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

Extended Version (2020)

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The document „SILVER, GOLD, PLATINUM - AND THE SOUND OF THE FLUTE", previously published on Researchgate, was a scan from the proceedings of the ISMA 2001 and based on Renate Linortner's master thesis. The great interest of the community induced us to provide an extended version with important details in order to make it easier for interested readers to evaluate the results. Sound examples can be found at https://iwk.mdw.ac.at/flutes/

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 a total of 111 testpersons, where the price of the instruments is between US $4,800 and $90,000. 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 readers are 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 key work.

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.

EXPERIMANTAL SETUP

1 THE INSTRUMENTS

All flutes made by Muramatsu, all instruments with B foot and except No. 6 and 7 with „open hole“ (Ringklappen).

1 EX RBE (solid silver head joint, body nickel, silver coated) .... 4,300.00 €
2 DS RBE (Head joint, body and key work solid silver) .... 10,000.00 €
3 PT/P RBE (solid silver with platinum coated) .... 18,500.00 €
4 9K.Gold RBE (head joint and body 9carat, key work silver) .... 20,000.00 €
5 14K.Gold RBE (head joint and body 14carat, key work silver with gold coated) .... 28,000.00 €
14K.Gold CBE (same as above but C-foot and closed holes used by 4 of 7 players and shown in Fig.1)
6 24K Gold CBE (head joint and body 24carat, key work 14carat gold, closed holes) .... 80,000.00 €
7 Platinum CBE (head joint and body solid Platinum, keywork 14crat gold, closed holes) .... ≈ 90,000.00 €
(depending on the version between 80,000 and 90,000 €)

But „solid“ silver, gold or platinum does not mean that the flute is 100% made of this material. For reasons of better workability and mechanical and chemical stability, the alloys also contain other materials in varying quantities:

solid silver = 92.5% Silver + 7.5% Copper
9 k gold = 37.5% Gold + 49.0% Copper + 9% Silver
14 k gold = 58.5% Gold + 25% Silver + 15 % Copper
24 k gold = 99.9% Gold + 0.1% Calzium Salt
solid-platinum = 95% Platinum + 5% Wolfram

Fig.1: Instruments used for the experiment.

2 THE RECORDING SETUP

The recordings took place in the anechoic room of the Department of Music Acoustics. In order to guarantee absolute values, the recording chain was levelled before each recording session by a calibrated siren, which always produced a 1 kHz signal with 100 dB SPL measured at a distance of one meter.

The recording microphone (AKG C414) was located one meter away from the edge of the mouth hole, 30 cm higher than the mouth hole of the flute being played. Another microphone (AKG C577) was positioned near the player‘s ear and provided the signal for a room simulator, whose signal was transmitted to the player via headphones in real time. The players were allowed to choose from 3 suitable rooms, the one most convenient for them.

To prevent unintentional changes in the distance to the recording microphone, an optical marker was placed on one of the wedges, which the player was asked to fix with his gaze during the recording.

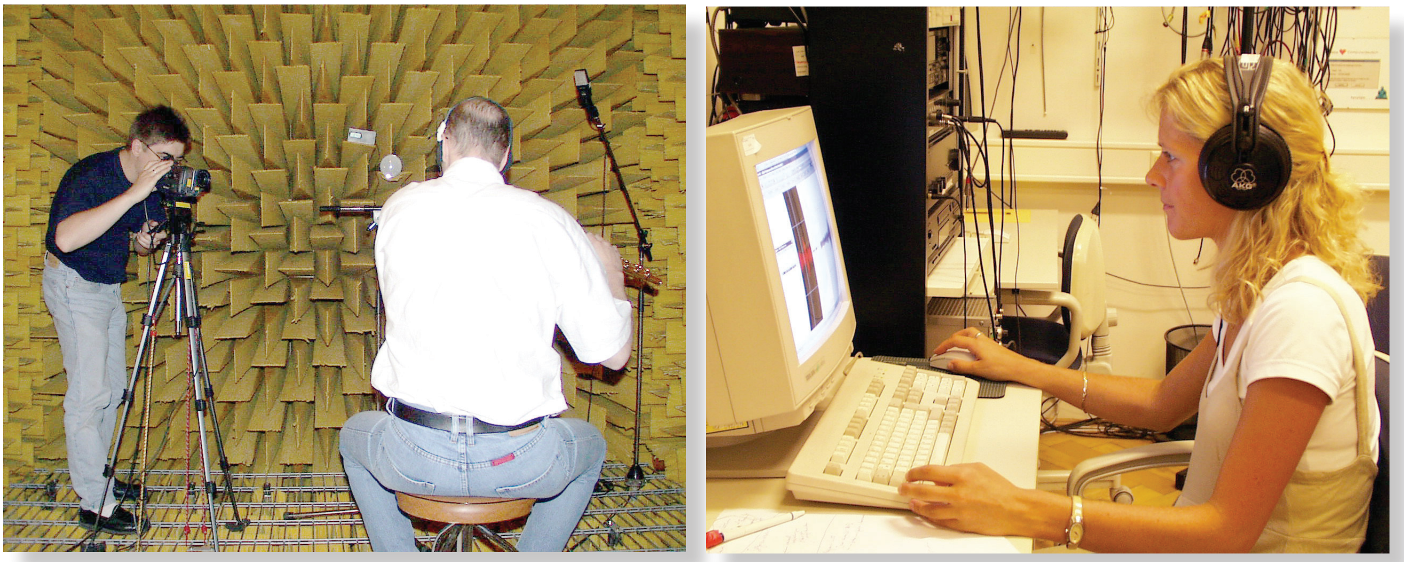


Fig. 2: Left: Recording situation in the anechic room, right: Renate Linortner, who conducted the experiments.

3 THE RECORDED SOUND MATERIAL

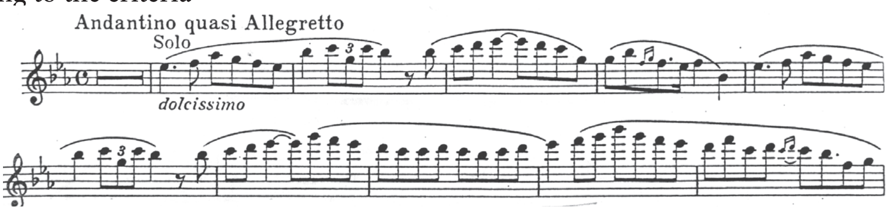
1. Gamut: A cromatic scale from c4 to c7 where all notes should be played one by one and well separated in a solid *mezzoforte*. The duration of each note should be about 1 second. The usual vibrato should be avoided.

2. Dynamic range: Play the notes g4, a5, and f6 as loud (*fff*) and as soft (*ppp*) as possible.

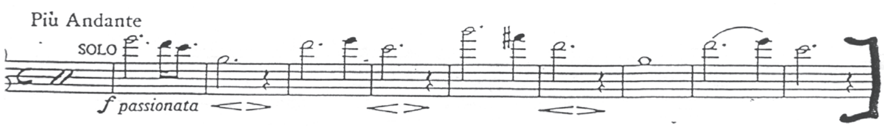
3. Crescendo: The notes a4, f5, d6 and b7 from *ppp* up to *fff.*

4. Typical audition pieces selected according to the criteria

- Cantabile and legato:
  Prelude 3rd act from Carmen by Bizet.
  Sound example 1 click here



- Loudness and volume:
  Solo part piu Andante from the 1st symphony by Brahms.
  Sound example 2



4 THE FLUTISTS

The 7 flutists (3 female, 4 male) are experienced professionals and members of the major Viennese orchestras (Vienna Philharmonic Orchestra, Vienna State Opera, Vienna Volksopera, etc.) and/or professors at the University of Music and Performing Arts Vienna, or at the Music and Arts University of the City of Vienna. The average professional playing experience is 20 years.

The order of the flutes played during the recordings was always the same:

1. 14K Gold (No.5 in Fig.1)

2. Platinum coated (No.3 in Fig.1)

3. Solid silver (No.2 in Fig.1)

4. 24K Gold (No.6 in Fig.1)

5. Silver coated (No.1 in Fig.1)

6. 9K Gold (No.4 in Fig.1)

7. Solid Platinum (No.7 in Fig.1)

In order to create as much equal recording conditions as possible for all players, nobody was allowed to play on the instruments before.

