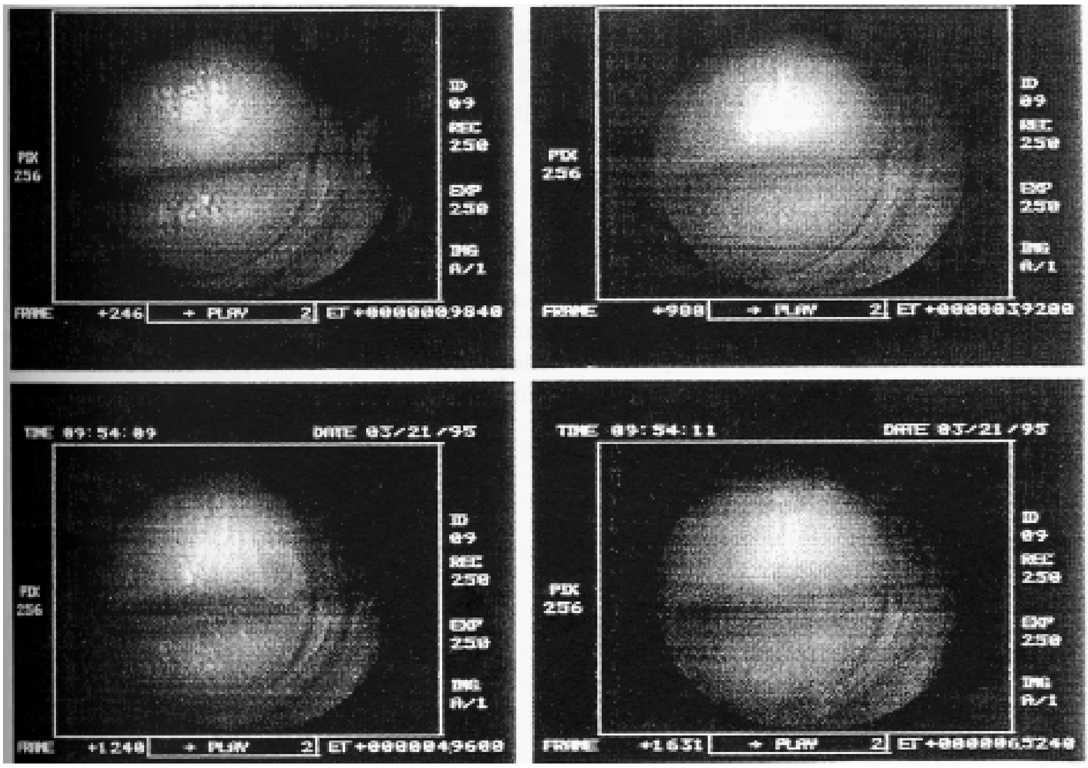
Tests with an "Infrared Camera"

The "Warm up" phenomenon is one subject of the studies recently started in Vienna. Preliminary tests with an infrared camera show actually interest changes in the surface temperature of the players skin caused by warming up. The picture below shows the author before and after he "warmed up" on a trumpet for 5 minutes in the low range. On the left hand side you can see brighter parts of the face than on the right hand side. It can be seen that some parts of the face get warmer than other. The greyscales express the temperature in 1° Celsius steps from white (below 26.6° C) to black (above 36,6° C). [Actually the scale consists of differnt colours] The shootings have been made with Dr. Anton Stabentheiner (Institut for zoology, University of Graz). The aim of further analysis is to reveal the coherence of the surface temperature and the muscle activity. Meantime the question rises up: Is the muscle activity the main reason for the rise in temperature ?

Infrared pictures of a trumpet player before and after a short "warm-up" (dark = warm)



"*High Speed Video*" pictures from vibrating lips
filmed with an endoscope inside the trumpet mouthpiece



Inside the moutpiece

Another approach to reveal new information on the embouchure is to film the vibrating lips inside the mouthpiece. Preliminary experiments from the author, together with Wilhelm Ziegler (ÖWF, Vienna) and Oliver Redl (USI, Vienna) have been made with an endoscope introduced lateral in a trumpet mouthpiece. The signal has been recorded with a "High Speed Video Camera " with up to 1000 pictures per second. The pictures shown above has been filmed with 250 pps and demonstrate a written "c1" (235 Hz) blown with four increasing dynamic levels. (top left: pianissimo , right: piano; bottom left: mezzoforte, right: forte). You can see an increasing aperture of the lips during louder sound generation (the blurred parts of the lips increase because one picture shows a whole cycle of the period). Aim of further experiments -using "stroboscope technique" - is to define the excitation spectrum through optical methods.

References: - BACKUS, John. Input impedance curves for the brass instruments. (in: JASA, Vol 60, No2. 1976) - BERTSCH, Matthias. Der Einfluß des Dämpfers auf das akustische Verhalten und die Klangfarbe der Trompete. (Dipl.-Arb.,Universität Wien 1992) - KURKA, Martin. A study of the acoustical effects of mutes on wind instruments. (Chicago, 1961) - MARTIN, Daniel W. Lip Vibrations in a Cornet Mouthpiece (1942) - SLUCHIN, B. CAUSSÉ, R. Sourdine des Cuivres. (Paris, 1991)

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ASPECTS OF TRUMPET PLAYING

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SUMMARY
The acoustics of brass instruments is a broad field. Some elements, where the "human-factor" is not dominant have already been investigated. As one model, the author shows the influence of several trumpet mutes on the timbre, intonation and responsiveness of trumpets. The actual tone generation (embouchure) is very complex. The factors influencing lip action are so numerous that no quantitative theory can be formulated without further experiments.

INTRODUCTION

It is very obvious that a note with a defined intensity sounds different on various musical instruments. One trumpet also doesn´t sound like another trumpet. That is also convincing, but why doesn`t one and the same trumpet doesn`t always sound the same? There can be several reasons for this. The most obvious one is the use of different mutes, which changes the tone color of the sound intentionally. These effects of trumpet-mutes will be discussed first in this article. Even without mutes one tone sounds different on the same trumpet if different players produce it. This depends on the different tone generation and individual embouchure set-up. Finally analysis shows that even one player produces dissimilar timbres on the same trumpet for all his efforts. This is caused by the complexity of embouchure. The second part of this article deals with parameters which have an effect on this complex.

I. TRUMPET MUTES

1. types: brochures reveal many types of mutes. Surveys of the author result in a ranking list of types which are in use. **1. Cup** (93 % of using); **2. Straight** (92%); **3. Harmon** (75%); **4. plunger** or anything like (44%); **5. Wah-Wah** (40%); **6. Velvet** or Bucket (22%); **7. Whisper** (8%); **8. Hat** or Derby) (6,%); **9.Mega-Clear-Tone** (3,%); **10. Buzz WOW** (3%); **11. Mel-O-Wah** (2%); **12. Pixie** or Snubtone (2%) *[The Practicemute (47 %) is out of ranking, because different types are used as Practicemute].* The six most-employed mutes have been subject matter of an acoustical investigation.

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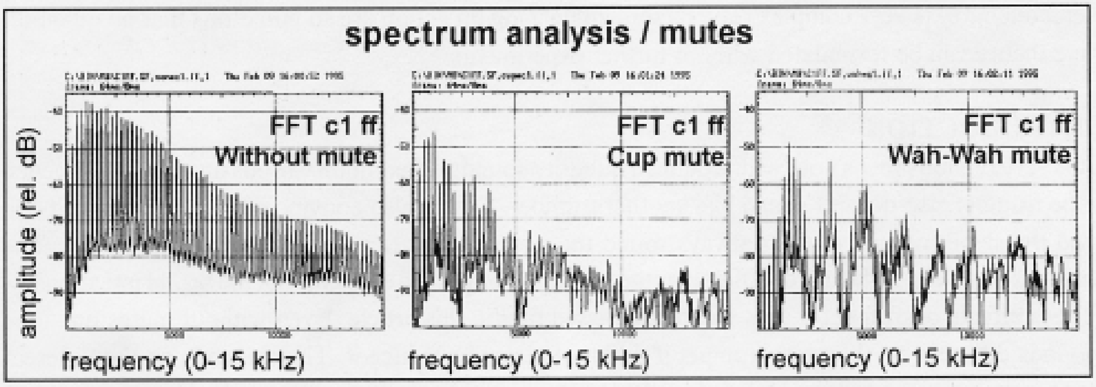
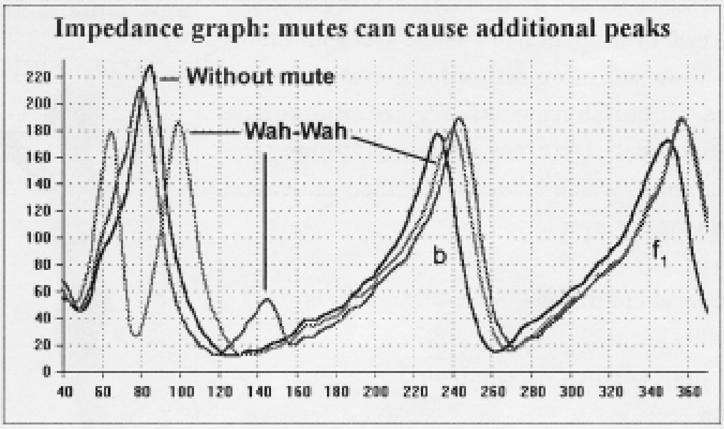
3. timbre: The sounds produced by some mutes are very characteristic, others sounds similar. The physical reason for a certain timbre are changes in the spectrum. Mutes cause typical formants and above all antiformants. The FFT-Spectrum of the Trumpet without mute is shown in the graph (tone c1, blown fortissimo). The formant area is around 1.2-1.5 kHz. The intensity of the higher partials



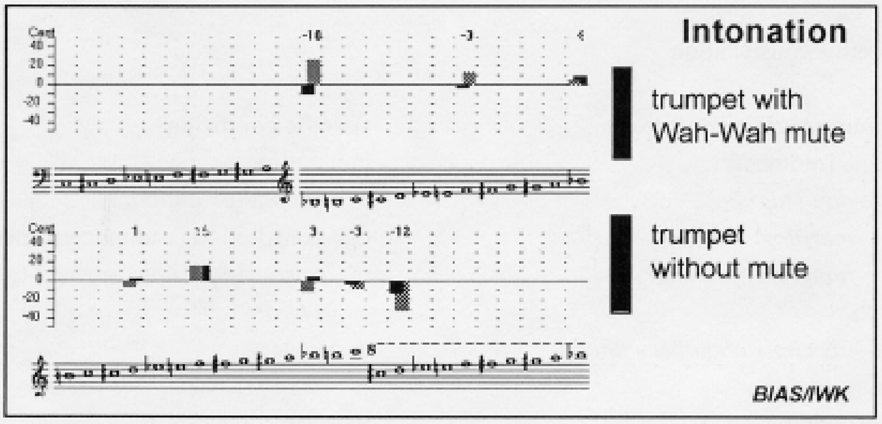
diminish gradually. The FFT of the Cup mute indicates antiformants at around 2.5 and 5 kHz. Also to be seen are the weakened partials over 10 kHz. The Cup prevents the radiation of wavelenghts shorter than the dimension of the mute. Very characteristic is the "Donald Duck" sound of the Wah-Wah mute. The FFT shows the alternating formants and antiformants. The foundamental is very faint. The strong partials around 1.5 kHz entail the nasal timbe. Some more examples for particular characteristics of the other types: The "classical" Straight mute has weak low partials, a formant around 2 kHz and an antiformant at 4 kHz. The Velvet has no antiformant or formant. It darkens the sound by attenuating the high frequencies. (The small wavelengths disappear in the cotton wool bucket).

The Formants of some mutes correspond with vocal formants. This is why the Harmon sounds like"ee"(it nickname is bee) and the Plunger sounds in the closed positition like "oo" (doo-wah discribes the closed-open omnopoetically).

4. response: Impedance-measurements display the influence of the mutes on acoustical behaviour. All investigated mutes except the Velvet add a additional resonance peak to the curve. This peak causes a shift-effect on the other resonance peaks. The dimension of the shift depends on the positon and magnitude of this additional peak. Good specimens of the Cup-, Straight-, Harmon,- Wah-Wah,- mute push the peak below the playing range of the trumpet, and the unintended shift is to a less degree. Bad specimens shift, and even suppress the resonances in the lower register considerable. The additional peak of the Plunger (closed position) lies in between the playing range and actual prevents the sound generation of a "correct" musical pitch. That doesn´t matter, because the Plunger is normally used for special "growl-technique".



5. intonation: The described shifts of the resonance-peaks affect the intonation. The graph shows one sample. In the lower register the trumpet with Wah-Wah mute is much sharper than the trumpet without mute (28 Cent above equal temperature pitch instead of 10 Cent below).

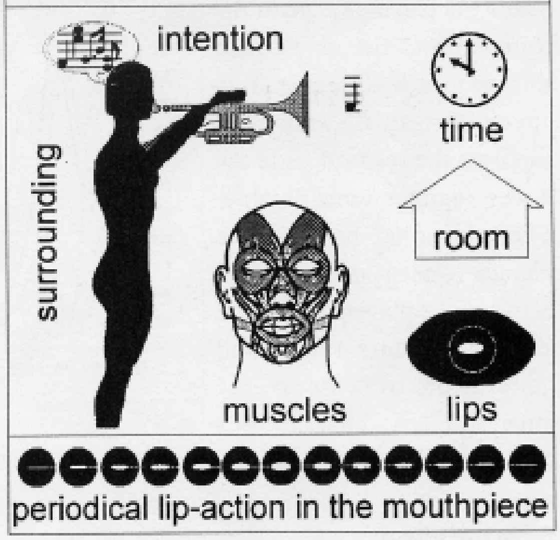


II. ON EMBOUCHURES

The embouchure is the interface between the musician and the brass instrument. The term embouchure is used in two different ways. On one hand, it implies in a narrower sense the on-set of the mouthpiece on the lips and the actual tone generation of the lips. On the other hand there is the meaning of the word in the wider sense. Phrases like "I have no good embouchure today" or "Soft-drinks are not beneficial for your embouchure" indicate two aspects of parameters which affect the player. There are quite a lot of complex parameters influencing the "human-part" of the linked system "player-instrument". Scientific approaches on this subject have been done from pedagogical side and from the instrumental-acoustic side. The bridge is missing. In fact, the tone generation is determinated by the air flow and the lip action. The principle have been known for many years. What makes the differences between the same note, played with the same instrument (and even the same player)?

Brass player are no determinable machines who can repeat the same MIDI sample every moment. Recent investigation in Vienna - using new tools to work out more detailed informations about the embouchure- will try to explain the differences. Here are some conditions (and examples) which influence the tone generation of a brass player :

the actual embouchure (tone generation) and some factors influencing lip action



general conditions
ability
more talented / less talented
age
education level
pupil / student / professional
school / teacher
Vienna / German ....
teeth - constellation

more specific conditions
time (moment)
-day / night
-morning / evening
-hungry / not hungry
room
-unechoic chamber / church
lung capacity
surounding
-alone / in front of orchestra
cognitive processes
temperature
-cold / warm / hot
intention (music-context)
classic / jazz / else
auditory-system
hearing-ability

specific conditions
motivation
-sympathy / antipathy
lips-constitution (and mucous membranes)
"warmed-up / not "warmed-up"
wet / dry
endurance
-more pressure / less pressure
muscles
relaxed / forced
breathing (air-flow)
dynamic
register (upper / lower)
Instrument
response, intonation
quality, characteristic
feeling (used to mouthpiece and instrument ?)

REFERENCES: - BACKUS, John. Input impedance curves for the brass instruments. (in: JASA, Vol 60, No2. 1976) - BERTSCH, Matthias. Der Einfluß des Dämpfers auf das akustische Verhalten und die Klangfarbe der Trompete.(Dipl.-Arb.,Universität Wien 1992) - KURKA, Martin. A study of the acoustical effects of mutes on wind instruments. (Chicago, 1961) - MARTIN, Daniel W. Lip Vibrations in a Cornet Mouthpiece (1942) - SLUCHIN, B. CAUSSÉ, R. Sourdine des Cuivres. (Paris, 1991)

Trumpet Mutes

Matthias Bertsch, IWK

CAC 23-26 September 95
32nd Czech Conference on Acoustics
Prague, Czech Republic

Abstract: What make mutes sound different ? Which effects have particular mutes on trumpet-playing ? Results of an investigation of trumpet mutes are presented where the influence of the most common trumpet mutes on the dynamic, timbre, intonation, sound radiation and responsiveness of trumpets is demonstrated. Some examples of typical effects are presented.

1. Types: Surveys of the author - in Austria, Germany and withon the trumpet newsagroup of the Internet - result in a ranking list of mostly used types: **1. Cup** (93 % of using); **2. Straight** (92%); **3. Harmon** (75%); **4. Plunger** or anything alike (44%); **5. Wah-Wah** (40%); **6. Velvet** or Bucket (22%); **7. Whisper** (8%); **8. Hat** or Derby) (6,%); **9. Mega-Clear-Tone** (3,%); **10. Buzz WOW** (3%); **11. Mel-O-Wah** (2%); **12. Pixie** or Snubtone (2%) *[The Practicemute (47 %) is out of ranking, because different types are used as Practicemute].* The six most-used mutes have been subject of an acoustical investigation.

