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

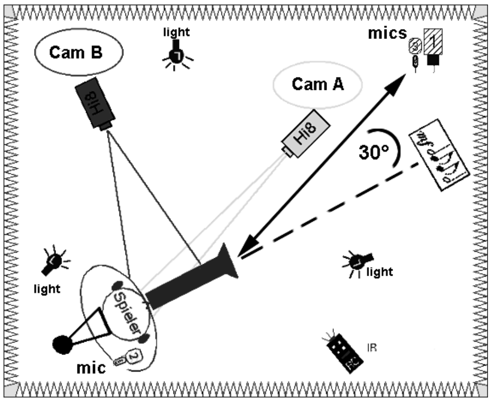
Professional, amateur and student trumpet players are invited (and still are, for further studies) to play 10 different tasks two times in the anechoic chamber of the "Institut für Wiener Klangstil" (n=35 in May, 97). First they played their own instruments (in Bb). The second time they all played on 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

”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) {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)).

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}

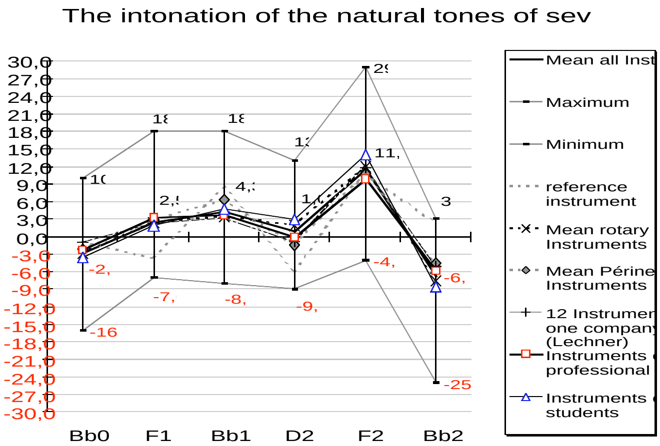
These 58 variables mentioned demonstrate the complexity of the generation of one single trumpet sound:

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}

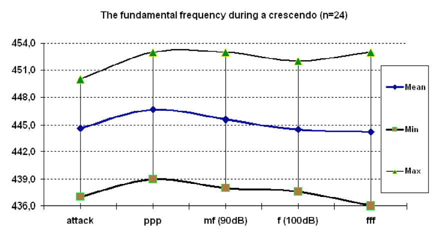
5. FIRST RESULTS ON SOME VARIABLES

5.1 Intonation [int]

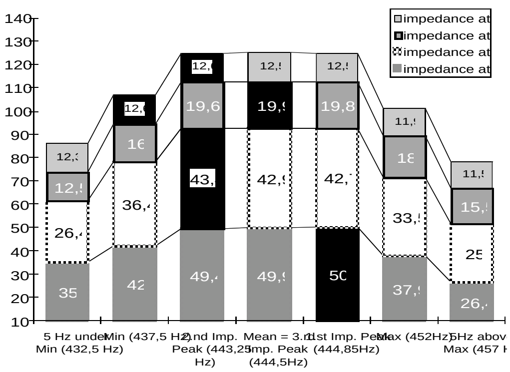
5.1.1 Intonation characteristic of multiple trumpets (n=33). Each trumpet of the participating musician is measured with the BIASsystem. It calculates the intonation error and the deviations of each tone in cent. [illustration: all instruments have a common tendency to be out of tune. The mean of the 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]

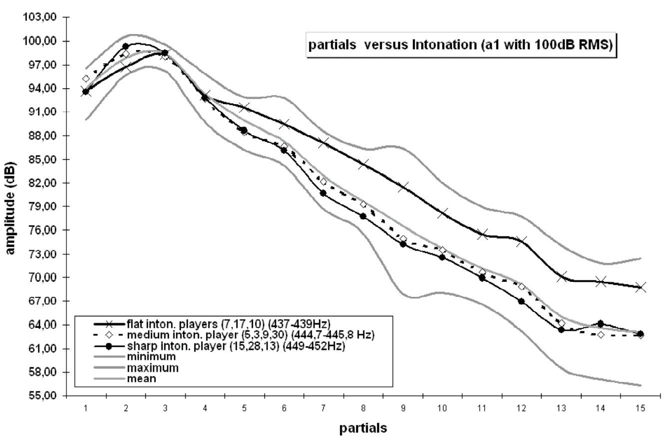


5.1.4 Variations between players. The intonation difference at mf (measured 90 dB) is 58 cent (min.=438 Hz; max.=453 Hz) and at f (measured 100 dB) is still 56 cent (min.=437, 6 Hz; max.=452 Hz)! The influence of different temperatures (18°C-23°C) during the recording cannot be the reason for the variations, 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.]

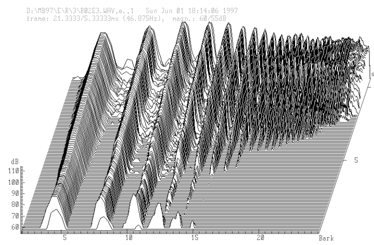


5.3 Dynamic range (a1 crescendo from ppp to fff)
5.3.1 Overall. The dynamic range general depends on the register. The measured mean value of the RMS for the a1 (which is in the middle register) on the reference instrument increases 27 dB from 81,3 dB at ppp (individual minimum amplitude) to 108,5 dB 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

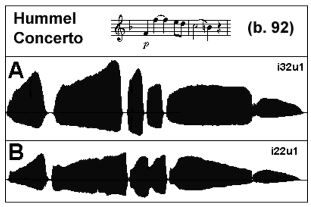
5.4.1 The influence of the microphone positions affects the recorded sound to a large extent. [room, evi] Behind the instrument, at the players ear, the sound is much duller, caused by the sound radiation characteristic of the trumpet (radiation focus to the front increases with the frequency). The nuances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



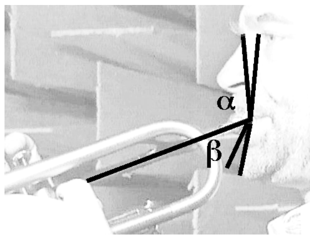
5.5 interpretation [rlz]

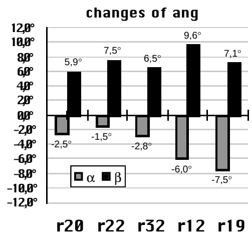
Of course, music does not only vary in dynamic or the spectrum of the quasistationary oscillation. It is often said that a trumpet player can be identified by his sound. This can only be justified if you take the changes versus time into account, which includes, for example, his articulation or interpretation. 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