RESULTS

1 SCALES AND THE RMS SOUND LEVEL OF EACH NOTE

Figure 3 shows the RMS of a played cromatic scale with the 37 notes from c4 to c7.

Although the players were told to play over the entire range with the same „loudness", the graphic shows quite different RMS levels. This is due to the way the instrument works: Notes, where almost all or all tone holes are open, have a low sound level (loudness). The reason for this is that the vibrating air column is very short and can store and radiate therefore only little energy due to its low „mass".

Such notes are also known as „sick" sounds. These are the notes 13 and 14, as well as 25 and 26 (both c and c#). The following tones are played again with the „long" instrument (many tone holes closed), i.e. „ overblown".

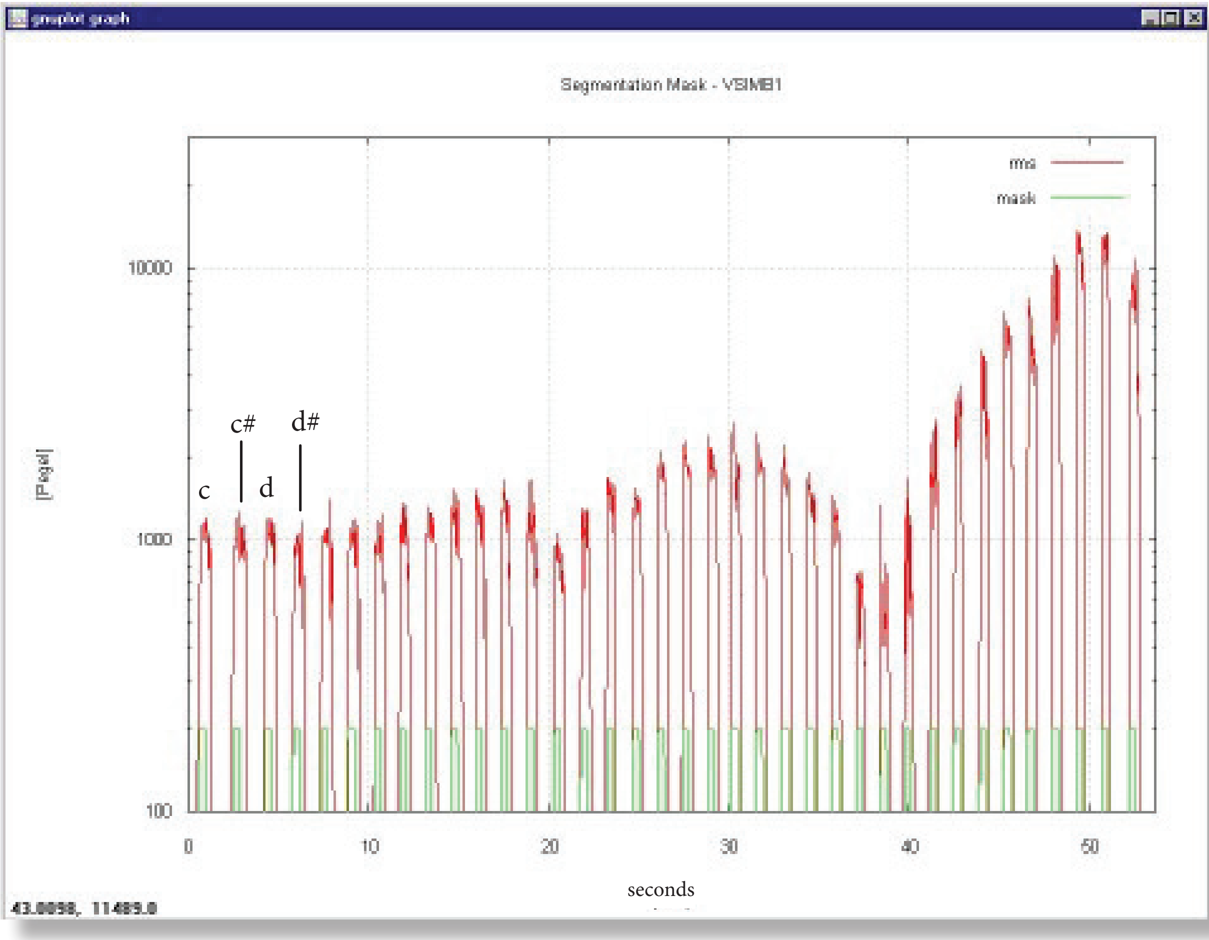
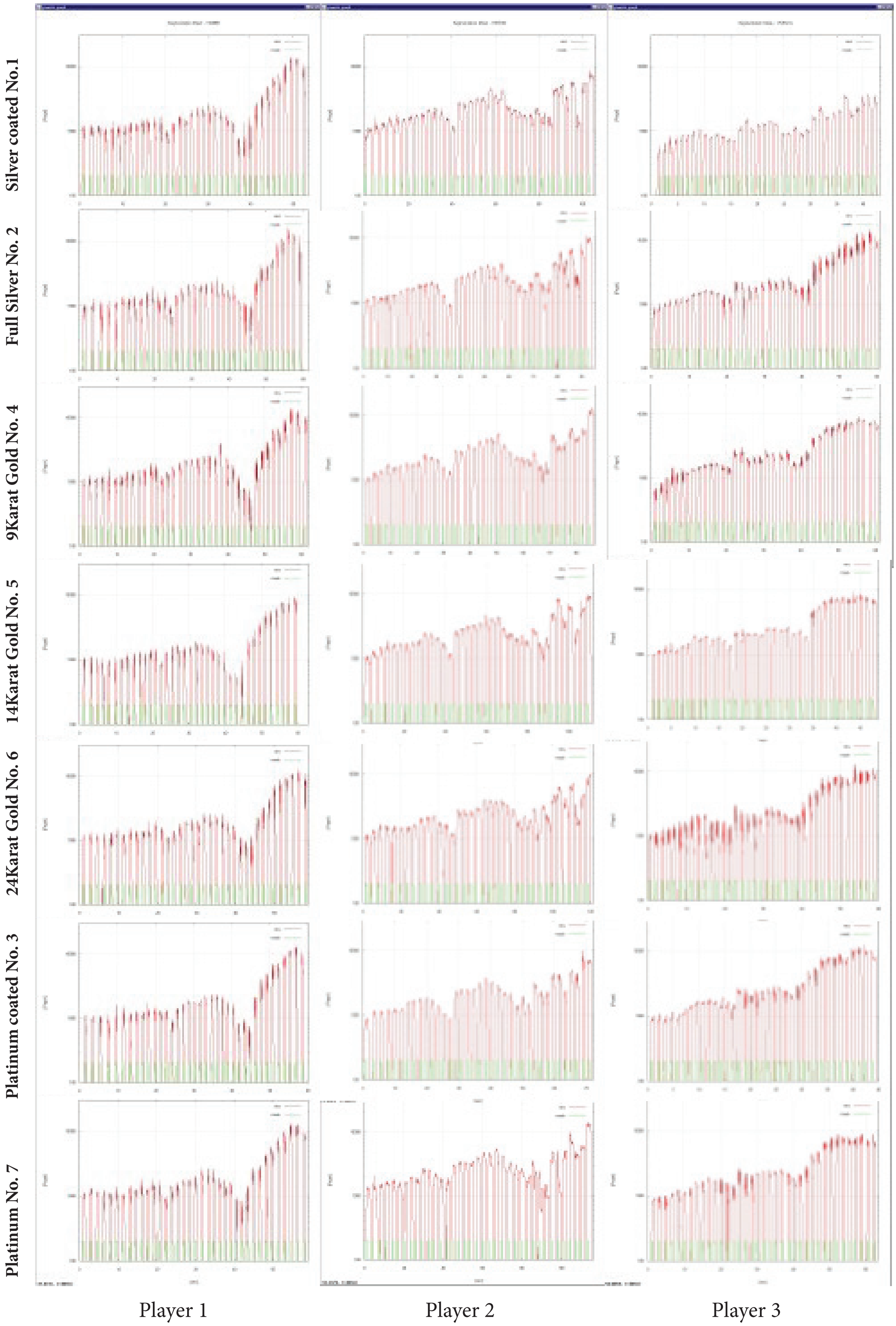