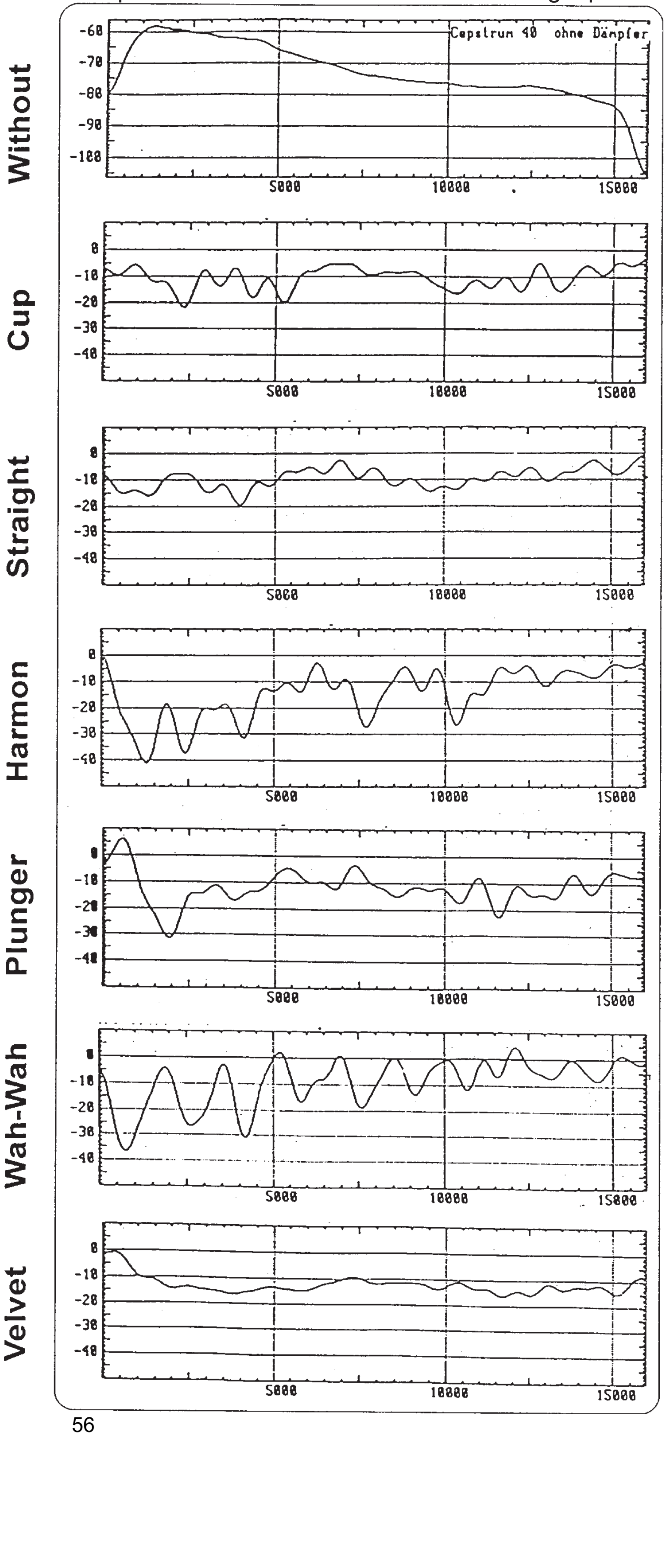
2. Dynamics: The dynamic range of the trumpet without mute depends on the register: about 30 phone in the lower and about 13 phone in the upper register (Meyer/1980). Measurements of a crescendo-tone in the anechoic chamber of the IWK reveal dynamic range values for the lower-register (written c1). The reference-amplitude 0 dB corresponds with the ppp (as soft as possible) on the trumpet without mute. The dynamic range of the trumpet without mute and with the plunger almost opened is about 30 dB. The Cup, Wah-Wah, Straight and Velvet Mutes have reduced dynamic ranges of about 24 dB. The Plunger has 21 dB at the almost-closed position and the Harmon reduces the dynamic range to 17 dB. The ability to play softer with a mute is only valid for the Cup, Wah-Wah, Straight and Velvet and Harmon mute. The ppp (as soft as possible) sounds -5/-8 dB lower than with without mute. The chance to play fff (as loud as possible) is extremly reduced with the Harmon. A fff is 20 dB weaker than without mute. This explains why the Harmon mute is usually amplified when it is in use. The fff played with Cup, Wah-Wah, Straight or Velvet mute is 12 dB softer than without. The dynamic level of the Plunger depends very much on the gap size. Almost closed (1cm gap) the fff is about 6dB lower than without mute.

Comparison of dynamic ranges

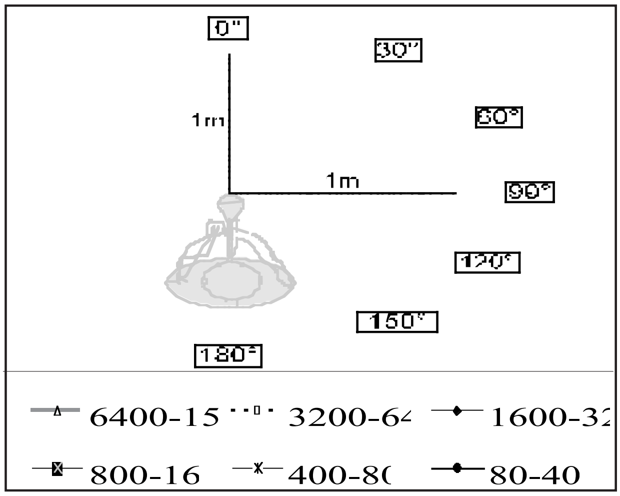
	ppp	fff	
ohne	***0***	***30***	
straight	-7	17	(-13)
cup	-5	18	(-12)
velvet	-7	17	(-13)
harmon	-8	9	(-21)
wah-wah	-7	16	(-14)
plunger zu	3	24	(- 6)
plunger offen	0	27	(- 3)

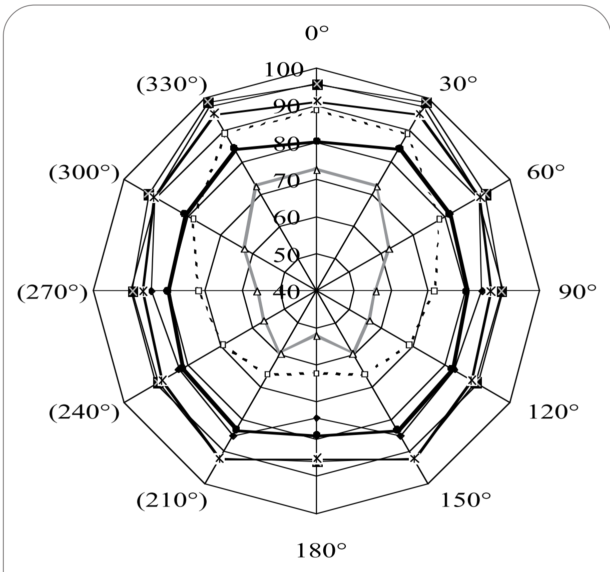
Values in relative dB in comporison to the trumpet without mute. 0 dB correspond about 65 dB(A).

3. Timbre: The sounds produced by some mutes are very characteristic, others sound similar. Physical reasons for a particular timbre are changes in the spectrum. Mutes cause typical formants and above all antiformants. The Cepstrum (40 Coeffizients) of the Trumpet without mute is shown in the graph on the top (tone written “c1”, blown fortissimo). The formant area is around 1.2-1.5 kHz. The intensity of higher partials diminish gradually. Below you can see the differnce-Cepstrum of the other typer. The values of the trumpet without mute are substracted. The difference-spectrum of the Cup mute indicates antiformants at 2.5 and 5 kHz. Also to be seen are the weakened partials over 10 kHz. The Cup prevents the radiation of wavelenghts shorter than the dimension of the mute. Very characteristic is the "Donald Duck" sound of the Wah-Wah mute. The difference-spectrum shows the alternating formants and antiformants. The foundamental is very faint. The strong partials around 1.5 kHz entail the nasal timbe. Some more examples for particular characteristics of other types: The "classical" Straight mute has weak low partials, a formant around 2 kHz and an antiformant at 4 kHz. The Velvet produces no antiformant or formant. It darkens the sound by attenuating generally high frequencies. (Frequencies with small wavelengths disappear in the cotton wool bucket). The Formants of some mutes correspond with vocal formants. E.g. the Harmon sounds like"ee"(it nickname is bee) and the Plunger sounds in the closed positition like "oo" (doo-wah discribes the closed-open onomatapoeicly).

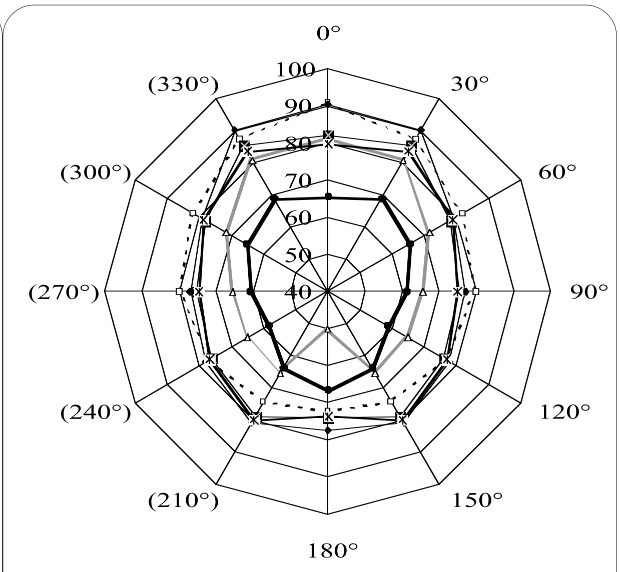


4. Sound Radiation: The radiaton of the trumpet is more or less affected by the use of different trumpet mutes. Measurements with seven mikrophones *(see illustration)* in the anechoic chamber at our Institute allow the analysis of the radiated signal energy in different frequency bands. The four diagramms below show the RMS recorded at the seven positions in 6 bands for the trumpet without mute, the trumpet with Straight,- Harmon- and Velvet mute. The antiformants remain dominant in all directions, through the higher frequencies are much more focused to the 0° frontal direction.



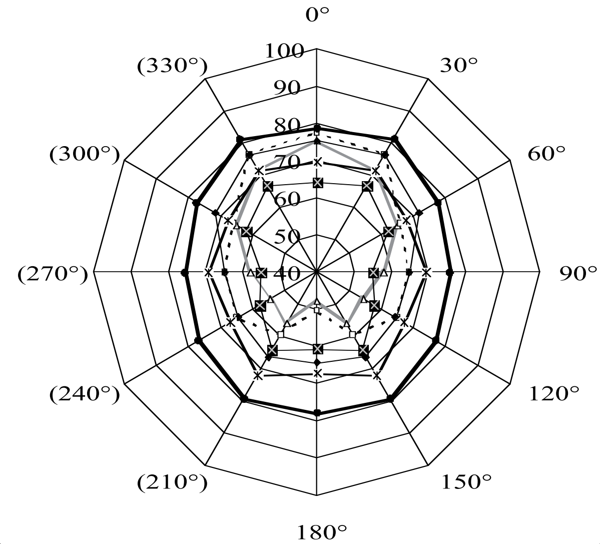


WITHOUT MUTE

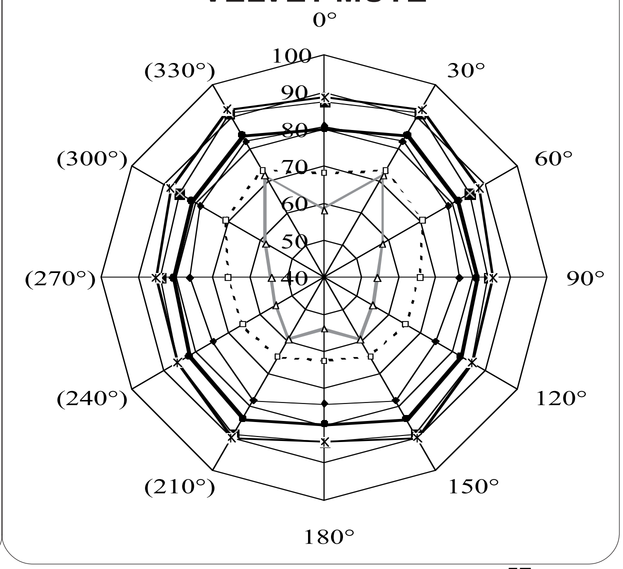


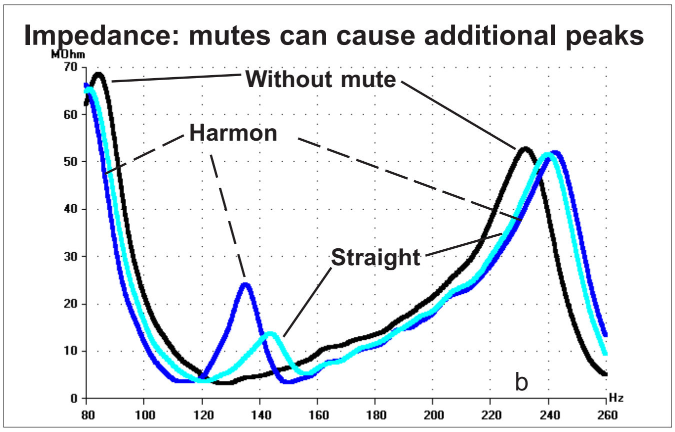
STRAIGHT MUTE

HARMON MUTE

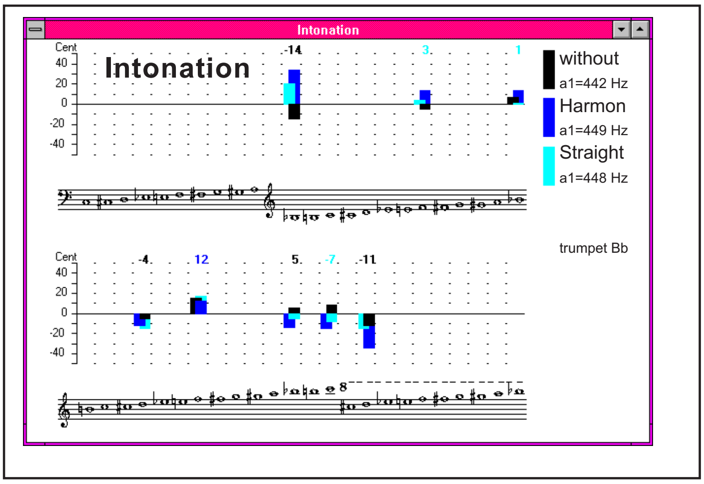


VELVET MUTE





5. Response: Impedance-measurements display the influence of mutes on acoustical behaviour. All investigated mutes - except the Velvet - add an additional resonance peak to the curve. This peak causes a shift-effect on further resonance peaks. The dimension of the shift depends on the positon and magnitude of this additional peak. Good specimens of the Cup-, Straight-, Harmon,- Wah-Wah,-mute push the peak below the playing range of the trumpet, and the unwanted shift is less disturbing. Bad specimens shift, and even suppress resonance peaks of the lower register considerable. The additional peak caused by the Plunger (closed position) is located within the playing range and prevents the sound generation of a "correct" musical pitch. That doesn´t matter, because the Plunger is mostly used for special effects like the "growl-technique". In the impedance graph you can see the additional peaks caused by the use of the Straight and Harmon mute. The lowest blown tone on the B-trumpet (written"c1"-second resonance peak) is shifted to higher frequencies because of the use of the mutes.



. Intonation: The shifts of the resonance-peaks described above influence the intonation. The graph shows one example. In the lower register the trumpet with Wah-Wah mute is much sharper than the trumpet without mute (28 Cent above the values of the equal temperature scale instead of 10 Cent below). The mutes causes a shift not only to the individual resonances but also the intonation in general (which can be reduced with the main tuning slide).

The intonation is less affected because of the use of the Straight, Cup and Bucket mutes, more with the Wah-Wah and Harmon mute and most with the plunger in the closed position (what doesnt matter for most musical purposes). For the most mutes the intonation of the lower playing-range of the instrument is in particular critical.

References: - BACKUS, John. Input impedance curves for the brass instruments. (in: JASA, Vol 60, No2. 1976) - BERTSCH, Matthias. Der Einfluß des Dämpfers auf das akustische Verhalten und die Klangfarbe der Trompete. (Dipl.-Arb.,Universität Wien 1992) - KURKA, Martin. A study of the acoustical effects of mutes on wind instruments. (Chicago, 1961) - MARTIN, Daniel W. Lip Vibrations in a Cornet Mouthpiece (1942) - SLUCHIN, B. CAUSSÉ, R. Sourdine des Cuivres. (Paris, 1991)

SILVER, GOLD, PLATINUM - AND THE SOUND OF THE FLUTE

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Abstract

The discussion on the influence of the material of wind instruments on the sound color is unending. While acousticians speak mostly of a negligible influence, players are convinced that the material highly influences the color of the radiated sound. This paper reports on experiments done with 7 different flute materials and 110 testpersons, where the price of the instruments is between US $1,000 and $70,000. Double blind tests and statistical analysis showed players‘ and listeners´stereotyped ideas on that matter and the non-recognizability of the used material. Sound analysis pointed out big differences in the sound level and sound color of played tones caused by the player and just measurable but not perceivable differences (< 0,5 dB) in sound color caused by the material. Sound examples are given and the audience is invited to judge for themselves.