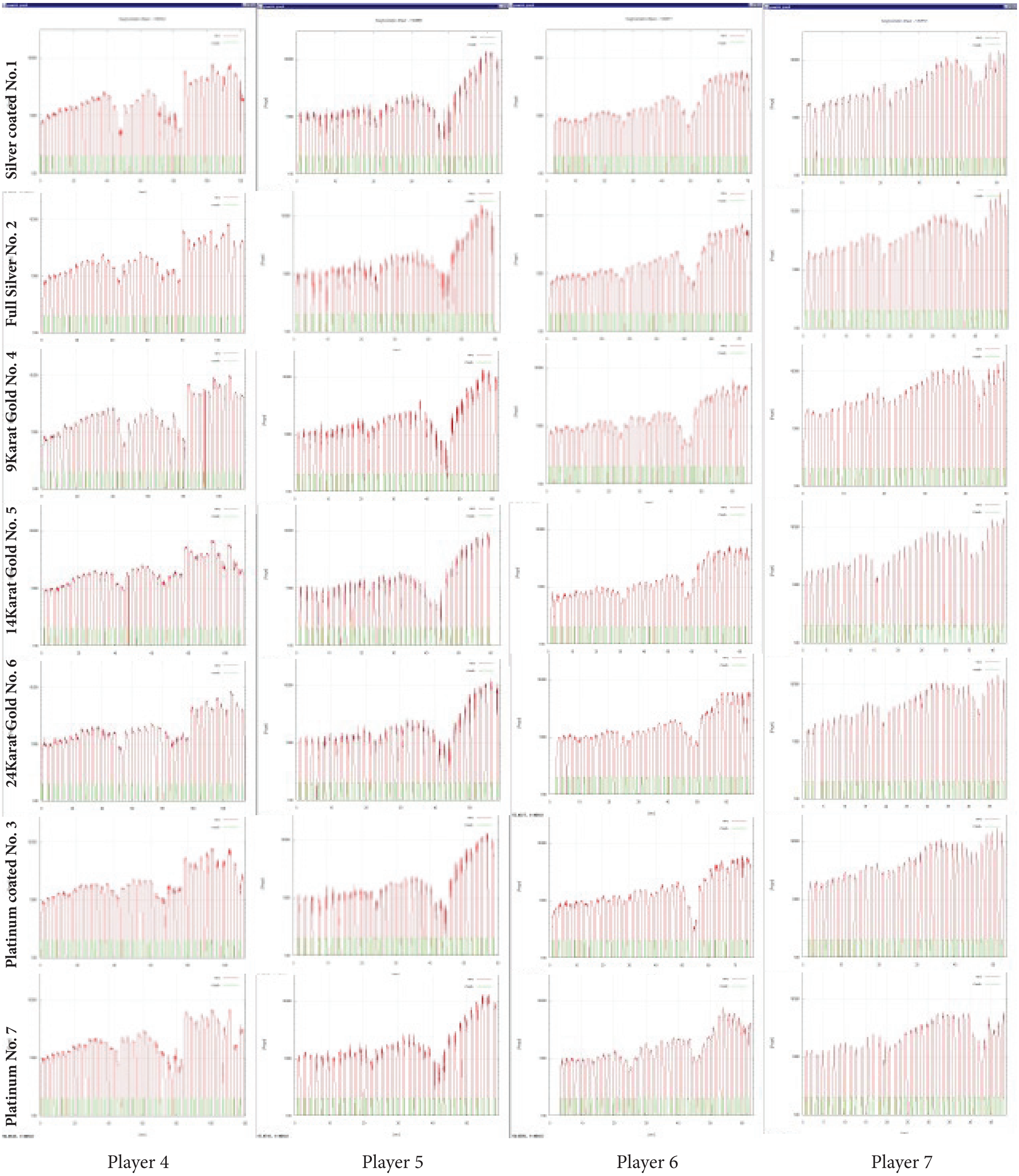
Fig. 3: Example for the RMS values of a cromatic scale

The clearly recognizable „frayed" peaks of the notes are not a indication of quality, but a consequence of the vibrato played. Each tone lasts about 0.5 - 1 second, this time span is compressed to less than one to two millimetres in the diagram above, whereby the controlled volume fluctuations, i.e. the vibrato, appear as „jagged" peaks at the tip of the tone.

All players with all flutes.
Vertical axis: flutes, horizontal axis: player



All players with all flutes.
Vertical axis: flutes, horizontal axis: player



From the preceding curves, it can be seen that the RMS curves are „player typical“. They show that the player plays amazingly similarly on all flutes. The curves of one player can be clearly distinguished from those of the other players. This implies that flute players can realise their subjective imagination of „a good sounding“ to a far extent independently of the instrument.

On the other hand, „flute-typical“ characteristics are not discernible. From this it can be concluded that the material of the flute has no or only a minimal influence on the volume of the sound. If so, this influence is unconsciously masked by the players.

2 DYNAMIC RANGE (FROM *PPP* UP TO *FFF*)

Since it has been repeatedly claimed that flutes made of certain materials can be played louder, or that the dynamic range is better, recordings of individual notes with the greatest possible crescendo were made and examined more closely. A crescendo was played on the notes a4, f5, d6 and Bb6 from as soft as possible to as loud as possible.

The sound levels achieved were measured and entered in a table, so that for these 4 tones the dynamic range of all players with all flutes can be shown.

The next 4 pages show all players with all flutes for the 4 tones mentioned above. Again, for one and the same instrument, the large differences between the individual players are striking, whereas no typical characteristics of an instrument can be detected among the different players.

The **vertical axis** of the diagrams shows the lowest and highest achieved sound level with the respective flute in absolute dB values.

The **horizontal axis** shows the player and the 7 instruments. The instruments are underlaid with different colours for a better overview.

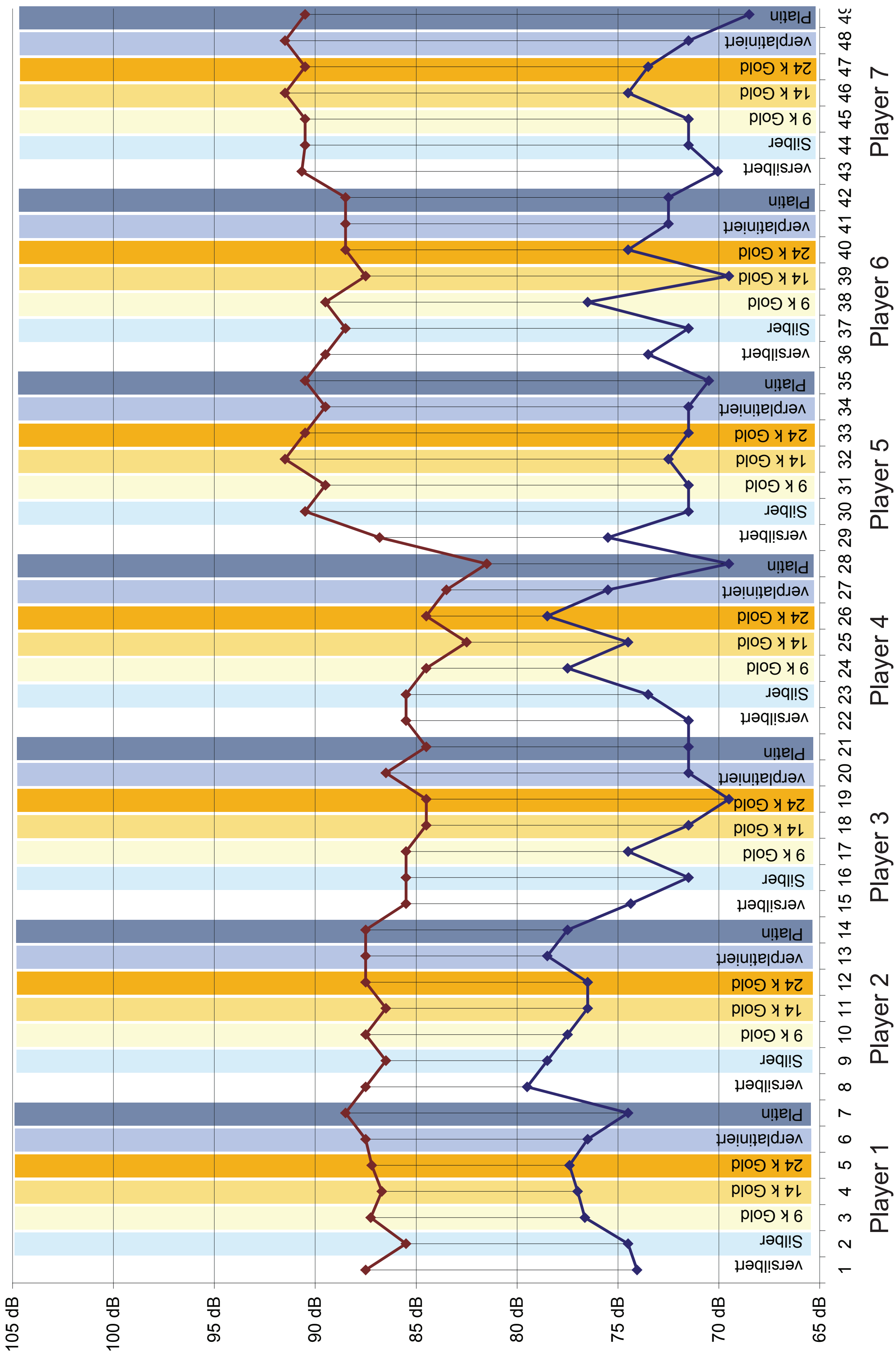
The difference between the blue and the red line represents the achieved „dynamic range“ for the player with each of the 7 instruments.

Explanation of the German instrument names of the following diagrams:

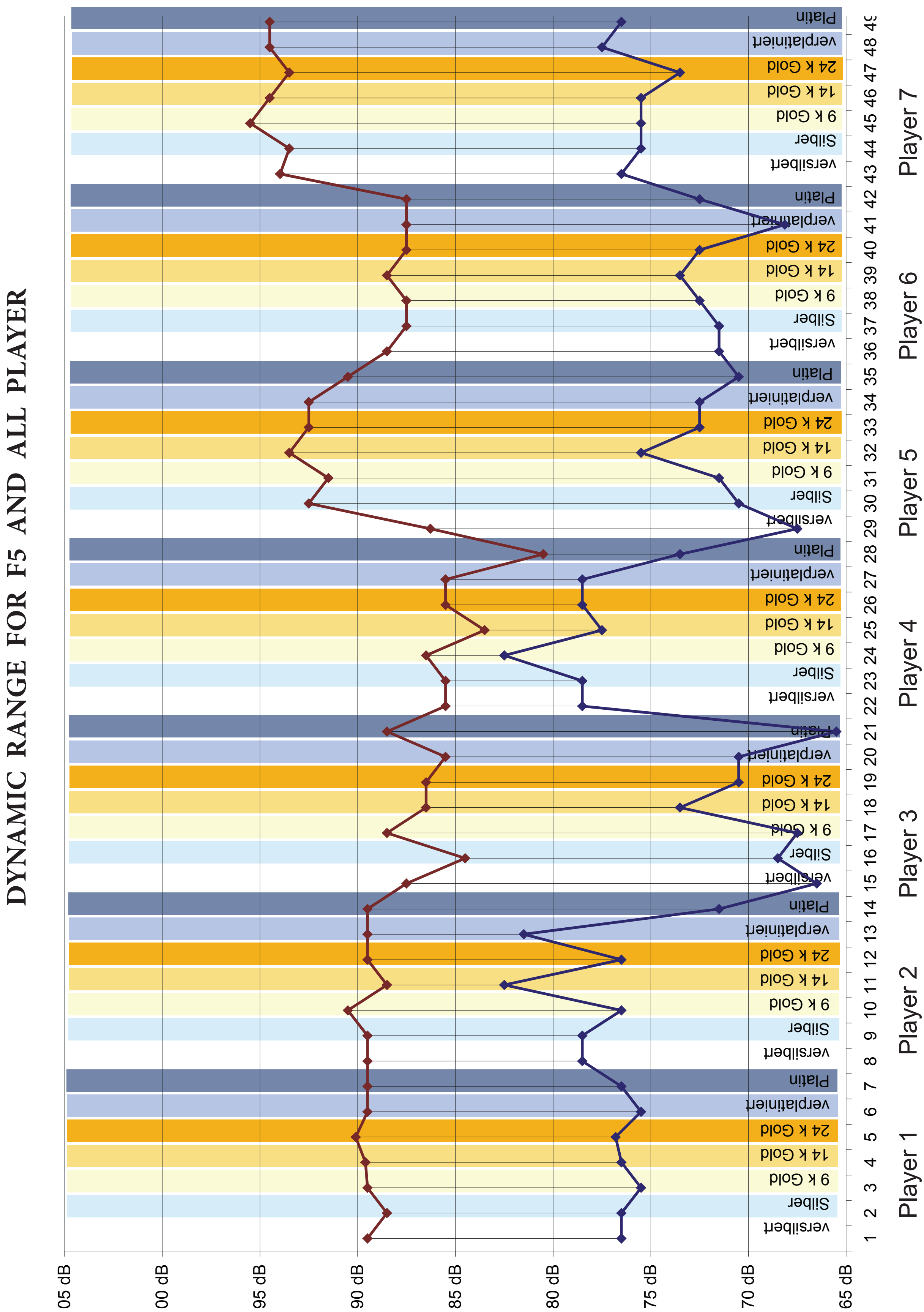
versilbert = silver coated (No. 1 in Fig.1)
Silber = solid silver (No. 2 in Fig.1)
9 k Gold = 9k Gold (No. 4 in Fig.1)
14 k Gold = 14k Gold (No. 5 in Fig.1)
24 k Gold = 24k Gold (No. 6 in Fig.1)
verplatiniert = Platinum coated (No. 3 in Fig.1)
Platin = solid Platinum (No. 7 in Fig.1)