INTRODUCTION

The role that the wall material plays in determining the tone quality of flutes has long been a subject of argument. Laboratory measurements of sustained tones in artificially blown wind instruments made by J. Backus in the 1960’s [1,2] generally showed no evidence that the wall material has an appreciable effect. But players and instrument makers didn’t accept these results because of the fact that the instruments were artificially blown. Therefor J. W. Coltman worked out an experiment with flutes made of three different materials (silver, copper and wood) and with different wall thickness. They were blown by the author himself and four different professional flutists [3]. The experiment was completed by listening test with 27 observers. The result of statistical analysis was that “no evidence has been found that experienced listeners or trained players can distinguish between flutes . . . whose only difference is the nature and thickness of the wall material of the body, even when the variations in the material and thickness are very marked.” Nevertheless instrument makers, players and listeners continue to insist that the nature of the wall material does indeed have an effect on the instruments’sound. Perhaps, from the point of view of flutists, there is a stigma attached to J. Coltmans´ experiment: the flutes where built especially for this experiment and without any keywork.

To terminate this discussion once and for all (which, as J. Backus pointed out [4], probably started in early Stone Age circles with assertions that a flute made from a human thigh bone had a much better tone than one made from a stick of bamboo), we chose seven identical flutes made by Muramatsu which only differ in the wall material and could be purchased by everybody.

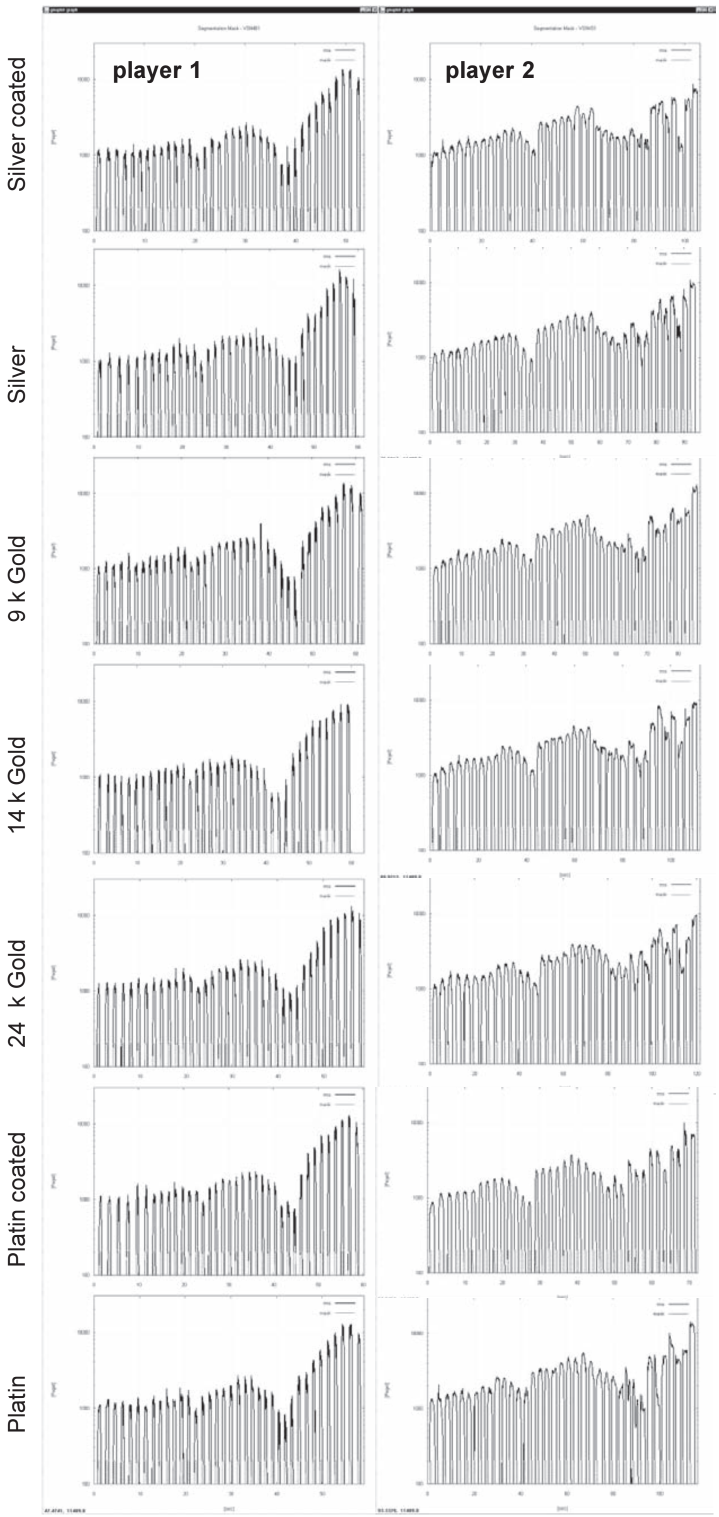
EXPERIMANTALSETUP

A silver coated, full silver, 9 karat gold, 14 karat gold, 24 karat gold, platinum coated and all-platinum flute was played by 7 professional flutists (members of Viennese orchestras including the Vienna Philharmonic orchestra) in an anechoic chamber. The recorded sound material: a chromatic scale over 3 octaves (c4-c7) instruction: convenient *forte*, a *crescendo* up to *fff* and a *decrescendo* up to *ppp* on the single notes a^4, f^5, d^6 and bb^6, the famous solo from Carmen (Bizet) and the solo of the 1st Symphony of J. Brahms.

The sound material was analyzed and prepared for a listening test with 15 experienced professional flute players including the seven test players. An additional opinion survey was done on the question of the influence of the material on the sound, response and if there is any relationship between the wall material and the soundcolor of a flute with 111 persons.

RESULTS

A good estimation of the influence of the player and the material on the radiated sound gives an RMS of the played chromatic scale. Figure 1 gives an example of two players with the seven test instruments.



Differences are rather seen between the players whilst those between the instruments are extremely small. This implies that flute players can realise their subjective imagination of “a good sounding” to a far extent independently of the instrument.

Dynamic

A common stereotype is that Platinum flutes provide the the player with a larger dynamic range.

Figure 2 on the next page shows the mean value of all players and four notes of the low, middle and high register for each instrument. The difference of the instrument with the smallest dynamic range (14 karat gold flute = 14.57 dB) and that with the largest range (platinum flute = 16.14 dB) is only 1.5 dB! The possibility that this difference becomes zero with an increased number of test players can not be excluded.

Quite different is the situation if one looks at the individual dynamic range of the players (Figure 3 next page). The obtained dynamic range is between 7 dB and 19.6 dB. The figure shows the mean values for each player, all instruments and the notes a^4, f^5, d^6 and bb^6. The highest obtained dynamic is four times as much as the lowest.

As the Dynamic range is a “relative” value, the table on the next page gives information on the obtained absolute values for each note.

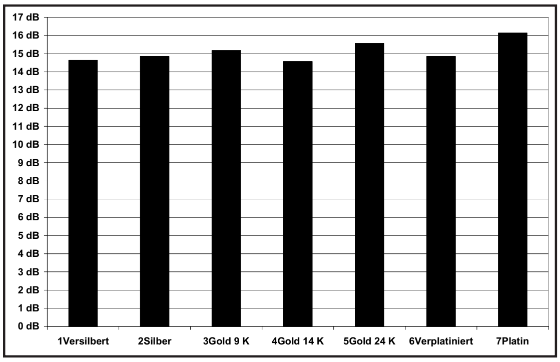


Figure 2: Mean value of the dynamic range for each instrument (7 players, 4 notes)

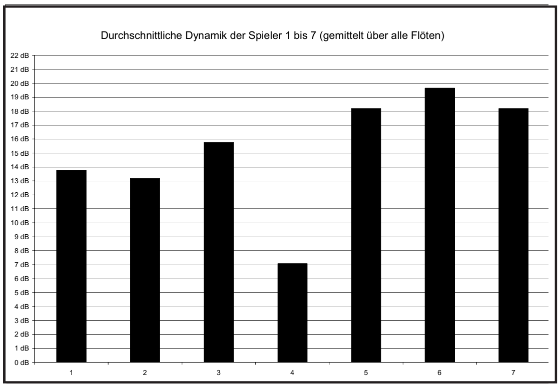


Figure 3: Mean value of the dynamic range obtained by the player (7 flutes, 4 notes)

	pp	*ff*
a^4	69-80 dB	82-92 dB
f^5	66-83 dB	81-96 dB
d^6	72-86 dB	88-100 dB
bb^6	72-95 dB	85-107 dB

Obtained absolute values for each note by 7 players.

Sound Color

Similar is the situation for the sound color. The sound spectrum differs extremely between the various players. But analyzing the sound spectra of the notes played by one player with different instruments, only just measurable but not recognizeable differences can be found. This fact was demonstrated strikingly by the listening tests.

Figure 4 (below) points out that the largest difference in sound caused by the material over the entire frequenc range of 0-16 kHz is less than 0.5 dB! The figure shows 7 lines (one line for each instrument). Each line represents the smoothed envelope (cepstrum with 36 coefficients) of the sound spectrum obtained from all players with one instrument. In this way, the influence of the individual player is eliminated.

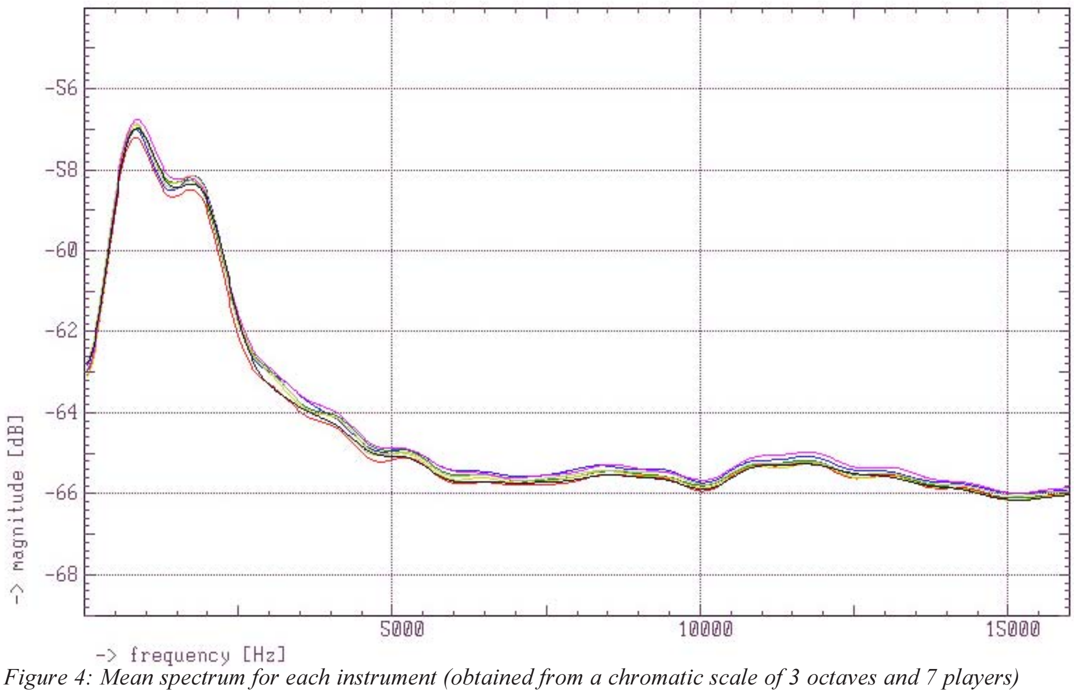


Figure 4: Mean spectrum for each instrument (obtained from a chromatic scale of 3 octaves and 7 players)

Listening tests

There were two tests made: in **TEST A,** the Carmen solo and the Brahms solo was presented (from a CD), at first from Player 1 with all instruments, then Player 2 with all instruments and so on. The test persons had to guess the instrument. The result was interesting: no instrument was identified correctly. The best value was that for the 24 k Gold flute: only 22% of the test persons identified it as a 24 k Gold flute. Whereas the wrong allocations had much higher values: 34% identified the Platinum flute as a 9 k Gold flute (only 6.8% identified it correctly) and 32% thought that the 14 k Gold flute is the Platinum flute (11.3% were right)!

With **TEST B,** we tried another approach: the test persons listened to one instrument played by all players. They had to describe the sound color and to guess the instrument/material. Then the next instrument played by all players was presented, and so on. Only one instrument (the all-silver flute) was identified correctly, with all other instruments the confusion was perfect! For instance: the 9 k gold flute was mainly misinterpreted as an all-silver instrument, the 14 k gold flute was identified as the platinum instrument and the silver coated instrument was assigned to all instruments (with each instrument at least one test person thought that it is the silver-coated instrument).
The descriptions of the soundcolor for each instrument were separated into 5 categories:

positive occupied expressions
negative occupied expressions
from all persons assigned expressions
contradictionary expressions
evaluation of the sound quality (1= very good, 5 = bad)

As expected, the most significant assigned expressions for all instruments were the "contradictionary expressions": for example, the sound color of each instrument was evaluated as "bright" and simultaneously as "dark" or "full/round" and "thin/sharp".
The evaluation of the sound quality showed a very small range: the values for all instruments can be found between 2.16 and 2.92. In addition to the evaluation of the sound quality, the test persons were free to use a "+" for "I like it" and a "-" for "I don't like it". The following table points out the listeners' preference depending on the played music.

Instrument	Sound Quality (mean value)	Brahms	Carmen
9 k Gold	2.16	++++	+++++ -
24 k Gold	2.38	+++ - -	+++ - - - -
Platinum	2.60	+ - - - -	++++ - - -
Silver coated	2.66	+++++ - -	+++++ - - - -
Platinum coated	2.79	+++ -	++ - -
14 k Gold	2.79	+++ - - -	++
All Silver	2.92	+ - -	++ - - - -

CONCLUSION

Tests with experienced professional flutists and listeners and one model of a flute made by Muramatsu from 7 different materials showed no evidence that the wall material has any appreciable effect on the sound color or dynamic range of the instrument. The common stereotypes used by flutists and flute makers are exposed as "stereotypes".

[1] J. Backus, JASA Vol.36, p. 1881-1887, (1964)
[2] J. Backus, T.C. Hundley, JASA Vol.39, p. 936-945, (1966)
[3] J. W. Coltman, JASA Vol.49, p. 520-523, (1971)
[4] J. Backus, *The Acoustical Foundations of Music*, p. 208, Norton, New York (1969)

Paper submitted to ISMA 2001 (Perugia, Italy)

VIBRATION PATTERNS AND SOUND ANALYSIS OF THE VIENNESE TIMPANI

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Abstract

Orchestras in Vienna traditionally use kettledrums with goatskin and a hand-tuning mechanism (so-called 'Hochrainer' timpani) and not modern pedal timpani that are international standard, which are equipped with Mylar membranes or calfskin. The 'Hochrainer' timpani sound is preferred in spite of the drum's disadvantages: the inhomogeneous skin is harder to tune and much more sensitive to moisture and temperature than plastic membranes. The objective of this study is to document the properties of the Vienna timpani and to compare the acoustic characteristics with international timpani. Studies using LASER interferometry and digital sound analysis of recordings (made in the anechoic chamber in the IWK) have been made with Viennese timpani and with standard timpani. Findings show similar mode frequency ratios with international timpani but the 'quasiharmonic' modes 11 and 31 have higher amplitudes in the membrane displacement and the resulting sound spectra, which provide more tonality. The laser study also allowed an animated documentation of the vibration patterns of the membranes.

INTRODUCTION

Vienna Tradition. While almost all international top orchestras in the world use rather similar and standardized sets of 'Dresden-type' pedal timpani, orchestra in Vienna still play mainly the old-fashioned 'Hochrainer' timpani with a hand-tuning mechanism. Schnellar and his heirs Hochrainer and Schuster were principal timpanists in the Vienna Philharmonic Orchestra and teachers at the University for music in Vienna. Hochrainer modified the 'Schnellar' Timpani (e.g. aluminum feet without rollers, instead the heavy tripods). This ideal circumstance, where the instrument maker himself is principal player of the Philharmonic Orchestra and teacher at the Music University, is unique within the development of a musical instrument, because the Vienna timpani tradition is not only based on the instrument but also on the playing-technique. It is said that Viennese timpanists 'play' the timpani, rather than 'hit' them, and that the sound never sounds vulgar, even if played forte.

Construction. The construction and properties of the Vienna timpani (VT) differ in many ways from the internationally used 'standard' pedal timpani (IT). Standard timpani change the tension of the membrane by means of a pedal. The membrane is held against a counterhoop that is pressed down via tension rods. The note of the resulted tension can (roughly) be seen at a tuning gauge. The Viennese timpani has no counterhoop and no pedal. These instruments have a single master screw to change the pitch. By means of the hand-tuning mechanism the whole kettle is lifted up and pressed against the membrane. 6 struts connected with the casters hold the membrane.

Membrane Material. Viennese Timpani only use goat skin (from Edlauer Enns, Austria) while other Timpani are either equipped with calfskin or with a plastic membrane (Mylar). The goatskin is thicker than calfskin, but both share many characteristics of natural skins, which have besides their unique sound qualities many disadvantages in handling. Natural skins are more sensitive to moisture and temperature and therefore more difficult to tune. Further, the material is not reproducible, harder to prepare and more expensive.