a^4

DYNAMIC RANGE FOR A4 AND ALL PLAYER

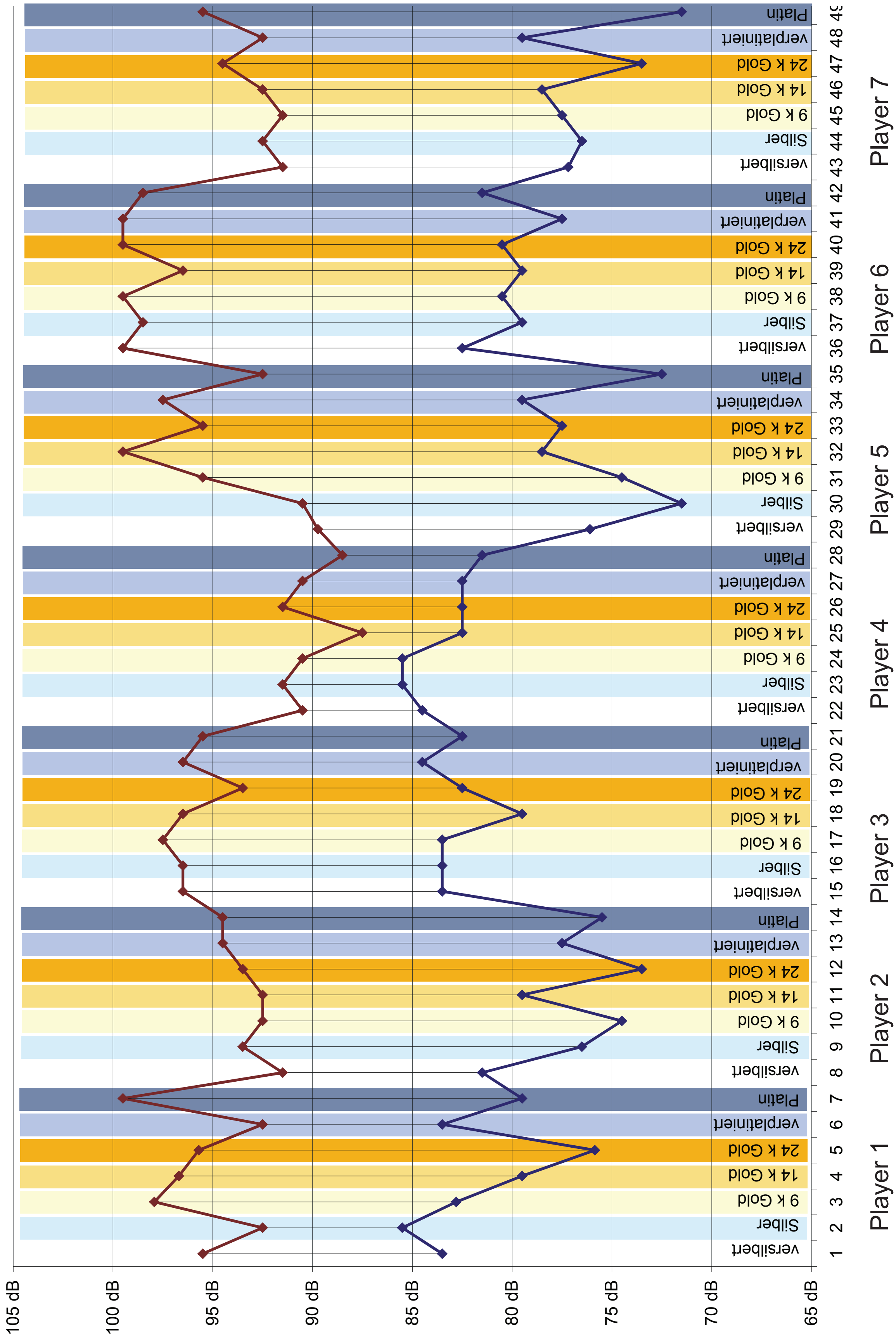


f^5


DYNAMIC RANGE FOR F5 AND ALL PLAYER
105 dB
100 dB
95 dB
90 dB
85 dB
80 dB
75 dB
70 dB
65 dB
versilbert
Silber
9 k Gold
14 k Gold
24 k Gold
verplatiniert
Platin
Player 1
Player 2
Player 3
Player 4
Player 5
Player 6
Player 7

d[6]

DYNAMIC RANGE FOR D6 AND ALL PLAYER



Bb⁶

DYNAMIC RANGE FOR BB6 AND ALL PLAYER

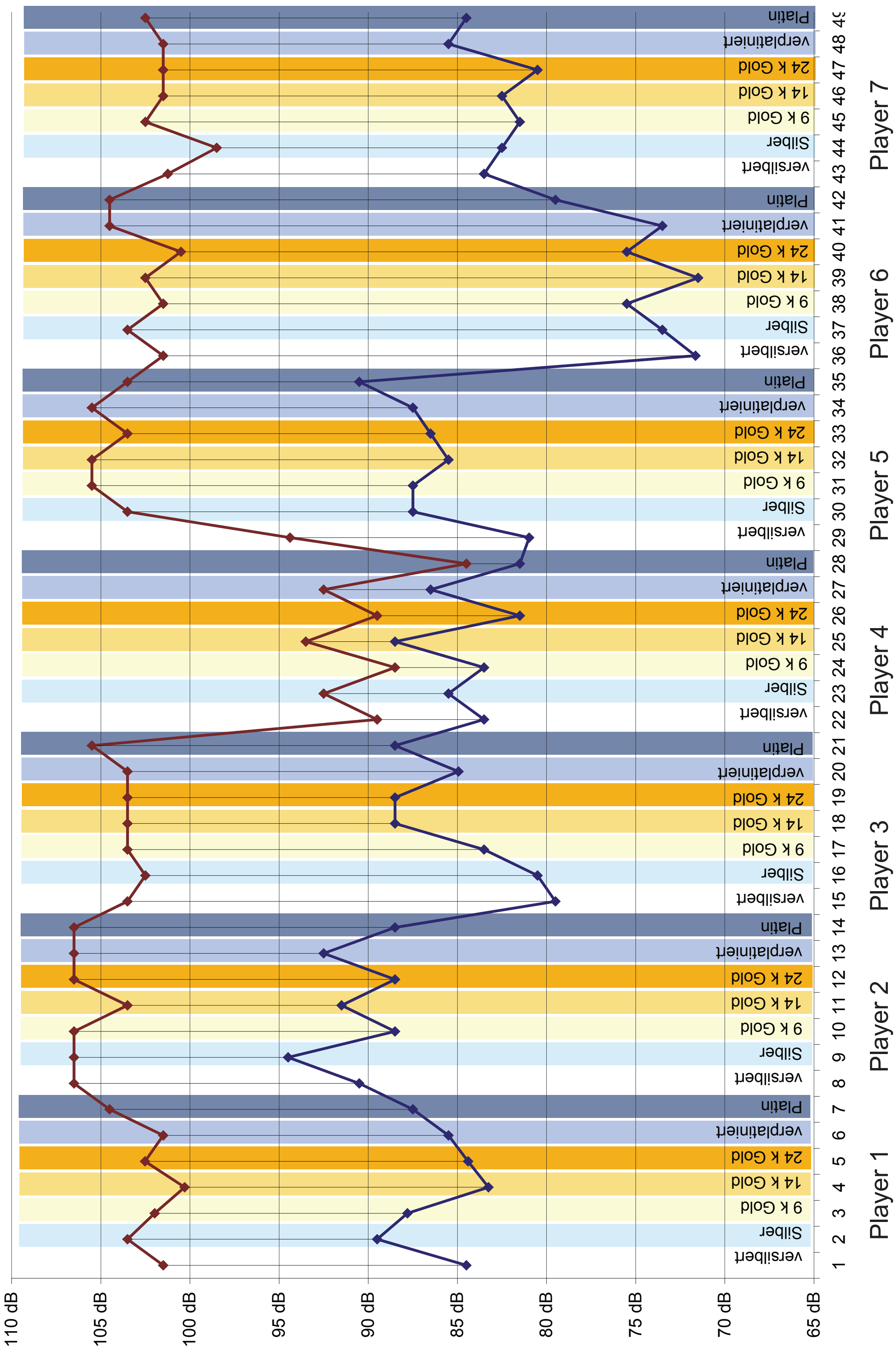


Figure 4 shows the mean value of all players and the 4 notes of the low, middle and high register for each instrument. The difference of the instrument with the smallest dynamic range (14 karat gold flute = 14.57 dB) and that with the largest range (platinum flute = 16.14 dB) is 1.5 dB. The possibility that this difference becomes zero with an increased number of test players can not be excluded.

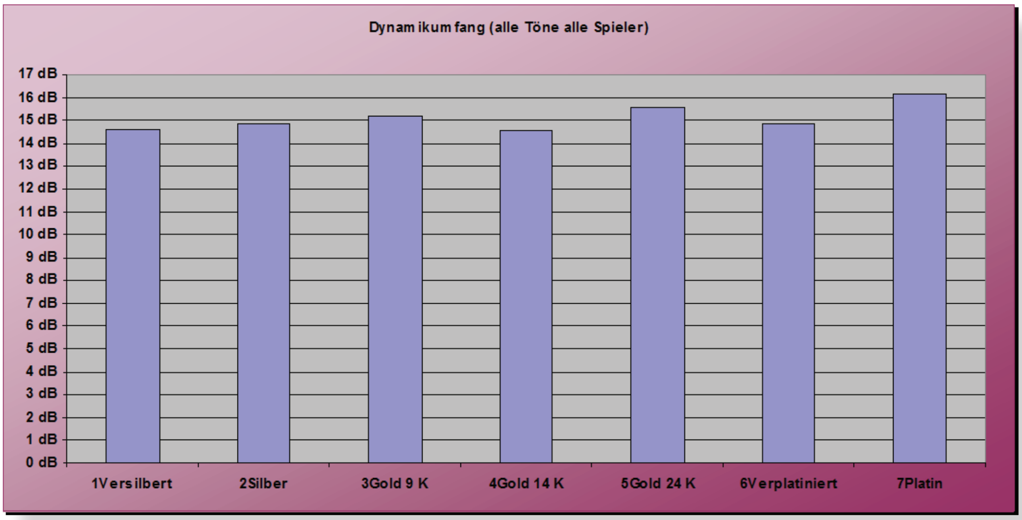


Fig. 4: Mean values of dynamic range for each flute by all players

Quite different is the situation if one looks at the Figure 5. The different conception of the players of dynamic, which is probably based partly on the sound imagination and partly on the playing technique, is clearly shown in the diagram below, which shows the dynamic achieved by each player, averaged over the four tones and over all flutes. 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 a4, f5, d6 and Bb6. The highest obtained dynamic is three times as much as the lowest.