Kettle. The kettle of Viennese timpani is- like other fine timpani -a hammered copper bowl (0.8mm in thickness), its shape is slightly different and equals one part of an ellipse. The hole in the bottom (slightly off centered) is without acoustic importance.

Setup. The setup of Viennese timpani is the 'German configuration'. Both lower timpani are stand-

Fig. 1. Vienna „Hochrainer“ Timpano manufactured by Schuster

ing at right side, a pair of smaller timpani on the left side of the player. This configuration equals the historical setup when timpani were played by musicians mounted on horses. Other orchestras outside Germany and Austria usually have the larger, lower timpani at the left side, like at a keyboard. The range of the large 76 cm timpani is from 'E2' (82.4 Hz) to 'c3' (131.8 Hz). The range of the smaller 69 cm timpani is from'Bb2' (116.5 Hz) to 'f3' (174.6 Hz). Besides these, a 59 cm soprano timpano is set up with a range from 'f3' (174.6 Hz) to 'a3' (220 Hz).

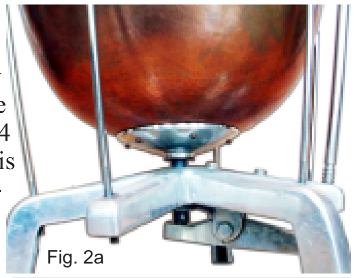


Fig. 2a

Fig. 2b: Hand tuning mechanism of the Viennese Timpani (left) and the "standard timpani" (right) with a pedal

METHODS

Literature. The acoustics of timpani have been studied in various investigations. In several publications the research results of the Northern Illinois University group were published by Rossing [1]. Besides the documentation of the 'normal modes', the influence of tension and diameter of membrane and the effect of air loading was demonstrated. Fleischer [2] made several studies using various methods (measurements, calculations, psychoacoustics experiments, modal analysis). Together with Fastl [3] they studied the influence of the air volume in the kettle and the influence on the membrane material. They found significant differences between synthetic skins and calfskin. Their focuses have been the sound and the position of the membrane modes. They also made a study on the clarity of pitches on timpani [4]. By means of psychoacoustics studies they found that the sound of a calfskin head is clearer than that of synthetic Mylar membranes and that for one timpano there are differences depending the tension of the head. Sullivan [5] made several measurements on timpani concerning an accurate frequency tracking of timpani spectral lines. He found that the most important factors appear to be the ability to produce a clear, focused pitch and the ability to achieve a good resonant sound, where partials such as a fifth or octave decay slowly.

Sound recordings. In 1999 a set of two Viennese Timpani (Schuster) and a set of two international pedal timpani (Premiere) were recorded in the anechoic chamber of our Institute. The excitation was realized by means of an electronically controlled machine (FIG 3) on both timpani sets with three mallet types (hard, medium and soft) and three tensions (high, medium and low tensions). An additional recording in 2000 was made with one pedal timpano (Aehnelt) to compare a plastic membrane (REMO Weatherking) and a goatskin membrane. The excitation was played by a professional timpani player.

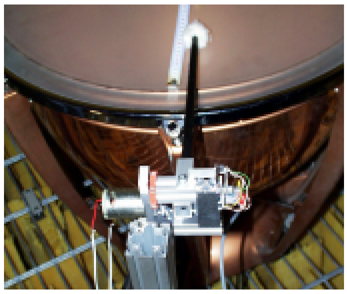


FIG. 3: An electronic controlled machine was used for a reproducable stroke.

Laservibrometry. The same instruments were measured both times with the Polytec Scanning Vibrometer PSV (scanning head: OFV 050; software vers. PSV 6.0 and controller OFV 3001S) that is owned by the technical Museum Vienna. PSV is a complete area vibration measurement and analysis system. PSV automatically collects complete vibration data from up to thousands of individual points on a user-defined area. (See FIG.4) The laser beam moves quickly, so PSV produces graphical, easily understood results. The setup 1999 included a chirp excitation with speaker, shaker (Oscillator: HP 33120) and with the electronic controlled machine; the 2000 setup was realized with a manual excitation (medium flannel mallet, mezzoforte)

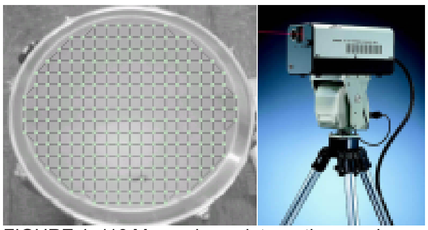


FIGURE 4: 110 Measuring points on the membrane (left) and the scanning head of the PSV system.

RESULTS

The Laservibrometry study 1999 provided a good documentation of the vibration patterns of the membranes. FIGURE 5 shows examples of some modes in two and three-dimensional representations. The Laservibrometry images of these modes from an international timpano with plastic head (IT) and from a Viennese Timpano (VT) look similar, (only the other representation is different.) The software also made it possible to create animated images of the following Modes: M01 (=Mode 01), M11, M21, M31, M41, M51, M02, M12, M22, M03 and M32. These modes have been found as peaks in an FFT of

the membrane displacement.
The positions of these peaks have been compared between the IT , VT and with reference values from the literature (Rossing et al) [1]. The frequencies of the peaks have been related to the main mode M11. FIGURE 6 shows this comparison for two measurements of the small timpani of both types (note B and D) and with both larger timpani, also with two different tensions (note G and B). All these measurements agree with measured and calculated values of the literature: M11, M21, M31, M41, M51 have a 'quasiharmonic' relation (1):(1,5):(2):(2,4):(2,9). FIG.4 also shows the relation of the other mode. Remarkable is that M01 changes its position depending on the tension.
Differences between VT and IT could be found in the magnitude of the peaks in the membrane displacement FFT.

FIGURE 7 shows the absolute maximum displacement for each measured mode in nanometers. The values for Mode 11 on the large timpani are 4000nm measured at VT and 3000nm for IT (both tensions) and 2800nm versus 1400nm and 5000nm versus 2200nm with the smaller timpani. Also Mode 21 and Mode 31 (fifth and octave of the Mode 11) have a higher magnitude with the Viennese Timpani (VT).

Analysis of the recorded sounds of the same sounds agrees with these findings. FIGURE 8 shows a 3D-FFT of 5 second tone D, played with medium mallets on IT and VT. The position of mode M11, M21 and M31 are indicated by a small circle. The amplitudes of the corresponding partials are higher at the VT. Higher partials in the radiated sound are stronger on the IT. This explains why the sound of VT has a more tonal and a less percussive characteristic than IT. This agrees with studies of Fleischer and Fastl on calfskin.

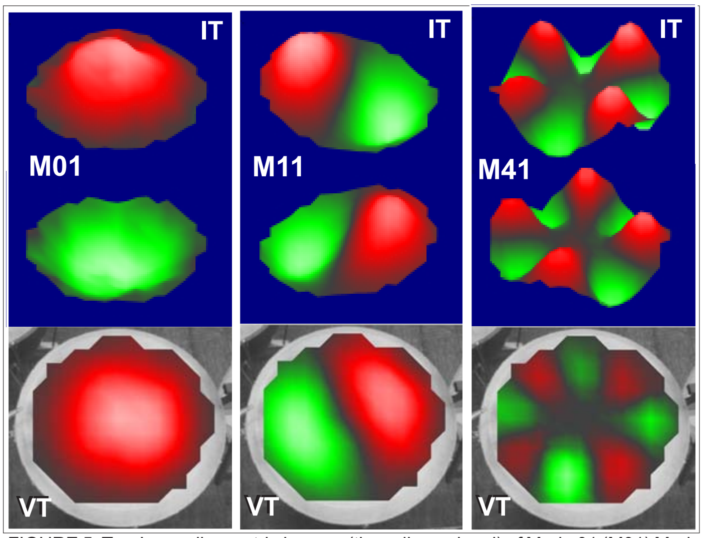


FIGURE 5: Two Laservibrometrie images (threedimensional) of Mode 01 (M01) Mode 11 (M11) and Mode 41 (M41) from international timpani with plastic head (IT) and the colormap images of a viennese Timpano (VT) below show similar characteristics.

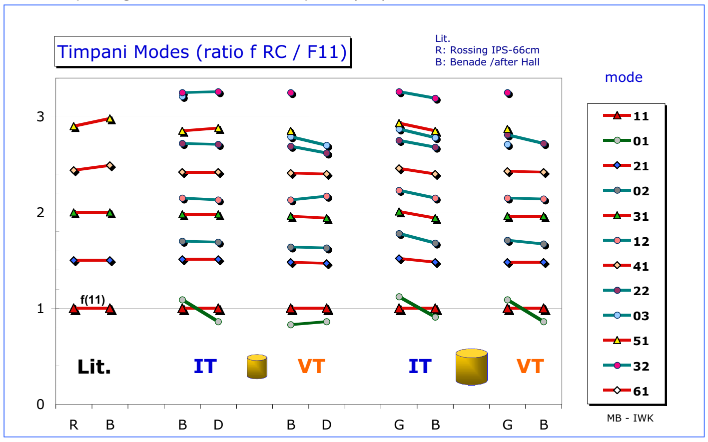
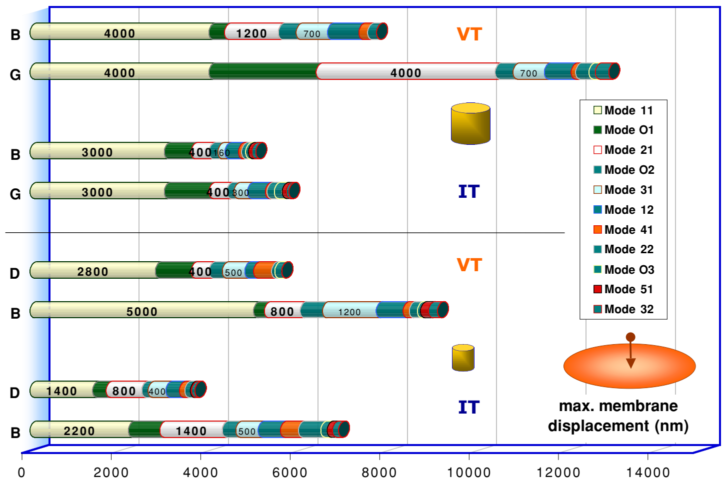
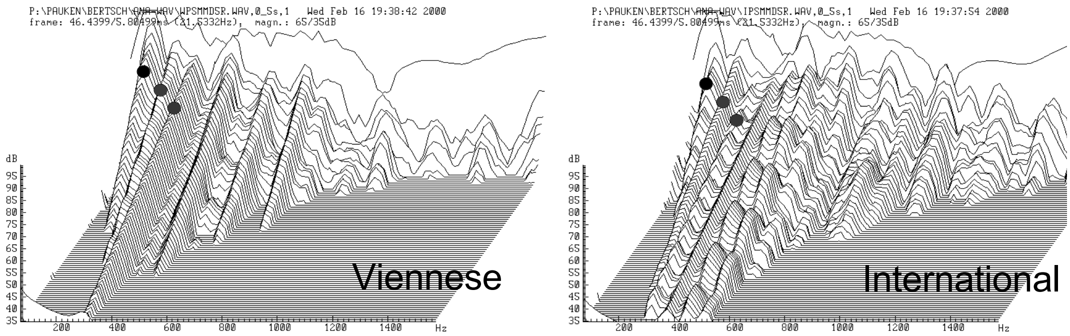


FIGURE 6 (above) : comparison of the mode ratios found in the laservibrometrie images compared to the normal modes found in the literature (Lit). The mode ratios of the Viennese timpani (VT) and the pedal timpani with plastic membrane (IT) are very similar. This could be found for both tensions (note B und D on the small timpani and note G and B on the large timpani). Mode 01 changes its position depending on the tension. FIGURE 7 (below): the correspinding magnitudes of membrane displacement for all modes in nanometer.

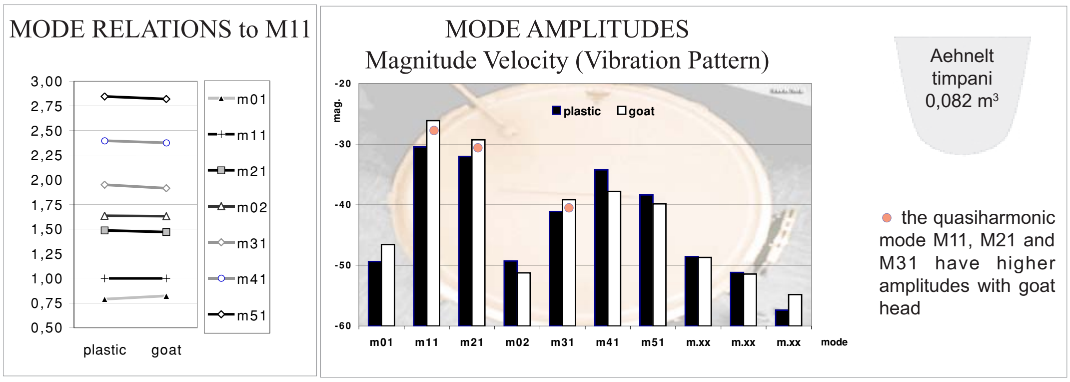




FIGURES 8: 5 sec. 3D-FFT of the recorded sounds of a small VT and IT. M11, M21 and M31 have a higher amplitdes in the VT sample.

Since the reason for this difference of VT could be the membrane or the other part (kettle) of the instrument, a follow up study was made (setup 2000) with only one pedal timpano and two different membranes. A goatskin and a plastic head. Again, sound recordings and Laservibrometry studies have been made, and the results of a similar analysis can be seen in FIGURE 9. The result of these measurements shows also similar mode relations for plastic and goat heads, but differences in the amplitudes. The important modes M11, M21 and M31 have higher magnitudes in the membrane displacement. This could be caused by the inhomogeneous skin structure of natural heads, in particular by the reinforcement of the skin from along the backbone of the animal (that can be seen as diagonal line over the membrane in FIG 1). Further studies could be focused on different natural membrane materials.

The analysis of the recorded sounds in the setup-2000 indicated also fewer higher harmonics with the



FIGURES 9: Laservibrometry results from the setup 2000: a plastic and a goatskin head on the same Aehnelt timpano.

VT, but the stronger lower 'quasiharmonic' partials could not be found. Since this setup derived from a human player, many reasons for the variation of sound quality could be assumed.

CONCLUSIONS

Viennese 'Hochrainer' Timpani are different since they use goatskin and a different tuning mechanism. The LASER interferometry and sound analysis results show similar mode ratios to the International Timpani but different mode amplitudes. Mode 11 (fundamental) and 31 (octave) are stronger, especially at higher tensions. This results in a different sound and more tonality. The 'Hochrainer' timpani are preferred by Viennese players despite of their sensitivity to moisture and temperature because of their unique sound qualities.

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CAN YOU IDENTIFY THE VIENNA PHILHARMONIC ORCHESTRA, COMPARED WITH THE BERLIN OR NEW YORK PHILARMONIC ?

PACS: 43.75.Cd

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ABSTRACT

Hundreds of participants, professionals and non-musicians, within and outside of Vienna, listened to 21 pairs of sound examples and tried to identify the recording of the Vienna Philharmonic [1]. The final results shows that the total group indeed heard Viennese characteristics in 14 examples. In 9 cases these characteristics have been assigned correctly to the Viennese orchestra. Since longer examples were identified more accurately than shorter ones, the playing style was found to be the major criterion for judgment, rather than the timbre. The study concludes that listeners can indeed hear differences, but interpretation style can be misleading, and sound characteristics can generally only be identified by highly-experienced listeners.

INTRODUCTION

“Vienna is Different!” is an official slogan of the City of Music, and the musical peculiarities and traditions of the city are a particular source of pride. The direct descendants of instrument types which have disappeared from the rest of the world, are still built, taught and played in the tradition of the Viennese Sound. Outside the city limits, audition applicants playing these special oboes and horns need not even apply. But luckily, Vienna has several first-class orchestras that demand exactly this sound. The special characteristics of these instruments have been scientifically examined, and published in previous studies [2,3,4]. For the moment, we will concern ourselves with the noticeable differences while listening CD recordings. It has been unquestionably established that hornists and experts can tell the difference between the Viennese horn and the international double horn when played solo. But with a recording of the mixed sounds of the entire orchestra, the question remains whether these typical Viennese sound qualities come through to the listener. Is the sound of the Vienna Philharmonic really distinctive, compared to any other world-class orchestra? Is there truly a "Viennese dialect" for the orchestral sound?

ABOUT THE LISTENING TEST

Method. To determine whether Viennese qualities really are audible on orchestral recordings, a large scale study was made by surveying hundreds of professional and amateur musicians, students and music lovers. (Preliminary results were presented at ISMA2001 [1].) Besides 556 Austrians, there were participant musician groups from Athens, Paris, Warsaw and Prague, as well as employees of Deutsche Grammophon in Berlin and Hamburg included in this survey. The task was to listen to two recordings of the same orchestral excerpt and to identify the one which was played by the Vienna Philharmonic. If possible, the listener was invited also to comment on which clues led him to his or her decision. The second excerpt was played either by the Berlin or the New York Philharmonic. This project is a scientific study of the author, conducted at the University of Music and Performing Arts, Vienna. The study was not commissioned by the Vienna Philharmonic, and was not about judging the preferential tastes of the listeners.