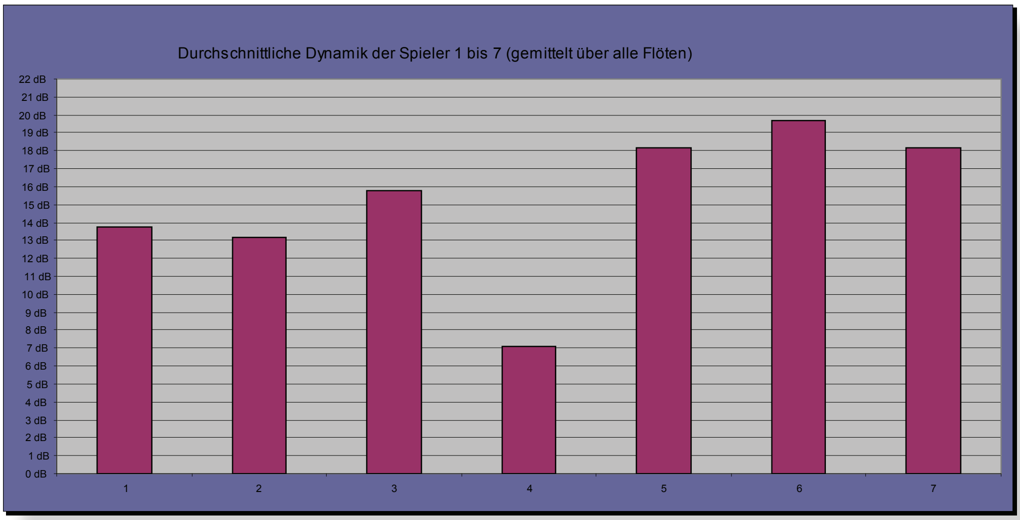


Fig. 5: Mean values of dynamic range for each player with all flutes

	ppp	*fff*
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

As the dynamic range is a „relative“ value, the table left gives information on the obtained absolute values for each note

3 SOUND COLOR

37 tones per instrument played on 7 different flutes by 7 flutists produce 1813 sound spectra.
These have been studied and analysed. Details about this would go beyond the scope of this report. Interested people can read more about it in Renate Linortner‘s master thesis with the title „Silver, Gold, Platinum... Der Materialaspekt bei Querflöten“ 2001 (in German), University of Music and performing Arts Vienna, Department of Music Acoustics.

The analyses carried out did not show any instrument-specific characteristics that could have been found in all or even just a few of the sounds produced by the 7 players. If any were present, they were 100% masked, consciously or unconsciously, by the flutists. The Figures 6 and 7 give an overview about that phenomenon. Both show the „envelope“ of the sound spectra, to improve the clarity, a visualisation as „cepstrum“ with different coefficients was chosen.

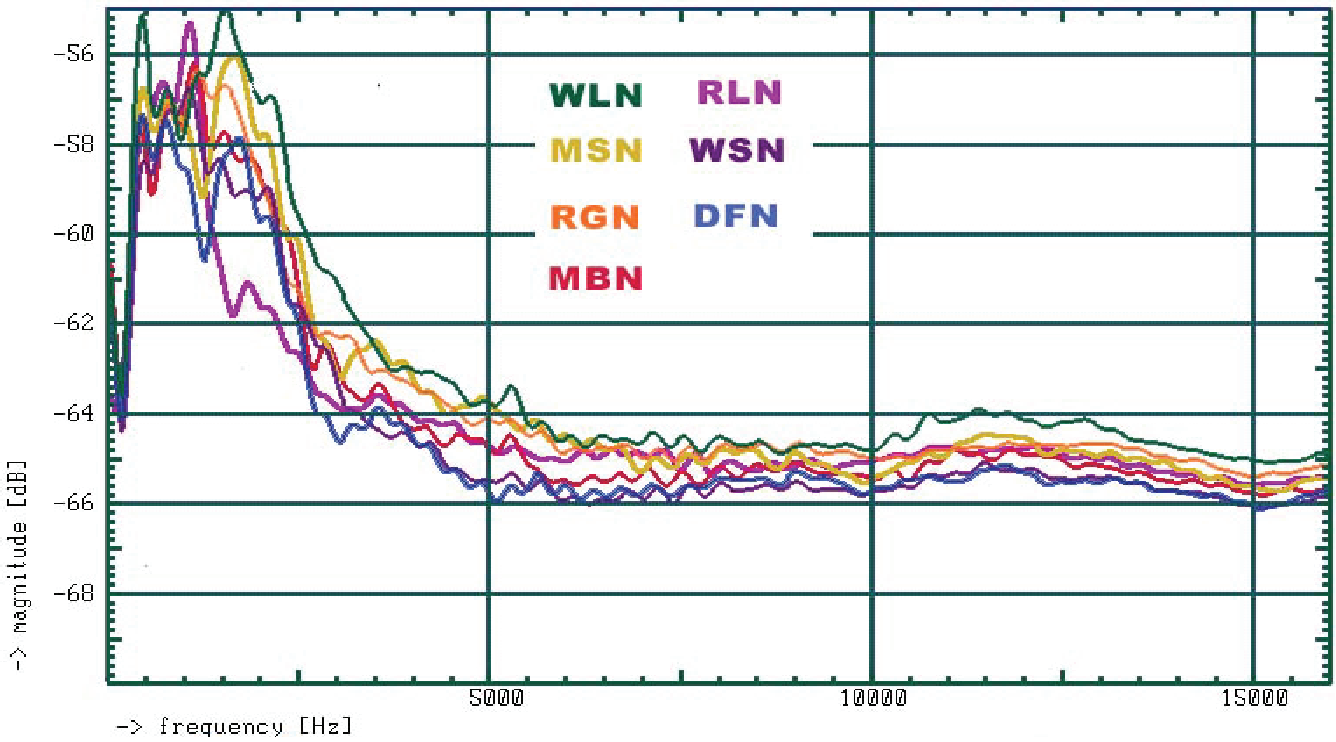


Figure 6: The averaged spectra of each of the 7 players on all flutes with all notes represented as FFT (cepstrum) with 128 coefficients up to 16 kHz. The maximum difference within the cepstrum is 7 dB.

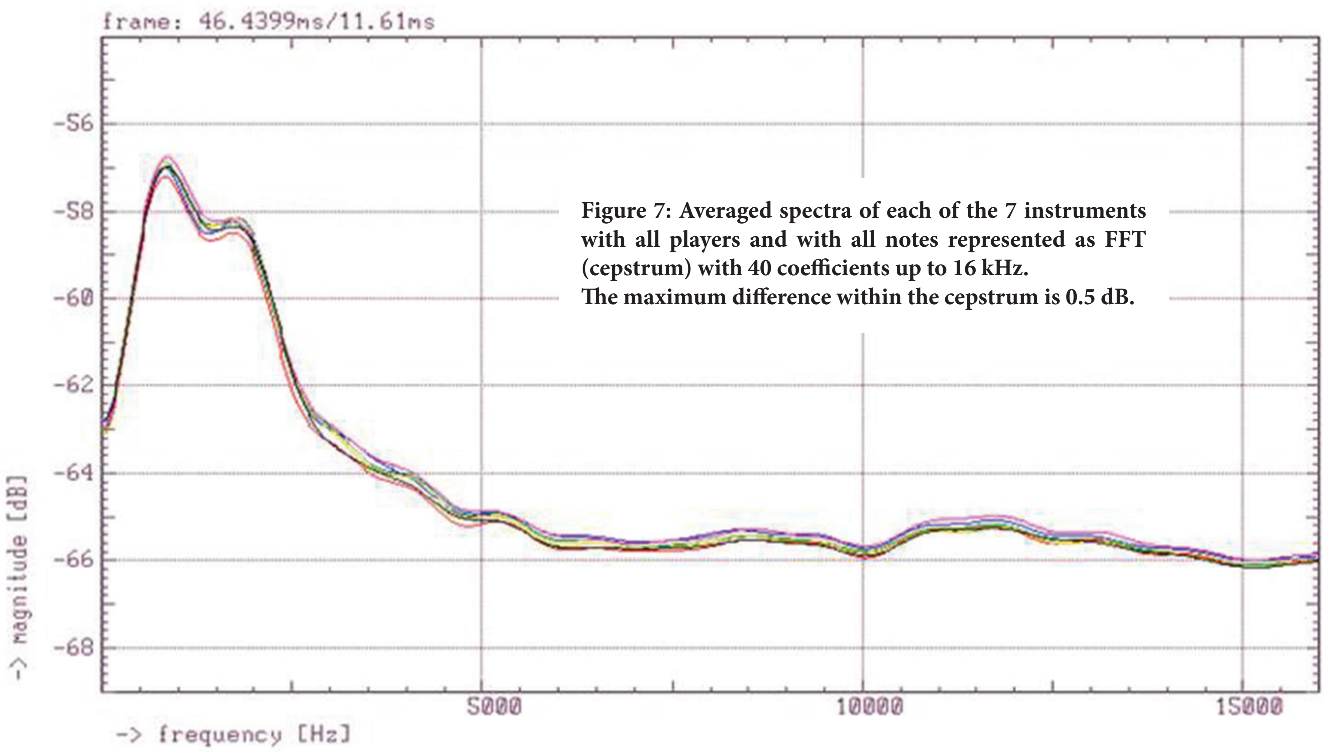


Figure 7: Averaged spectra of each of the 7 instruments with all players and with all notes represented as FFT (cepstrum) with 40 coefficients up to 16 kHz.
The maximum difference within the cepstrum is 0.5 dB.