Background to this study. An example of the project director's motivation for the study: at an interview before the entry examination audition at the University in Vienna, the professor, a member of the VPO, told the candidate, "You can forget even thinking about the audition with that "jazz trumpet" (a classical Bach Stradivarius). Here, we play this trumpet and this mouthpiece!" This statement naturally raises the question how much the instrument contributes to the resulting sound, and how much the musician. There were, however, even more important reasons to research the Viennese Sound. In world politics, globalization is on everyone's lips. It's therefore a legitimate question to ask how distinctive the symphonic orchestras and their products - concerts and CDs - really are from one another. Is there such a thing as the "Golden Sound" of the Vienna Philharmonic, and if so, what is it? Aside from ideological reflections, there are a few critical practical ones for musicians and instrument makers, as well: Is it worth it to learn such a specialized instrument, if the job market is so limited? Is it worth it for the instrument maker to make these instruments if the market is so small? Production is costly and requires special know-how, which also needs to be learned. At the University (formerly "Hochschule"), money and time are invested in two classes of instruments: one for Viennese, and the other for international instruments.

The participants of the listening test were divided into statistical groups that were used for criteria in the final analysis. 179 participants (20%) have occupations actively involved with music, which includes orchestral musicians, but also recording engineers and instrument makers. 119 listeners (13%) are music lovers who are not active musicians. The largest group of over 600 listeners either study music or consider themselves amateurs. 60% of the participants are Austrians, and most of the non-Austrians live in Vienna. To consider sound recognition in other countries, 200 listeners from Germany, the Czech Republic, France and Greece were included. The distribution of the participants was balanced, with 446 women (w) and 478 men (m). In the breakdown into instrument groups, males were more prevalent among brass players (10w/70m) and percussion instruments (14w/51m), while women among woodwinds (193w/111m) were more numerous. In other instrument groups such as strings (155w/145m), keyboard instruments (275w/251m), plucked instruments (66w/109m), and among those who neither sing nor play an instrument (31w/34m) were more or less balanced. A detailed breakdown by instrument, as well as the actual listening examples from the test, can be found at the project home page http://www.bias.at/wbny.

TWENTY-ONE TASKS OF THE LISTENING TEST

[Task 1-2] Mozart: Symph. Nr. 41 (3. Menuetto) [1788]
Task 1: tutti in 3/4 - [bar 52 - 59]. (dynamic =f) - flute, oboe, bassoon, horn, trump., timp., 1. viol., 2. viol., cello, bass, viola Task 2: - downward phrase, 3/4 - [bar 44 - 51]. (dynamic =p) - flute, oboe, bassoon
[Task 3-5] Beethoven: Symph. Nr. 3 "Eroica" (4. Finale) [1804]
Task 3: - strings pizzicato, woodwind staccato - [bar 12 - 27]. (dynamic =p) - flute, clar., bassoon, 1. viol., 2. viol., viola, cello, bass Task 4: flute solo (16th) above orchestra - [bar 182 - 198]. (dynamic =p) - flute, oboe, 1. viol., 2. viol., viola, cello, bass Task 5: tutti passage, theme played by horn and basses - [bar 380 - 388]. (dynamic =ff) - flute, oboe, clar., bassoon, horn, trump., timp., 1. viol., 2. viol., viola, cello, bass
[Task 6] Beethoven: Symph. Nr. 7 (2. Allegretto) [1812]
Task 6: - slow theme played by strings; poco a poco crescendo - [bar 51 - 66]. (dynamic =p-mf) - 1. viol., 2. viol., viola, cello, bass
[Task 7-8] Schubert : Symph. Nr. 8 "Unvollendete" (1. Allegro) [1822]
Task 7: celli theme, syncopic contrapunct - [bar 44 - 47]. (dynamic =pp) - clar., viola, cello, bass Task 8: strings theme - [bar 312 - 316]. (dynamic =p) - flute, oboe, bassoon, horn, 1. viol., 2. viol., viola, cello, bass
[Task 9] Brahms: Symph. No. 4 e-moll op. 98 (4. Allegro) [1885]
Task 9: begin, accord theme played by all wind players - [bar 1 - 8]. (dynamic =f) - flute, oboe, clar., bassoon, horn, trump., tromb., timp.
[Task 10-13] Bruckner: Symph. Nr. 7 E-Dur (3.Scherzo) [1883]
Task 10: trumpet - theme, strings rhythmic accomp. - [bar 5 - 8]. (dynamic =p) - trump., 1. viol., 2. viol., viola, cello, bass Task 11: tutti, trumpet ff punctated motifs - [bar 77 - 89]. (dynamic =ff) - flute, oboe, clar., bassoon, horn, trump., tromb., tuba, timp., 1. viol., 2. viol., viola, cello, bass Task 12: begin, timpani solo - [bar 273 - 276]. (dynamic =pp) - timp. Task 13: end of trio, flute melodic motifs - [bar 397 - 405]. (dynamic =p) - flute, oboe, clar., timp., 1. viol., 2. viol., viola, cello, bass
[Task 14] Berlioz: Symph. fantastique (1. Rêveries) [1831]
Task 14: oboe and bassoon motivs - [bar 456 - 460]. (dynamic =p) - oboe, clar., bassoon, horn, bass
[Task 15,16,17] Mahler: Symph. Nr. 1 "Der Titan" (2. Kräftig bewegt) [1889]
Task 15: beginn, 3/4 "Ländler", rough motifs - [bar 1 - 22]. (dynamic =f) - flute, oboe, bassoon, horn, triangel, 1. viol., 2. viol., viola, cello, bass Task 16: stringendo, climax, "Ländler"-theme, tutti - [bar 132 - 169]. (dynamic =ff-fff) - flute, oboe, clar., bassoon, horn, trump., tromb., tuba, timp., triangel, 1. viol., 2. viol., viola, cello, bass Task 17: - horn solo, rit. dim. - [bar 171 - 175]. (dynamic =mf-pp) - horn
[Task 18-21] Mahler: Symph. Nr. 5 (1. Trauermarsch) [1904]
Task 18: - trumpet solo - [bar 0 - 5]. (dynamic =p-mf) - trump. Task 19: strings "Weinend" (sad), legato - [bar 42 - 50]. (dynamic =pp-ppp) - clar., bassoon, 1. viol., 2. viol., viola, cello, bass Task 20: tutti, triplets, tuba solo - [bar 254 - 265]. (dynamic =ff-pp) - clar., bassoon, horn, trump., tromb., tuba, timp., drum, l.drum Task 21: horn theme, 1.violin contrapart, strings triplet motifs - [bar 337 - 344]. (dynamic =f-ff) - horn, 1. viol., 2. viol., viola, cello, bass.

"Wow, That Was Pretty Hard!" …was the response of almost all participants. The short duration of the sound examples, or a solo excerpt whose instrument was not so familiar, were typical pitfalls. Most decisions were "gut reactions", that is, from subconsciously perceived clues. With the given reasons for certain decisions, many conclusions were quite interesting. Many participants opted to submit their questionnaire anonymously. The considerations while choosing were diverse among the listeners, and in the end, many aspects can be attributed to "acoustic trademarks". The Viennese Sound is a complex phenomenon, and a multitude of factors contribute significantly to it. Though these factors largely are not possible to express in numbers, the following formula might be “a nice try” in clarifying how the various factors interrelate. Though this “Wiener Klangstil” is surely incalculable, it's worth considering that the listening test resulted in 19,500 single experiments (930 listeners, twenty-one examples) in order to solve the following equation:

$$WKS = V\,T\,Ps = \left\{ \sum_{j=1}^{80} \left[\left(\sum_{i=1}^{n_j} M_{i,j} \times I_{i,j} \right) \right] \times LT \right\}^{C} \times \left[r\ t \right] \times \left\{ \int_{Q=-\infty}^{+\infty} RT \times \sum_{n \to \infty} XP \right\}$$

WKS = Wiener Klangstil	**M = Musician**	**r = Room**	**RT = Recording Technique**
V = Vienna	**I = Instrument**	**t = Time**	**Q = Recording Quality**
T = Timbre	**LT = local tradition**		**XP = Listeners individual Experience**
Ps = Playing style	**C = Conductor**		

“Wiener Klangstil” (Ger.) is a combination of the Viennese playing style and the Viennese instrumental timbre. Both result through the interaction between the musician (M) with his or her instrument (I). || A symphonic orchestra is the sum (∑) of 80 musicians. || The interpretation of a work is determined by the local tradition (LT). || Altogether can be potentialized or masked by a conductor (C) through his or her individual interpretation. || Of course, there are differences in the room (r) and time (t). || With recordings, the sound depends on the recording techniques (RT), whose quality (Q) can span from an infinite minus to an infinite plus. || As last and most important factor, the individual listener's experiences (XP) determine which characteristics are perceived.

Sometimes, no characteristics were heard, and the listener just guessed. Examples particularly difficult were where typical characteristics appeared alongside atypical ones. For example, "The sound of the instrument is typical, but not the interpretation." In these cases, the interpretation and rhythmical phrasing carried more weight in deciding.
Just as some qualities are attributed to the Vienna Philharmonic, others are seldom attributed to it ("The Viennese never hack into their violins like that"). Furthermore, some listeners claimed to hear characteristics of the Berlin or New York Philharmonic. Each listener used his or her own listening experience as a point of reference. Zubin Mehta, long-time conductor of the New York Philharmonic, paid close attention to his special experiences with musicians that he knows well, or to the special recording techniques of different orchestras. (FIG 1). He, as well as many others, speculated about the hall, the conductor, or musical personalities in the examples. [Question to Zubin Mehta: "When you are standing in front of a first-class orchestra with your eyes closed, how can you tell if they are the Vienna Phil?" Answer Mehta: "It's very simple - if I give the first beat, and nothing happens!" This is a characteristic which is difficult to hear on a CD, but that a live audience at a performance can recognize.]

FIG.1 Interviews with Zubin Mehta and Seji Ozawa gave additional information from the conductor’s point of view. Maestro Mehta also took part in the listening test.

% correct answers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
all /n= 923	52,8%	56,9%	45,3%	59,0%	44,7%	52,1%	48,0%	56,6%	36,2%	43,5%	56,8%	50,3%	53,9%	60,6%	30,3%	50,9%	49,9%	62,7%	61,6%	47,9%	56,4%
male /n= 473	53,1%	54,8%	46,9%	56,0%	46,0%	49,7%	50,1%	53,8%	40,6%	45,5%	60,3%	50,4%	54,4%	59,7%	32,2%	52,0%	53,3%	63,6%	61,0%	51,1%	55,2%
female /n= 444	51,8%	59,4%	43,6%	62,3%	43,0%	54,7%	46,0%	59,5%	31,8%	41,4%	53,2%	50,1%	53,2%	62,0%	28,4%	49,0%	46,5%	61,7%	62,4%	44,6%	57,6%
brass /n= 77	54,5%	59,7%	46,8%	63,6%	58,4%	45,5%	41,6%	50,6%	51,9%	51,3%	59,7%	50,6%	57,9%	57,1%	32,5%	54,5%	57,9%	64,9%	58,7%	51,3%	58,7%
wood /n= 257	53,3%	58,0%	47,8%	66,1%	43,0%	57,2%	51,2%	57,4%	31,4%	43,0%	57,6%	43,5%	52,3%	58,5%	28,8%	48,8%	56,8%	65,0%	65,2%	51,6%	53,9%
string /n= 274	54,0%	59,0%	42,0%	59,5%	46,0%	57,3%	46,7%	55,3%	36,9%	48,4%	54,6%	50,4%	53,1%	60,6%	28,5%	49,6%	47,4%	59,7%	65,1%	44,9%	55,7%
percussion /n= 48	50,0%	57,1%	51,0%	59,2%	38,8%	39,6%	53,1%	61,2%	40,8%	55,1%	71,4%	49,0%	46,9%	49,0%	30,6%	49,0%	57,1%	67,3%	46,9%	53,1%	57,1%
professionals /n= 179	55,9%	55,9%	49,2%	55,9%	48,6%	51,4%	50,8%	53,1%	40,8%	49,1%	61,5%	42,9%	56,4%	46,9%	39,1%	45,8%	56,2%	60,9%	68,2%	50,3%	54,8%
stud./Amat. /n= 617	52,7%	57,4%	44,4%	60,7%	43,7%	51,6%	47,2%	58,2%	35,2%	43,2%	56,6%	52,6%	53,1%	63,1%	28,0%	53,9%	49,9%	65,1%	59,3%	49,1%	55,6%
passive.listener /n= 119	49,6%	56,8%	45,3%	57,1%	43,7%	57,6%	47,0%	52,5%	35,0%	35,7%	51,3%	49,1%	53,0%	67,5%	30,2%	40,4%	37,4%	52,6%	63,5%	38,8%	63,5%
Austrians /n= 553	49,7%	58,3%	44,0%	60,4%	41,7%	53,3%	48,6%	57,3%	35,9%	37,7%	58,5%	51,4%	52,7%	61,9%	31,0%	48,3%	47,4%	60,3%	63,8%	48,1%	57,8%
Non-Austr. /n= 359	58,2%	54,7%	47,3%	57,6%	49,3%	50,8%	46,7%	55,0%	36,9%	53,1%	53,7%	48,2%	55,0%	58,3%	29,6%	54,8%	53,5%	66,3%	58,2%	47,9%	53,7%
age 0-19 /n= 268	53,0%	55,2%	46,6%	61,7%	46,5%	48,9%	44,8%	60,0%	32,6%	40,0%	59,3%	48,3%	52,8%	63,3%	23,7%	55,0%	48,3%	65,9%	58,4%	49,8%	49,8%
age 20-39 /n= 460	54,3%	56,4%	44,9%	58,4%	43,5%	52,0%	48,4%	55,0%	39,8%	45,4%	57,1%	48,8%	55,4%	57,5%	31,5%	49,9%	48,8%	62,2%	63,1%	48,6%	59,3%
age 40-99 /n= 181	48,1%	59,2%	43,9%	57,5%	44,8%	59,1%	52,0%	53,9%	33,0%	43,8%	52,5%	55,8%	49,4%	63,7%	36,7%	44,9%	53,9%	58,9%	62,0%	42,8%	57,5%
flute /n= 76	55,3%	56,0%	47,3%	73,3%	50,0%	53,9%	43,2%	47,4%	30,3%	32,0%	61,3%	41,9%	61,8%	56,6%	28,9%	47,4%	54,7%	68,0%	63,2%	60,8%	58,7%
clarinet /n= 38	47,4%	57,9%	37,8%	57,9%	42,1%	60,5%	57,9%	55,3%	31,6%	50,0%	63,2%	33,3%	50,0%	47,4%	29,7%	47,4%	68,4%	60,5%	75,7%	52,6%	50,0%
oboe /n= 21	57,1%	71,4%	45,0%	61,9%	52,4%	52,4%	57,1%	61,9%	52,4%	52,4%	65,0%	28,6%	42,9%	57,1%	28,6%	55,0%	42,9%	66,7%	57,1%	57,1%	47,6%
horn /n= 24	54,2%	50,0%	54,2%	66,7%	75,0%	41,7%	29,2%	58,3%	66,7%	54,2%	54,2%	29,2%	78,3%	50,0%	41,7%	58,3%	62,5%	79,2%	56,5%	60,9%	70,8%
trumpet /n= 28	53,6%	60,7%	39,3%	60,7%	42,9%	67,9%	53,6%	42,9%	46,4%	50,0%	57,1%	57,1%	46,4%	67,9%	32,1%	64,3%	53,6%	64,3%	60,7%	50,0%	53,6%
trombone /n= 19	52,6%	57,9%	52,6%	63,2%	57,9%	26,3%	52,6%	52,6%	52,6%	38,9%	52,6%	63,2%	42,1%	52,6%	26,3%	36,8%	50,0%	52,6%	44,4%	42,1%	47,1%
timpani /n= 16	37,5%	50,0%	37,5%	56,3%	50,0%	50,0%	50,0%	62,5%	56,3%	43,8%	62,5%	31,3%	31,3%	37,5%	18,8%	56,3%	62,5%	68,8%	62,5%	56,3%	56,3%
violin /n= 163	53,4%	59,3%	40,9%	62,0%	46,0%	57,1%	43,8%	52,5%	35,0%	48,1%	56,8%	49,7%	58,9%	65,0%	28,2%	52,1%	46,6%	55,6%	64,6%	45,7%	54,3%
viola /n= 45	48,9%	55,6%	51,1%	55,6%	37,8%	73,3%	50,0%	51,1%	37,8%	48,9%	44,4%	57,8%	44,4%	60,0%	28,9%	35,6%	46,5%	64,4%	64,4%	40,0%	53,3%
cello /n= 59	57,6%	61,0%	41,4%	61,0%	47,5%	55,9%	44,8%	59,3%	42,4%	40,7%	52,5%	54,2%	51,7%	55,9%	28,8%	47,5%	45,8%	66,1%	62,7%	51,7%	67,8%
bass /n= 26	50,0%	46,2%	46,2%	50,0%	57,7%	46,2%	57,7%	42,3%	46,2%	61,5%	50,0%	38,5%	30,8%	50,0%	34,6%	50,0%	61,5%	61,5%	61,5%	42,3%	46,2%
piano /n= 433	52,7%	57,8%	47,6%	60,6%	39,9%	48,8%	45,3%	55,6%	32,6%	43,2%	55,0%	50,0%	53,2%	62,2%	27,2%	50,6%	48,7%	62,0%	62,7%	49,4%	57,4%
conducter /n= 21	61,9%	66,7%	47,6%	57,1%	47,6%	42,9%	35,0%	61,9%	28,6%	61,9%	38,1%	47,6%	52,4%	52,4%	38,1%	57,1%	61,9%	47,6%	61,9%	47,6%	66,7%
NO instrument /n= 64	54,7%	55,6%	39,7%	56,3%	41,5%	53,1%	40,6%	53,8%	33,8%	27,7%	52,3%	55,6%	53,1%	67,2%	25,0%	39,7%	35,4%	56,3%	61,9%	34,9%	60,9%
Europe ext /n=104	52,9%	50,0%	37,1%	50,0%	51,4%	45,7%	36,5%	57,1%	29,1%	47,6%	57,1%	47,6%	66,7%	58,1%	28,6%	57,1%	50,5%	69,5%	57,1%	55,8%	57,1%

Table 1: The "Bullseye" Quota, for all 21 Examples. Correct answers in percent for all and groups of listeners. Values above 50 % are green, below 50 % are red. The corresponding significance can be seen in table 2.

significance	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
all /n= 923	9,32	0,01	0,44	0,01	0,13	19,92	23,53	0,01	0,01	0,01	0,01	86,86	1,77	0,01	0,01	59,82	94,74	0,01	0,01	21,08	0,01
male /n= 473	18,24	3,85	18,05	0,88	8,09	89,01	96,32	9,82	0,01	5,27	0,01	85,36	5,37	0,01	0,01	38,33	15,40	0,01	0,01	64,60	2,40
female /n= 444	44,77	0,01	0,76	0,01	0,33	4,67	9,63	0,01	0,01	0,03	18,29	96,18	18,29	0,01	0,01	66,82	13,99	0,01	0,01	2,24	0,15
brass /n= 77	42,50	8,74	56,88	1,67	13,85	42,50	13,85	90,93	73,24	81,85	8,74	90,93	16,87	21,00	0,21	42,50	16,87	0,88	13,33	81,85	13,33
wood /n= 257	28,89	1,05	48,92	0,01	2,50	2,10	70,77	1,80	0,01	2,44	1,46	3,80	45,50	0,62	0,01	70,87	2,90	0,01	0,01	61,71	21,31
string /n= 274	18,38	0,30	0,87	0,17	18,38	1,57	27,51	7,92	0,01	58,60	13,03	90,35	30,35	0,01	0,01	90,38	39,60	0,13	0,01	8,96	6,06
percussion /n= 48	99,99	31,73	88,64	19,85	11,61	14,89	66,82	11,61	19,85	47,51	0,27	88,64	66,82	88,64	0,66	88,64	31,73	1,52	66,82	66,82	31,73
professionals /n= 179	11,65	11,65	82,16	11,65	70,86	70,86	82,26	41,10	1,36	82,06	0,22	5,88	8,56	41,10	0,36	26,22	9,92	0,36	0,00	94,01	20,13
stud./Amat. /n= 617	18,40	0,02	0,60	0,01	0,17	42,11	17,07	0,01	0,01	0,07	0,10	19,80	12,70	0,01	0,01	4,93	96,79	0,00	0,00	65,89	0,56
passive.listener /n= 119	92,70	14,08	30,92	11,91	16,91	9,75	51,75	58,07	0,12	0,21	78,15	85,01	51,39	0,02	0,01	3,94	0,68	57,75	0,38	1,58	0,38
Austrians /n= 553	89,85	0,01	0,47	0,01	0,01	12,55	52,21	0,06	0,01	0,01	0,01	51,98	20,00	0,00	0,01	41,74	21,58	0,01	0,01	37,01	0,02
Non-Austr. /n= 359	0,18	7,31	31,46	0,38	79,24	75,18	20,59	5,78	0,01	24,63	15,53	49,38	5,85	0,16	0,01	6,55	18,70	0,01	0,18	42,98	15,53
age 0-19 /n= 268	32,84	8,72	26,97	0,01	24,67	71,50	8,84	0,10	0,01	0,10	0,23	58,32	36,04	0,00	0,01	9,97	58,18	0,01	0,61	95,14	95,14
age 20-39 /n= 460	6,22	0,60	3,09	0,03	0,52	40,03	48,38	3,20	0,01	4,97	0,24	60,76	1,97	0,13	0,01	96,29	60,84	0,01	0,01	54,40	0,01
age 40-99 /n= 181	60,29	1,36	10,11	4,48	15,79	1,42	59,88	29,67	0,01	9,73	50,35	12,73	88,15	0,02	0,03	17,73	29,40	1,71	0,13	5,26	4,36
flute /n= 76	35,88	29,87	64,19	0,01	99,99	49,13	24,50	64,64	0,06	0,18	4,96	16,30	3,89	25,13	0,02	64,64	41,89	0,18	2,18	6,29	13,33
clarinet /n= 38	74,56	33,04	13,90	33,04	33,04	19,44	33,04	51,64	2,31	99,99	10,48	4,55	99,99	74,56	1,37	74,56	2,31	19,44	0,18	74,56	99,99
oboe /n= 21	51,27	4,95	65,47	27,52	82,73	82,73	51,27	27,52	82,73	82,73	17,97	4,95	51,27	51,27	4,95	65,47	51,27	12,66	51,27	51,27	82,73
horn /n= 24	68,31	99,99	68,31	10,25	1,43	41,42	4,12	41,42	10,25	68,31	68,31	4,12	0,67	99,99	41,42	41,42	22,07	0,43	53,16	29,71	4,12
trumpet /n= 28	70,55	25,68	25,68	25,68	44,97	5,88	70,55	44,97	70,55	99,99	44,97	44,97	70,55	5,88	5,88	13,06	70,55	13,06	25,68	99,99	70,55
trombone /n= 19	81,85	49,13	81,85	25,13	49,13	3,89	81,85	81,85	81,85	34,58	81,85	25,13	49,13	81,85	3,89	25,13	99,99	81,85	63,74	49,13	80,84
timpani /n= 16	31,73	99,99	31,73	61,71	99,99	99,99	99,99	31,73	61,71	61,71	31,73	13,36	13,36	31,73	1,24	61,71	31,73	13,36	31,73	61,71	61,71
violin /n= 163	38,89	1,84	2,15	0,23	30,86	7,16	11,61	52,97	0,01	63,74	8,39	93,72	2,31	0,01	0,01	58,35	38,60	15,73	0,02	27,14	27,14
viola /n= 45	88,15	45,61	88,15	45,61	10,11	0,17	99,99	88,15	10,11	88,15	45,61	29,67	45,61	17,97	0,46	5,26	64,73	5,26	5,26	17,97	65,47
cello /n= 59	24,13	9,06	18,92	9,06	69,61	36,21	43,08	15,21	24,13	15,21	69,61	51,51	79,28	36,21	0,11	69,61	51,51	1,34	5,08	79,28	0,63
bass /n= 26	99,99	69,49	69,49	99,99	43,28	69,49	43,28	43,28	69,49	23,93	99,99	23,93	4,99	99,99	11,67	99,99	23,93	23,93	23,93	43,28	69,49
piano /n= 433	26,90	0,11	31,06	0,01	0,01	63,12	4,93	1,88	0,00	0,46	3,88	99,99	17,89	0,01	0,01	81,05	59,71	0,01	0,01	81,05	0,21
conducter /n= 21	80,55	13,96	10,69	8,48	70,98	45,33	6,28	53,51	2,67	90,13	90,13	80,55	21,84	99,99	0,68	62,25	21,84	53,51	0,92	80,55	46,02
NO instrument /n= 64	45,33	37,78	10,15	31,73	17,24	61,71	13,36	53,51	0,92	0,03	70,98	37,78	61,71	0,60	0,01	10,15	1,84	31,73	5,88	1,67	8,01
Europe ext /n=104	55,63	99,99	0,84	99,99	76,97	37,98	0,60	14,32	0,01	62,56	14,32	62,56	0,06	9,71	0,01	14,32	92,23	0,01	14,32	23,93	14,32

Table 2: Significance of Chi^2 values for the results of table 1. Values below 5 % indicate that answers are probably not random. Significance depends greatly on the number of members within a group (n=). With a smaller group, there is a high quota of hits or misses necessary to rule out random chance. Very significant data are underlined.

A FEW TYPICAL AND ATYPICAL EXAMPLES

Example Number 18 was recognized the best by all participants. The triplet pick-up to the trumpet signal from Mahler's 5th Symphony was identified significantly as played by a Viennese. It was especially clear that listeners from outside of Vienna (Athens, Paris...) heard the difference. Listeners who play no instrument identified the example least often. Listeners found the rhythmic interpretation and the dynamic characteristics, like accents and decay, typically Viennese. A darker, softer sound was also a major hint.

Example 19 was well-recognized by musicians and non-musicians alike. The Viennese legato passage from Mahler's 5th was correctly identified by 68% of professional musicians and also by 62% of listeners who play no instrument. Both excerpts in Example 19 were directed by Leonard Bernstein. The Viennese outtake was, however, played more warmly and with "schmalz" (vibrato, phrasing).

Example 9 (Brahms' 4th Symphony, beginning of the 4th Mvt.) was identified poorly on the whole. Only hornists heard the typical Viennese horn sound. Oboists had an average rate of success, along with timpanists and sound engineers. Incorrect identification was attributed to interpretive factors and to the total sound ("that sound couldn't be in Vienna"). The recording of Berlin with Claudio Abbado was closer to listeners' expectations of Viennese interpretation than Carlos Kleiber's with the VPO. Experts on the Viennese instruments heard the differences much better than "normal" listeners, who were far more interpretation-oriented, and in this case, deceived.

Example 14, a short excerpt from Berlioz' Symphonie Fantastique, was correctly identified by non-musicians more often than professionals. "Hit" quotas among instrument groups were inconsistent. Percussionists had fewer hits than string or wind players. The additional comments show that listeners prefer the Viennese recording. Woodwind experts also identified the Viennese orchestra better by the sound of the instruments than those who decided based on phasing and rhythm.

Example 15 is very interesting, indeed. Though most listeners were confident that they chose correctly, this example was identified correctly less often than any other! Only 30% of listeners were able to assign Paul Kletzki's interpretation of Mahler to the Vienna Philharmonic. The other recording, from Bernstein with the New York Phil, sounded for most listeners much more "wienerisch". But this is easily explained, due to Bernstein's influence on the tradition of Mahler interpretation in Vienna in the 60's and 70's. Listeners were influenced mostly by stylistic elements like rhythm interpretation and phrasing with this example. In the typical alpine 3/4 rhythm (Ländler), Kletzki demanded a very straight rhythm. Bernstein's freer rhythm sounds for most listeners like it has more feeling, rounder, and softer, and therefore more typically Viennese. Only a few listeners noticed the more rich forte overtones of the Viennese horns enough to correctly identify the example. This is yet another example showing not the sound of the instruments, but the characteristics of the interpretation (dependent on the time and conductor) as the primary factor in choosing the correct orchestra.

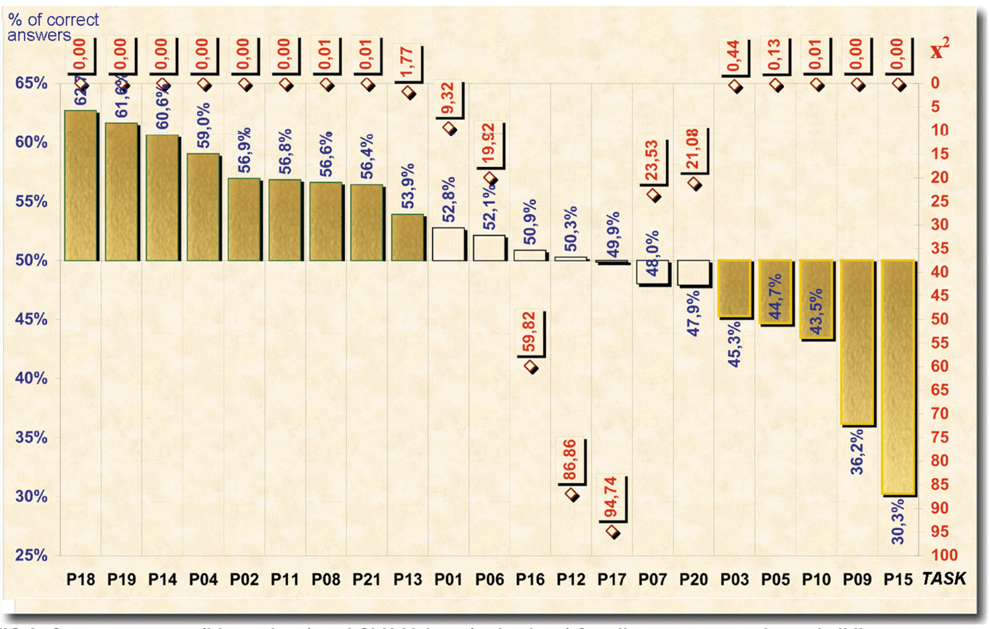

FIG 2: Correct answers (blue values) and Chi2 Values (red values) for all twenty-one tasks and all listeners

IS THERE A TYPICAL ORCHESTRA SIGNATURE IN VIENNA, AUSTRIA ?

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Abstract

"Vienna is Different" is the slogan you read when you enter the city on the highways. Differences are also associated with the sound of the famous Vienna Philharmonic Orchestra (VPO). This orchestra's individual sound characteristic is caused partly by different musical instruments (oboe, horn or timpani), and partly through a specific playing style. While the individual sound variations of these instruments have been investigated in previous studies at our Institute, this paper presents a more general approach to the "distinguishing mark" of this orchestra. 21 sound-pairs of orchestral CD-recordings were offered to test subjects: one example from the VPO and a second from the Berlin Philharmonic or New York Philharmonic Orchestras. The task was to listen and to identify the Viennese one. Listener test data are statistically analyzed to find who identified the orchestra correctly most often and through which examples (involved instruments in the example, musical background and origin of the listener, etc. are taken into account). The aim of the study is to find out which instruments do establish the typical Vienna orchestra signature.
Which instruments give the best clues for identifying the VPO? The members of the audience are invited to make their own decisions.

INTRODUCTION

What is special about the Viennese orchestra ? This question exists as long as the world famous orchestra itself. There are thousands of individual hypothesis and millions of ideas for possible reasons among musicians, audiences and scientists. In the 1950‘s the University of Music founded an institute to provide objective data on that question, but very first studies already showed that the question is much too complex for a simple answer. Too many variables are involved in the process of creation and perception. Since then, single parameters became the focus, which are obvious different in the Viennese orchestra: musical instruments such as the oboe, the horn and the timpani. The particular characteristics of these Viennese musical instruments have been studied in previous projects [1,2,3,4]. An important relevance of these studies was also that survival of these „red watch list“ instruments was endangered. In the 1970‘s almost all original Vienna horns and oboes were in disrepair, and the know-how to build these instrument was almost lost in Austria. Today, the first “brood” of new instruments can be heard in the orchestra.
So, even though “musical acoustics” already helped the Viennese orchestra tradition, there is still no answer about what the main acoustical trademarks of these orchestras are. Which of our scientific methods could solve a task this difficult ? The approach of this project is to carry out an elementary study of musical acoustics: to hear music with a large amount of experienced ears and to collect their analytical power: a large-scale listening test setup including hundreds of musicians and listeners.

METHOD

The question “Is there a typical orchestra signature in Vienna, Austria ?” has been asked using a listening test in Vienna, which started in March 2001 and is going on till December 2001. Since the aim of the test is to collect about 1000 test persons, this paper presents a documentation of the setup and shows preliminary results from 302 test persons. As the test is still in progress, details on the tasks will not be revealed. The unveiling of the final results will be presented at Forum Acusticum in Seville 2002.

The task of the listening test itself is simply to decide which of two sound examples was recorded by the

Vienna Philharmonic Orchestra (VPO). 21 pairs of sound examples from CD-recordings of nine standard orchestral pieces (see LIST “21 tasks”), are played to the test persons. The recording of the alternative sound example in the test pair is either played by the Berlin Philharmonic Orchestra or the New York Philharmonic. The sound examples were unmodified digital copies of pieces from commercial CDs. The duration of the examples is between 3 and 35 seconds (15 seconds on average). While short examples allow the comparison of timbre and short time elements, longer examples are preferred by most listeners to focus on the interpretation. A compromise for the duration of the tasks and many other variables had to be made for a better chance of comparison of other parameters.