To check the shown results yourself, click here: https://iwk.mdw.ac.at/flutes/

		silver coated	solid silver	9k gold	14k gold	24k gold	platinum coated	solid platinum
Sound example 3+4:	Player 1: Tone # 4 with	SIc	SI	9c	14c	24c	PTc	PT
	Tone #32 with	SIc	SI	9c	1 4c	24c	PTc	PT
Sound example 5+6:	Player 3: Tone # 4 with	SIc	SI	9c	14c	24c	PTc	PT
	Tone #32 with	SIc	SI	9c	1 4c	24c	PTc	PT
Sound example 7+8:	Player 7: Tone # 4 with	SIc	SI	9c	14c	24c	PTc	PT
	Tone #32 with	SIc	SI	9c	1 4c	24c	PTc	PT

Please note: All notes of the sound examples are taken from the played chromatic scale as they are and have not been modified. Therefore, they sometimes have a different length or a slight vibrato or a slightly different pitch. Since the flutists were not allowed to „warm up“ on the instruments beforehand, sometimes uncertainties can be heard at the beginning of some notes. Please concentrate on the timbre of the stationary part of the tone and ignore any response problems.

Sound example 9+10: All players with Flute 14 Carat Gold: Tone # 4
Tone # 20

As a conclusion it can be stated that the sound spectra differ 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 7 on the contrary points out that the largest difference in sound caused by the material over the entire frequency range of 0-16 kHz is less than 0.5 dB. The figure shows seven lines (one line for each instrument). Each line represents the smoothed envelope (cepstrum with 40 coefficients) of the sound spectrum obtained from all players with one instrument. In this way, the influence of the individual player is eliminated.

Note:

- From all the analyses it must therefore be concluded that there are slightly measurable differences in sound depending on the material, but that these are not noticeable to the listener.

- Another component is also not covered by these studies: Musicians have a very concrete idea of the sound they want to produce and therefore always try to realize it - no matter what instrument they use. It could therefore be that this ideal sound is easier, simpler or more difficult to achieve with one instrument or another. But the listener only perceives the final product, which is the same in each case. This may explain the players' preferences for a certain material.

- Not even those musicians who played the flutes themselves during the sound recordings were able to assign the flutes to the sounds in a reasonably correct way - neither in the recordings of the other players nor in the sounds they played themselves.

Since tones as part of a musical phrase are played differently than tones of a scale without any musical context, we also took a closer look at some of the audition passages (Carmen and Brahms). Figure 8 shows as an example for the note Bb5 from the Carmen solo the time function and the corresponding spectrum for the 7 players. The sound example can be found here: Sound example 11

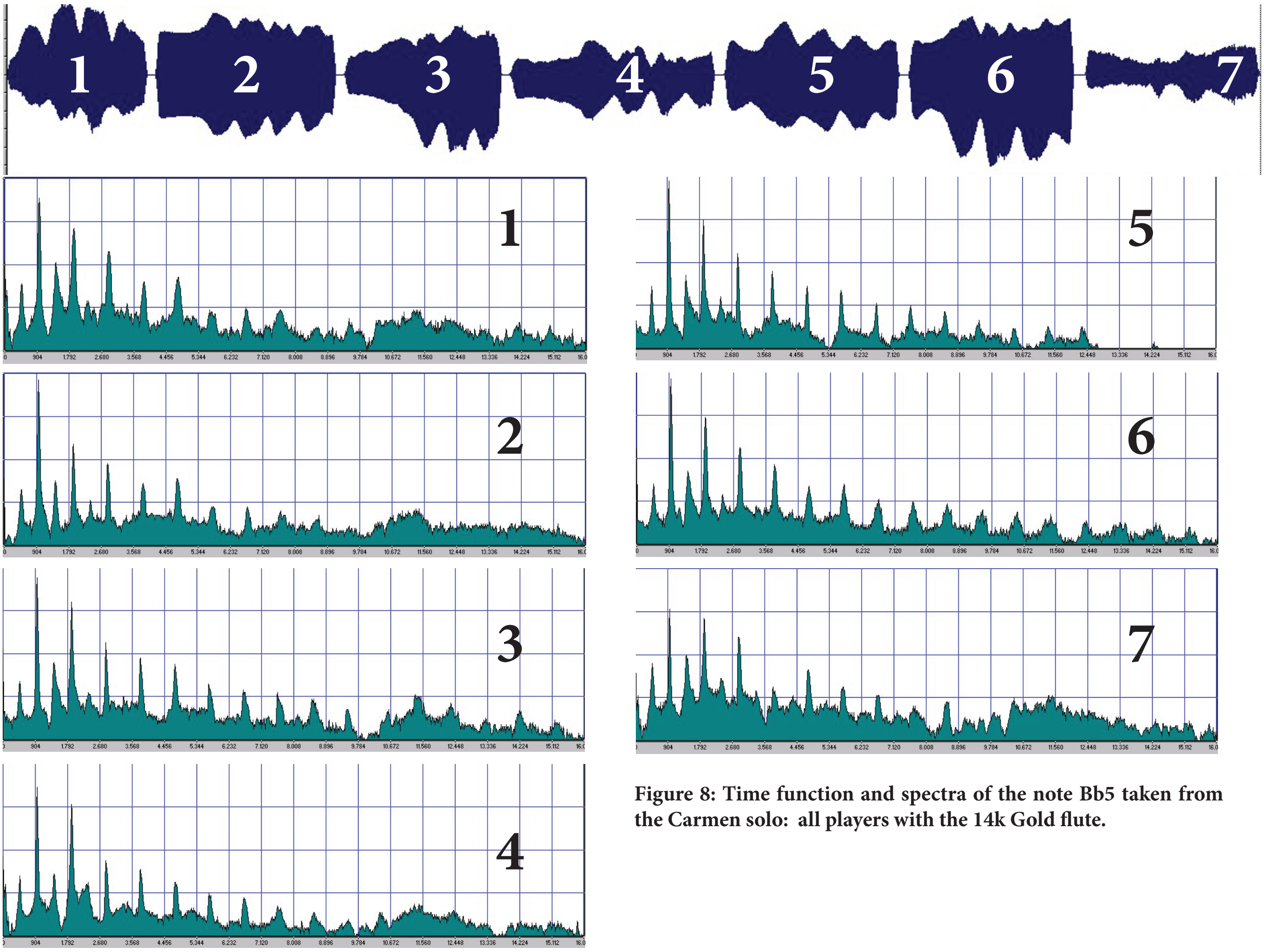


Figure 8: Time function and spectra of the note Bb5 taken from the Carmen solo: all players with the 14k Gold flute.