Test Parameters. While previous studies by the author have named almost 100 influencing parameters for the tone generation on a trumpet [5], the numbers of parameters influencing a orchestral CD recording is even larger. A large number of individual players, individual instruments are building an orchestra formed by a conductor to interpret a work in a single moment (time) at particular place (room). The recording of this event results in a product that is sold as CD. The recording-technique and the post-production has not a little effect on this result and audio engineers have many powerful tools to manipulate the original sound. In spite of the infinite differences between various CD recordings, the consumer must decide on one recording in the shop, and which one he chooses depends not only on the cover design, but

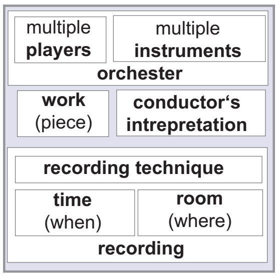


FIG 1: varying CD parameters

21 tasks of the listening test : „Vienna-Berlin-New York 2001“

[Task 1-2] Mozart: Symph. Nr. 41 (3. Menuetto) [1788]
Task 1: tutti in 3/4 - [bar 52 - 59]. (dynamic =f) - flute, oboe, bassoon, horn, trump., timp., 1. viol., 2. viol., cello, bass, viola Task 2: - downward phrase, 3/4 - [bar 44 - 51]. (dynamic =p) - flute, oboe, bassoon
[Task 3-5] Beethoven: Symph. Nr. 3 “Eroica” (4. Finale) [1804]
Task 3: - strings pizzicato, woodwind staccato - [bar 12 - 27]. (dynamic =p) - flute, clar., bassoon, 1. viol., 2. viol., viola, cello, bass Task 4: flute solo (16th) above orchestra - [bar 182 - 198]. (dynamic =p) - flute, oboe, 1. viol., 2. viol., viola, cello, bass Task 5: tutti passage, theme played by horn and basses - [bar 380 - 388]. (dynamic =ff) - flute, oboe, clar., bassoon, horn, trump., timp., 1. viol., 2. viol., viola, cello, bass
[Task 6] Beethoven: Symph. Nr. 7 (2. Allegretto) [1812]
Task 6: - slow theme played by strings; poco a poco crescendo - [bar 51 - 66]. (dynamic =p-mf) - 1. viol., 2. viol., viola, cello, bass
[Task 7-8] Schubert : Symph. Nr. 8 "Unvollendete" (1. Allegro) [1822]
Task 7: celli theme, syncopic contrapunct - [bar 44 - 47]. (dynamic =pp) - clar., viola, cello, bass Task 8: strings theme - [bar 312 - 316]. (dynamic =p) - flute, oboe, bassoon, horn, 1. viol., 2. viol., viola, cello, bass
[Task 9] Brahms: Symph. No. 4 e-moll op. 98 (4. Allegro) [1885]
Task 9: begin, accord theme played by all wind players - [bar 1 - 8]. (dynamic =f) - flute, oboe, clar., bassoon, horn, trump., tromb., timp.
[Task 10-13] Bruckner: Symph. Nr. 7 E-Dur (3.Scherzo) [1883]
Task 10: trumpet - theme, strings rhythmic accomp. - [bar 5 - 8]. (dynamic =p) - trump., 1. viol., 2. viol., viola, cello, bass Task 11: tutti, trumpet ff punctated motifs - [bar 77 - 89]. (dynamic =ff) - flute, oboe, clar., bassoon, horn, trump., tromb., tuba, timp., 1. viol., 2. viol., viola, cello, bass Task 12: begin, timpani solo - [bar 273 - 276]. (dynamic =pp) - timp. Task 13: end of trio, flute melodic motifs - [bar 397 - 405]. (dynamic =p) - flute, oboe, clar., timp., 1. viol., 2. viol., viola, cello, bass
[Task 14] Berlioz: Symph. fantastique (1. Rêveries) [1831]
Task 14: oboe and bassoon motivs - [bar 456 - 460]. (dynamic =p) - oboe, clar., bassoon, horn, bass
[Task 15,16,17] Mahler: Symph. Nr. 1 “Der Titan” (2. Kräftig bewegt) [1889]
Task 15: beginn, 3/4 “Ländler”, rough motifs - [bar 1 - 22]. (dynamic =f) - flute, oboe, bassoon, horn, triangel, 1. viol., 2. viol., viola, cello, bass Task 16: stringendo, climax, “Ländler”-theme, tutti - [bar 132 - 169]. (dynamic =ff-fff) - flute, oboe, clar., bassoon, horn, trump., tromb., tuba, timp., triangel, 1. viol., 2. viol., viola, cello, bass Task 17: - horn solo, rit. dim. - [bar 171 - 175]. (dynamic =mf-pp) - horn
[Task 18-21] Mahler: Symph. Nr. 5 (1. Trauermarsch) [1904]
Task 18: - trumpet solo - [bar 0 - 5]. (dynamic =p-mf) - trump. Task 19: strings “Weinend” (sad), legato - [bar 42 - 50]. (dynamic =pp-ppp) - clar., bassoon, 1. viol., 2. viol., viola, cello, bass Task 20: tutti, triplets, tuba solo - [bar 254 - 265]. (dynamic =ff-pp) - clar., bassoon, horn, trump., tromb., tuba, timp., drum, l.drum Task 21: horn theme, 1.violin contrapart, strings triplet motifs - [bar 337 - 344]. (dynamic =f-ff) - horn, 1. viol., 2. viol., viola, cello, bass

also on the associations he makes with a specific orchestra. These characteristics attributed to an orchestra are an important commercial factor for a label and the orchestra itself. The objective of this study is to reveal if there are acoustic orchestra trademarks and if yes, how significant different groups of listener can recognize them.

Statistic groups of 302 listener (all). female: 46%, male: 54% ; age0-19years: 36%, age20-39years: 44%, age40-99years: 20%, Austrian: 75%, Non-Austrian: 25%, professional-musican: 14%, student-amateur-musician: 70%, passive-listener: 16%. The absolute number (n=) of each group can be seen in table 1 (first column). Further groups are formed by instrument sections of all test persons playing string, brass, woodwind or percussive instruments, for persons who conduct or compose music, for each single instrument and persons playing no instrument (for final analysis at least 30-65 listeners in each group are planned). Three groups are formed by persons with 9-12 of 21 correct answers, persons with 13 or more correct answers and those with a result of 8 or less correct answers.

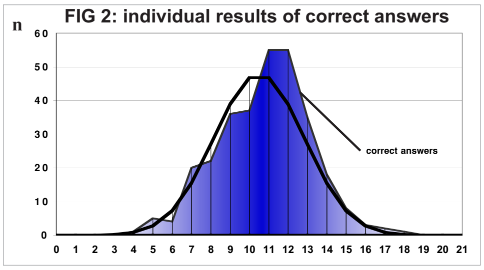


FIG 2: individual results of correct answers

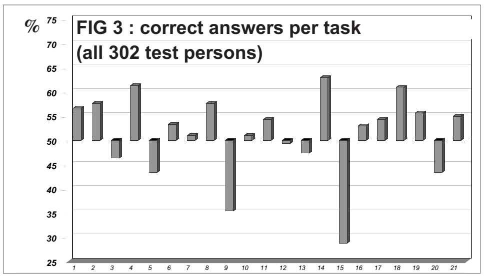


FIG 3 : correct answers per task (all 302 test persons)

RESULTS

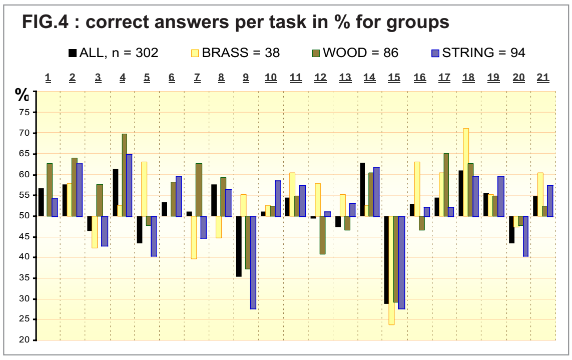
Since the test setup is very simple, each single decision has a 50 % chance to be correct. If the decisions were random, 10,5 correct answers of each test person can be expected. The actual preliminary result over all tasks with 52% is just slightly higher (FIG 2). Also, if the decisions were random, the expected amount of correct answers (k) for each task were 50%. In fact, the preliminary results show a large variation of correct answers for each of the 21 tasks. (FIG 3) While 63% of 302 test persons identified the Vienna orchestra in task 14, only 29% decided the correct answer in task 15. The difference of correct answers varies also between the test groups (FIG 4). All mean values of k can be found in table 1.

Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
ALL, n = 302	56,6	57,6	46,3	61,3	43,4	53,3	51,0	57,6	35,4	51,0	54,3	49,3	47,4	62,9	28,8	53,0	54,3	60,9	55,6	43,4	55,0
MALE = 162	58,0	52,5	47,5	56,8	46,3	47,5	50,0	53,7	40,1	54,9	60,5	51,2	46,9	61,1	32,1	57,4	56,8	61,1	57,4	45,7	52,5
FEMALE = 138	54,3	64,5	45,6	65,9	39,9	59,4	52,2	62,3	30,4	46,4	47,8	46,4	48,6	65,2	25,4	47,1	51,4	60,1	53,6	41,3	58,0
BRASS = 38	50,0	57,9	42,1	52,6	63,2	50,0	39,5	44,7	55,3	52,6	60,5	57,9	55,3	52,6	23,7	63,2	60,5	71,1	55,3	47,4	60,5
WOOD = 86	62,8	64,0	57,6	69,8	47,7	58,1	62,8	59,3	37,2	52,3	54,7	40,7	46,5	60,5	29,1	46,5	65,1	62,8	54,7	47,7	52,3
STRING = 94	54,3	62,8	42,9	64,9	40,4	59,6	44,7	56,4	27,7	58,5	57,4	51,1	53,2	61,7	27,7	52,1	52,1	59,6	59,6	40,4	57,4
PERC = 10	50,0	70,0	50,0	70,0	30,0	40,0	50,0	80,0	30,0	60,0	60,0	20,0	30,0	70,0	30,0	40,0	80,0	60,0	40,0	40,0	30,0
PROF = 42	50,0	59,5	53,7	45,2	47,6	57,1	54,8	40,5	33,3	45,2	59,5	61,9	61,9	54,8	52,4	42,9	69,0	50,0	64,3	52,4	54,8
STUD = 210	57,6	57,6	44,9	64,3	43,8	52,4	52,4	63,8	35,7	54,3	56,7	46,7	45,7	63,3	25,2	58,1	55,7	66,7	51,4	44,3	53,8
LISTENER = 48	58,3	58,3	47,9	60,4	39,6	54,2	41,7	45,8	37,5	43,8	39,6	47,9	41,7	68,8	25,0	37,5	33,3	45,8	64,6	33,3	60,4
AT = 221	53,4	59,3	42,2	63,8	41,2	54,3	48,4	56,6	33,5	45,2	56,6	52,0	47,5	67,0	29,4	49,8	52,0	60,2	58,8	45,2	54,8
NON-AT = 79	64,6	54,4	57,7	54,4	50,6	50,6	58,2	60,8	41,8	68,4	48,1	41,8	46,8	53,2	27,8	60,8	59,5	63,3	45,6	39,2	55,7
A.0-19 = 105	52,4	56,2	44,7	66,7	39,0	48,6	48,6	69,5	26,7	57,1	54,3	37,1	49,5	66,7	14,3	55,2	57,1	71,4	48,6	43,8	45,7
A.20-39 = 133	59,4	60,2	47,3	56,4	46,6	54,9	53,4	54,1	44,4	49,6	55,6	50,4	47,4	58,6	38,3	52,6	57,9	54,9	55,6	45,1	60,9
A.40-99 = 62	58,1	54,8	46,8	61,3	45,2	56,5	50,0	45,2	32,3	43,5	51,6		43,5	66,1	33,9	48,4	40,3	56,5	66,1	38,7	58,1
FLUTE = 22	77,3	63,6	54,5	81,8	54,5	54,5	50,0	63,6	45,5	45,5	50,0	50,0	59,1	63,6	22,7	45,5	54,5	72,7	54,5	59,1	50,0
CLAR = 12	66,7	50,0	63,6	58,3	33,3	58,3	66,7	58,3	33,3	58,3	66,7	25,0	50,0	58,3	33,3	41,7	83,3	50,0	66,7	41,7	50,0
OBOE = 9	55,6	77,8	66,7	55,6	33,3	33,3	44,4	22,2	55,6	55,6	44,4	33,3	55,6	77,8	11,1	66,7	55,6	66,7	66,7	66,7	44,4
HORN = 11	54,5	45,5	45,5	45,5	81,8	72,7	27,3	45,5	72,7	54,5	54,5	27,3	81,8	36,4	45,5	63,6	54,5	81,8	72,7	63,6	81,8
TRP = 15	46,7	60,0	20,0	46,7	46,7	60,0	40,0	40,0	46,7	40,0	66,7	53,3	53,3	60,0	20,0	80,0	73,3	60,0	53,3	40,0	60,0
TRB = 9	22,2	66,7	44,4	66,7	55,6	22,2	55,6	55,6	55,6	55,6	44,4	77,8	22,2	55,6	11,1	33,3	44,4	66,7	44,4	33,3	33,3
TIMP = 4	75,0	75,0	50,0	75,0	25,0	50,0	75,0	75,0	25,0	25,0	25,0	0,0	0,0	50,0	25,0	75,0	50,0	25,0	50,0	50,0	50,0
VIOLIN = 54	53,7	63,0	44,2	72,2	38,9	59,3	44,4	55,6	33,3	53,7	63,0	53,7	57,4	68,5	27,8	55,6	48,1	53,7	64,8	44,4	53,7
VLA = 12	33,3	50,0	50,0	58,3	25,0	66,7	33,3	41,7	58,3	75,0	50,0	75,0	58,3	41,7	41,7	33,3	50,0	66,7	83,3	50,0	50,0
CELLO = 29	58,6	65,5	42,9	55,2	48,3	58,6	37,9	51,7	20,7	62,1	48,3	55,2	41,4	55,2	24,1	51,7	51,7	65,5	41,4	41,4	72,4
BASS = 6	50,0	50,0	66,7	66,7	50,0	50,0	83,3	50,0	33,3	66,7	33,3	16,7	66,7	66,7	50,0	33,3	100,0	50,0	66,7	33,3	16,7
PIANO = 119	55,5	61,3	46,6	65,5	37,8	50,4	49,6	52,9	30,3	47,9	51,3	48,7	45,4	69,7	26,9	47,9	52,1	63,9	54,6	46,2	54,6
DIR/COMP = 15	40,0	60,0	33,3	53,3	66,7	46,7	60,0	40,0	20,0	53,3	60,0	46,7	33,3	60,0	33,3	46,7	60,0	46,7	73,3	33,3	60,0
No-INSTR. = 22	59,1	54,5	31,8	63,6	45,5	59,1	31,8	45,5	27,3	31,8	22,7	54,5	27,3	68,2	18,2	45,5	22,7	45,5	63,6	27,3	59,1
Res13+ = 67	85,1	70,1	58,2	74,6	68,7	74,6	61,2	77,6	40,3	62,7	64,2	62,7	64,2	64,2	41,8	70,1	68,7	82,1	64,2	61,2	67,2
Res9-12 = 183	51,9	58,5	48,3	62,3	39,9	53,6	53,0	56,3	33,9	48,6	55,7	50,8	47,5	68,3	26,8	50,3	53,6	57,4	58,5	42,6	53,6
Res8- = 53	36,5	38,5	23,5	40,4	23,1	25,0	30,8	36,5	34,6	44,2	36,5	26,9	25,0	42,3	19,2	40,4	38,5	46,2	34,6	23,1	44,2

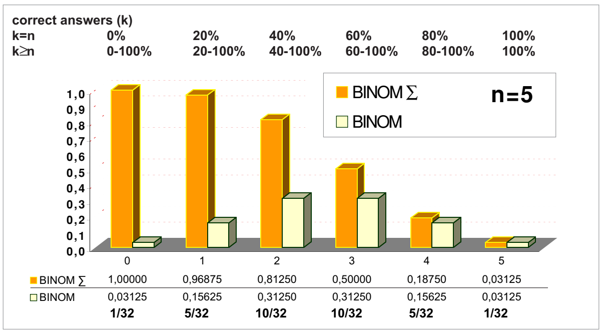
■— shown in FIG 3 (ALL row)

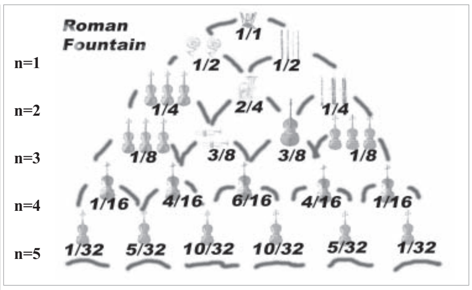
TABLE 1: correct answers of groups per task in percent.

The first statistical approach was to find the probability of these results. The statistical probability of success in a binominal test can be demonstrated in a ‘roman fountain’. FIG 5 and FIG 6 gives an example for 5 decisions. The probability for 5 correct answers (k=5or k=100%) in 5 decisions (n=5) is 1/32 (p=0,03125). The probability to have at least 4 correct answers (n=5, k≥4 or k≥80%, cumulated probability) is 5/32 plus 1/32 (p=0,18750).



The preliminary results (X) in TABLE 1 represent the percentage of correct answers. TABLE 2 shows the corresponding values of their probabilities [P(X)≥k]. Values of p below 0.001 (highly significant), below 0,01 (very significant) and below 0,05 (significant) can be found. This indicates that the decisions of the test persons are not always random, (as many of the comments of the test persons and there overall tasks result indicates). For example, in task 4, test persons playing a woodwind or string instrument had significant better identification of the Vienna orchestra than brass players. This and many more comparisons of the results from test persons playing brass, woodwind or string instruments can be concluded from TABLE 1,2 and FIG 4.





left: FIG 5 above: FIG 6 below: TABLE2

p (k≥Ø)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
ALL, n = 302	0,009	0,003	0,907	0,000	0,991	0,113	0,387	0,003	1,000	0,387	0,075	0,569	0,836	0,000	1,000	0,164	0,075	0,000	0,022	0,991	0,048
MALE = 162	0,017	0,291	0,760	0,049	0,846	0,709	0,531	0,194	0,993	0,091	0,005	0,347	0,760	0,003	1,000	0,035	0,049	0,003	0,035	0,881	0,291
FEMALE = 138	0,175	0,000	0,866	0,000	0,993	0,011	0,276	0,002	1,000	0,825	0,724	0,825	0,601	0,000	1,000	0,778	0,399	0,007	0,222	0,975	0,037
BRASS = 38	0,564	0,128	0,872	0,436	0,072	0,564	0,928	0,686	0,314	0,436	0,072	0,128	0,314	0,436	1,000	0,072	0,072	0,003	0,314	0,564	0,072
WOOD = 86	0,011	0,006	0,080	0,000	0,627	0,080	0,011	0,033	0,994	0,373	0,166	0,947	0,775	0,020	1,000	0,775	0,003	0,011	0,166	0,627	0,373
STRING = 94	0,177	0,009	0,910	0,003	0,975	0,025	0,823	0,090	1,000	0,061	0,090	0,459	0,303	0,009	1,000	0,303	0,303	0,025	0,025	0,975	0,090
PERC = 10	0,623	0,172	0,623	0,172	0,945	0,828	0,623	0,055	0,945	0,377	0,377	0,989	0,945	0,172	0,945	0,828	0,055	0,377	0,828	0,828	0,945
PROF = 42	0,561	0,140	0,322	0,780	0,678	0,220	0,220	0,860	0,990	0,780	0,140	0,082	0,082	0,220	0,322	0,780	0,004	0,561	0,022	0,322	0,220
STUD = 210	0,016	0,016	0,926	0,000	0,969	0,224	0,224	0,000	1,000	0,095	0,023	0,815	0,905	0,000	1,000	0,008	0,056	0,000	0,365	0,944	0,150
LISTENER = 48	0,156	0,156	0,557	0,056	0,944	0,235	0,844	0,765	0,970	0,844	0,944	0,557	0,844	0,007	1,000	0,970	0,993	0,765	0,030	0,993	0,056
AT = 221	0,173	0,003	0,989	0,000	0,997	0,089	0,657	0,022	1,000	0,931	0,022	0,295	0,749	0,000	1,000	0,553	0,295	0,001	0,005	0,931	0,069
NON-AT = 79	0,003	0,250	0,088	0,250	0,411	0,411	0,088	0,021	0,912	0,001	0,674	0,912	0,674	0,326	1,000	0,021	0,036	0,012	0,750	0,979	0,130

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A new search for acoustic „distinguishing marks“ of the Vienna Philharmonic Orchestra

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"Vienna is Different" is the slogan you read when you enter the city on the highways. Differences are also associated with the sound of the famous Vienna Philharmonic Orchestra (VPO). This orchestra's individual sound characteristic is caused partly by different musical instruments (oboe, horn or timpani), and partly through a specific playing style. While the individual sound variations of these instruments have been investigated in previous studies at our Institute, this paper presents a more general approach to the "distinguishing mark" of this orchestra. 21 sound-pairs of orchestral CD-recordings were offered to test subjects: one example from the VPO and a second from the Berlin Philharmonic or New York Philharmonic Orchestras. The task was to listen and to identify the Viennese one. Listener test data are statistically analyzed to find who identified the orchestra correctly most often and through which examples (involved instruments in the example, musical background and origin of the listener, etc. are taken into account). The aim of the study is to find out which instruments do establish the typical Vienna orchestra signature. Which instruments give the best clues for identifying the VPO? The members of the audience are invited to make their own decisions.

INTRODUCTION

What is special about the Viennese orchestra ? This question exists as long as the world famous orchestra itself. There are thousands of individual hypothesis and millions of ideas for possible reasons among musicians, audiences and scientists. In the 1950‘s the University of Music founded an institute to provide objective data on that question, but very first studies already showed that the question is much too complex for a simple answer. Too many variables are involved in the process of creation and perception. Since then, single parameters became the focus, which are obvious different in the Viennese orchestra: musical instruments such as the oboe, the horn and the timpani. The particular characteristics of these Viennese musical instruments have been studied in previous projects [1,2,3], but there is still no answer about what the main acoustical trademarks of these Viennese orchestra are. The approach of this project is to carry out an elementary study of musical acoustics: to hear music with a large amount of experienced ears and to collect their analytical power: a large-scale listening test setup including hundreds of musicians and listeners.

METHOD

The question “Is there a typical orchestra signature in Vienna, Austria ?” has been asked using a listening test in Vienna, which started in March 2001 and is going on till December 2001. Since the aim of the test is to collect about 1000 test persons, this paper presents a documentation of the setup and shows preliminary results from 302 test persons. As the test is still in progress, details on the tasks will not be revealed. The unveiling of the final results will be presented at Forum Acusticum in Seville 2002.

The task of the listening test itself is simply to decide which of two sound examples was recorded by the Vienna Philharmonic Orchestra (VPO). 21 pairs of sound examples from CD-recordings of nine standard orchestral pieces (see LIST “21 tasks”), are played to the test persons. The recording of the alternative sound example in the test pair is either played by the Berlin Philharmonic Orchestra or the New York Philharmonic. The sound examples were unmodified digital copies of pieces from commercial CDs. The duration of the examples is between 3 and 35 seconds (15 seconds on average). While short examples allow the comparison of timbre and short time elements, longer examples are preferred by most listeners to focus on the interpretation. A compromise for the duration of the tasks and many other variables had to be made for a better chance of comparison of other parameters (e.g. the involved instrumtents). The availibilty of CD recordings also restricted the possibility to maintain factors as the conductor, the year, place and technique of the recording.

Statistic groups of all 302 listener and there absolute number (n=) can be seen in the first row of table 1. Groups are formed by instrument sections of all test persons playing string, brass, woodwind instruments. For final analysis at least 30-65 listeners in additional groups *(female, male, age0-19years, age20-39years, age40-99years, Austrian, Non-Austrian, professional-musican, student-amateur-musicians, passive-listener:, conducters and for each single instrument and persons playing no instrument)* are planned.

PRELIMINARY RESULTS

Since the test setup is very simple, each single decision has a 50 % chance to be correct. The actual preliminary result over all tasks with 52% is just slightly higher. Also, if the decisions were random, the expected amount of correct answers (k) for each task were 50%. In fact, the preliminary results show a large variation of correct answers for each of the 21 tasks. (FIG 1) While 63% of 302 test persons identified the Vienna orchestra in task 14, only 29% decided the correct answer in task 15. The difference of correct answers varies also between the test groups. All mean values of k can be found in TABLE 1.

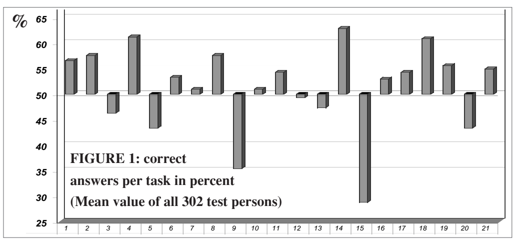


FIGURE 1: correct answers per task in percent (Mean value of all 302 test persons)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
ALL, n = 302	56,6	57,6	46,3	61,3	43,4	53,3	51,0	57,6	35,4	51,0	54,3	49,3	47,4	62,9	28,8	53,0	54,3	60,9	55,6	43,4	55,0
BRASS = 38	50,0	57,9	42,1	52,6	63,2	50,0	39,5	44,7	55,3	52,6	60,5	57,9	55,3	52,6	23,7	63,2	60,5	71,1	55,3	47,4	60,5
WOOD = 86	62,8	64,0	57,6	69,8	47,7	58,1	62,8	59,3	37,2	52,3	54,7	40,7	46,5	60,5	29,1	46,5	65,1	62,8	54,7	47,7	52,3
STRING = 94	54,3	62,8	42,9	64,9	40,4	59,6	44,7	56,4	27,7	58,5	57,4	51,1	53,2	61,7	27,7	52,1	52,1	59,6	59,6	40,4	57,4

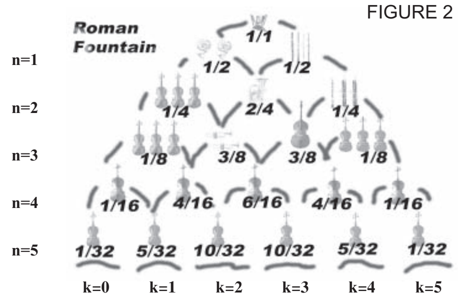
p (k≥Ø)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
ALL, n = 302	0,009	0,003	0,907	0,000	0,991	0,113	0,387	0,003	1,000	0,387	0,075	0,569	0,836	0,000	1,000	0,164	0,075	0,000	0,022	0,991	0,048
BRASS = 38	0,564	0,128	0,872	0,436	0,072	0,564	0,928	0,686	0,314	0,436	0,072	0,128	0,314	0,436	1,000	0,072	0,072	0,003	0,314	0,564	0,072
WOOD = 86	0,011	0,006	0,080	0,000	0,627	0,080	0,011	0,033	0,994	0,373	0,166	0,947	0,775	0,020	1,000	0,775	0,003	0,011	0,166	0,627	0,373
STRING = 94	0,177	0,009	0,910	0,003	0,975	0,025	0,823	0,090	1,000	0,061	0,090	0,459	0,303	0,009	1,000	0,303	0,303	0,025	0,025	0,975	0,090

TABLE 1 (top): Mean value (ø) of correct answers (k) of groups per task in % TABLE 2 (below) corresponding values of their probabilities [P(X)≥k]

21 tasks of the listening test

[Task 1-2] Mozart: Symph. Nr. 41 (3. Menuetto) [1788] Task 1: tutti in 3/4 - [bar 52 - 59]. (dynamic =f) - flute, oboe, bassoon, horn, trump., timp., 1. viol., 2. viol., cello, bass, viola Task 2: - downward phrase, 3/4 - [bar 44 - 51]. (dynamic =p) - flute, oboe, bassoon **[Task 3-5] Beethoven: Symph. Nr. 3 "Eroica" (4. Finale) [1804]** Task 3: - strings pizzicato, woodwind staccato - [bar 12 - 27]. (dynamic =p) - flute, clar., bassoon, 1. viol., 2. viol., viola, cello, bass Task 4: flute solo (16th) above orchestra - [bar 182 - 198]. (dynamic =p) - flute, oboe, 1. viol., 2. viol., viola, cello, bass Task 5: tutti passage, theme played by horn and basses - [bar 380 - 388]. (dynamic =ff) - flute, oboe, clar., bassoon, horn, trump., timp., 1. viol., 2. viol., viola, cello, bass **[Task 6] Beethoven: Symph. Nr. 7 (2. Allegretto) [1812]** Task 6: - slow theme played by strings; poco a poco crescendo - [bar 51 - 66]. (dynamic =p-mf) - 1. viol., 2. viol., viola, cello, bass **[Task 7-8] Schubert : Symph. Nr. 8 "Unvollendete" (1. Allegro) [1822]** Task 7: celli theme, syncopic contrapunct - [bar 44 - 47]. (dynamic =pp) - clar., viola, cello, bass Task 8: strings theme - [bar 312 - 316]. (dynamic =p) - flute, oboe, bassoon, horn, 1. viol., 2. viol., viola, cello, bass **[Task 9] Brahms: Symph. No. 4 e-moll op. 98 (4. Allegro) [1885]** Task 9: begin, accord theme played by all wind players - [bar 1 - 8]. (dynamic =f) - flute, oboe, clar., bassoon, horn, trump., tromb., timp. **[Task 10-13] Bruckner: Symph. Nr. 7 E-Dur (3.Scherzo) [1883]** Task 10: trumpet - theme, strings rhythmic accomp. - [bar 5 - 8]. (dynamic =p) - trump., 1. viol., 2. viol., viola, cello, bass Task 11: tutti, trumpet ff punctated motifs - [bar 77 - 89]. (dynamic =ff) - flute, oboe, clar., bassoon, horn, trump., tromb., tuba, timp., 1. viol., 2. viol., viola, cello, bass Task 12: begin, timpani solo - [bar 273 - 276]. (dynamic =pp) - timp. Task 13: end of trio, flute melodic motifs - [bar 397 - 405]. (dynamic =p) - flute, oboe, clar., timp., 1. viol., 2. viol., viola, cello, bass **[Task 14] Berlioz: Symph. fantastique (1. Rêveries) [1831]** Task 14: oboe and bassoon motivs - [bar 456 - 460]. (dynamic =p) - oboe, clar., bassoon, horn, bass **[Task 15,16,17] Mahler: Symph. Nr. 1 "Der Titan" (2. Kräftig bewegt) [1889]** Task 15: beginn, 3/4 "Ländler", rough motifs - [bar 1 - 22]. (dynamic =f) - flute, oboe, bassoon, horn, triangel, 1. viol., 2. viol., viola, cello, bass Task 16: stringendo, climax, "Ländler"-theme, tutti - [bar 132 - 169]. (dynamic =ff-fff) - flute, oboe, clar., bassoon, horn, trump., tromb., tuba, timp., triangel, 1. viol., 2. viol., viola, cello, bass Task 17: - horn solo, rit. dim. - [bar 171 - 175]. (dynamic =mf-pp) - horn **[Task 18-21] Mahler: Symph. Nr. 5 (1. Trauermarsch) [1904]** Task 18: - trumpet solo - [bar 0 - 5]. (dynamic =p-mf) - trump. Task 19: strings "Weinend" (sad), legato - [bar 42 - 50]. (dynamic =pp-ppp) - clar., bassoon, 1. viol., 2. viol., viola, cello, bass Task 20: tutti, triplets, tuba solo - [bar 254 - 265]. (dynamic =ff-pp) - clar., bassoon, horn, trump., tromb., tuba, timp., drum, l.drum Task 21: horn theme, 1.violin contrapart, strings triplet motifs - [bar 337 - 344]. (dynamic =f-ff) - horn, 1. viol., 2. viol., viola, cello, bass

FIGURE 2



The first statistical approach was to find the probability of these results. The statistical probability of success in a binominal test can be demonstrated in a 'roman fountain'. FIGURE 2 gives an example for 5 decisions. The probability for 5 correct answers (k=5or k=100%) in 5 decisions (n=5) is 1/32 (p=0,03125). The probability to have at least 4 correct answers (n=5, k≥4 or k≥80%, cumulated probability) is 6/32 (p=0,18750).

The preliminary results (X) in TABLE 1 represent the percentage of correct answers. TABLE 2 shows the corresponding values of their probabilities [P(X)≥k]. Values of p below 0.001 (highly significant), below 0,01 (very significant) and below 0,05 (significant) can be found. This indicates that the decisions of the test persons are not always random, (as many of the comments of the test persons and there overall tasks result indicates). For example, in task 4, test persons playing a woodwind or string instrument had significant better identification of the Vienna orchestra than brass players. This and many more comparisons of the results from test persons playing brass, woodwind or string instruments can be concluded from TABLE 1 and 2.

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[3] Online Publications of our Institute can be found at **http://iwk.mdw.ac.at**

About

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* 1966 born in Kehl am Rhein, Germany
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* 1987 trumpet player with the music corps "Stabsmusikkorps der Bundeswehr", Bonn
* 1988 studies in musicology at the University of Vienna, Austria
* privat trumpet studies with Manfred Stoppacher, Vienna
* 1992 hired for research work at the IWK, Univ. of Music, Vienna
* 1993 graduation M.A. in musicology
* marriage with Isabelle Bertsch (teacher of cello and elementary music)
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About the Dissertation

(Submitted at the University of Vienna in September 1998)

Original Title: **Studien zur Tonerzeugung auf der Trompete**

English Title: **Studies on trumpet-playing**

Subject: **Musicology**

Supervisors: **O.-Prof. Mag. Dr. Franz Födermayr**
O.-Prof. Dr. Oskar Elschek

Abstract

This thesis establishes a systematic of sound influencing variables. Properties of the instrument, characteristics of musician and environment produce results that vary in many aspects. Studies on the aspects „warm-up“ and „intonation“ follow.

During the warm up, muscle contractions and increased blood flow result in a higher temperature of the overlying skin. This effect can be visualized and quantified by infrared-thermography. The analysis demonstrates that the main facial muscle activity during warm-up is restricted to only a few muscle groups (M.orbicularis oris, M.depressor anguli oris). The „trumpeter‘s muscle“ (M.buccinator) proved to be of minor importance. Less trained players expressed an inhomogeneous thermo graphic pattern compared to well-trained musicians. Infrared thermography could become a useful tool for documentation of a trumpeter‘s playing technique.

The intonation study determines the intonation properties of trumpets and compares empirical data of played trumpets with a.) theoretical tuning systems such as equally tempered, Pythagorean tuning, or just intonation and b.) with the “objective intonation” which has been calculated by means of input impedance measurements. Results show that there are great differences amongst players, even when playing on the same reference instrument. The mean of the „played intonation“ correlates best with the calculated “objective intonation” and matches better the equally tempered than other theoretical tuning systems.

Keywords: trumpet, playing-technique, warm-up, intonation, thermography, input impedance measurements

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