4 THE LISTENING TESTS

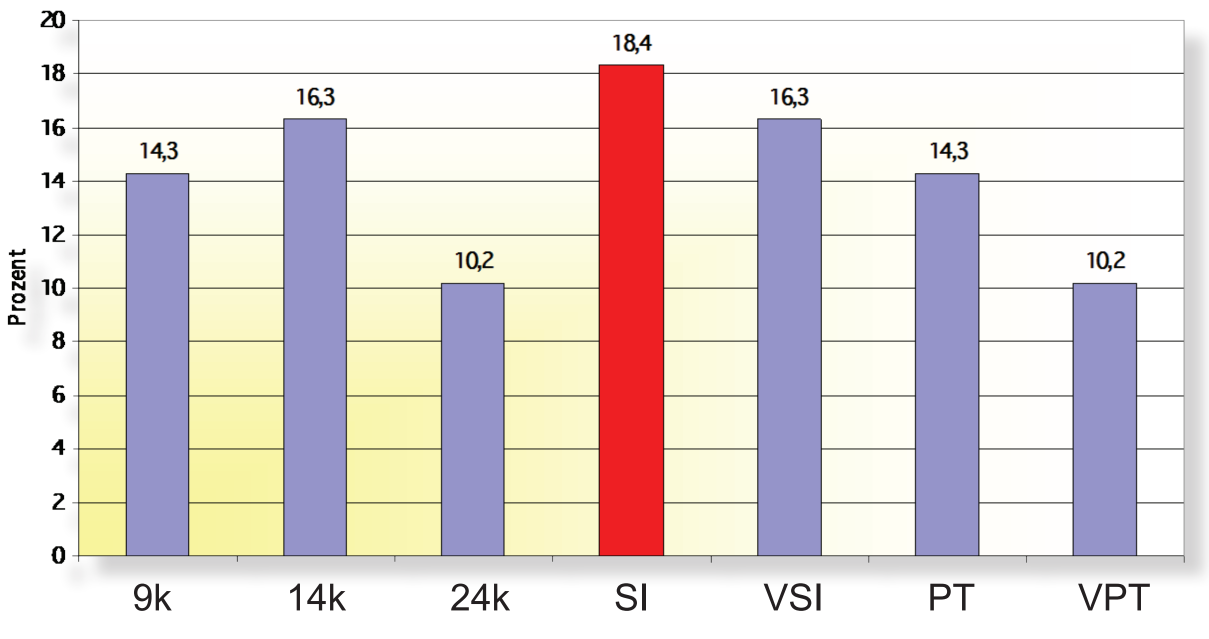
Two different listening tests were carried out with a group of 15 very experienced flutists, which included also the 7 players of the sound samples. The Carmen solo and the solo from Brahms' First Symphony were used as sound samples.

TEST A

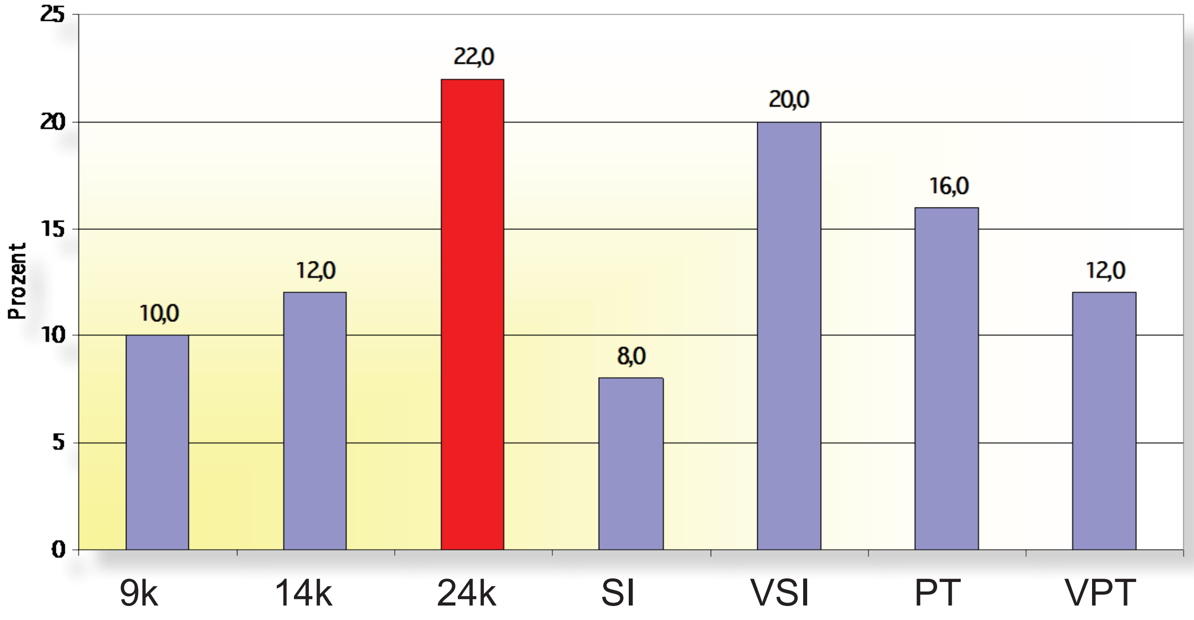
In listening test **A,** the solos were presented to the test persons by one player on all flutes, then the next player with all flutes, etc. The test persons should be able to identify which flute / which material is involved. They could repeat each sample several times if they wanted to be sure in their decision. This means that during the 7 rounds (each player with all instruments) each test person heard and identified all flutes. Therefore, each instrument was identified 7 times (by no means always identically and correctly) by one test person.

The motivation for this task was provided by a survey of 111 professional flutists around Vienna, where almost all of them were convinced that they could tell from the sound of the instrument which material is involved. The result of the hearing test **A** showed that the opposite is true. The following diagrams show the assignments made in percent based on the two listening examples. If each test person correctly identifies the material of the flute, there is only the red bar for the corresponding instrument with 100%.

The highest correct allocation was 22% (!) for the 24K gold flute, i.e. only 1/5 was allocated correctly at most. In contrast, the highest wrong allocation is much higher in some cases. Platinum was confused by 34% with the 9K gold flute. The 14K gold flute was also assigned by a high percentage (32%) to the solid platinum flute. The platinum-coated flute was assigned to the 24K gold flute by 23% of listeners.



9 k = 9k Gold (No. 4 in Fig.1) .... 20.000,00 €
14 k = 14k Gold (No. 5 in Fig.1) .... 28.000,00 €
24 k = 24k Gold (No. 6 in Fig.1) .... 80.000,00 €
SI = solid silver (No. 2 in Fig.1).......................... 10.000,00 €
VSI = silver coated (No. 1 in Fig.1).........................4.300,00 €
PT = solid Platinum (No. 7 in Fig.1)................... 80.000,00 €
VPT = Platinum coated (No. 3 in Fig.1)................ 18.500,00 €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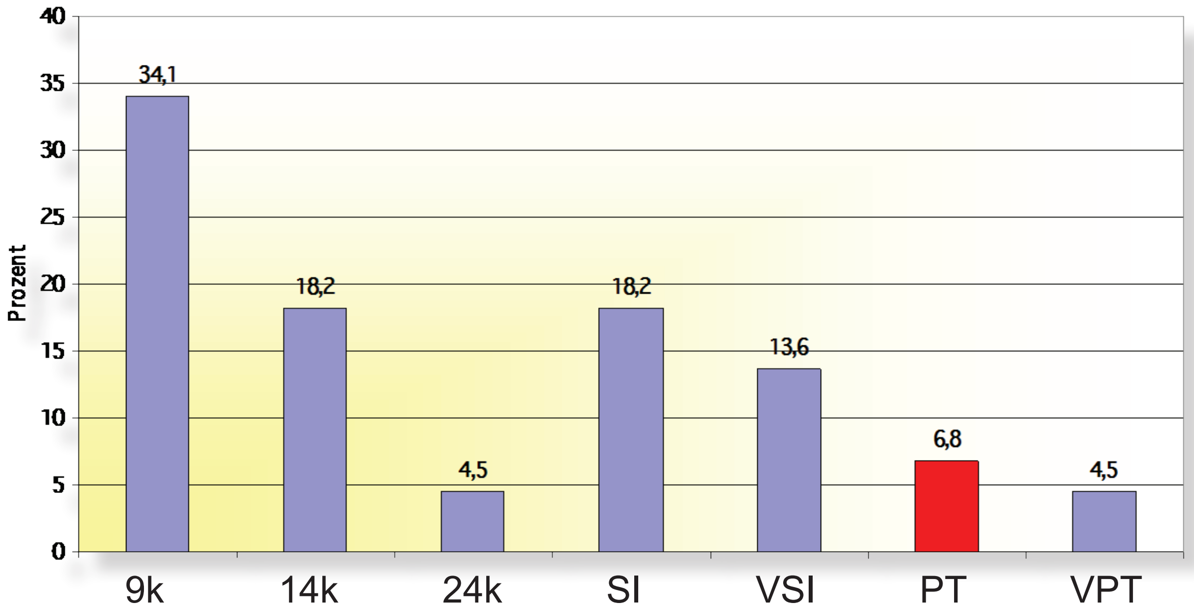
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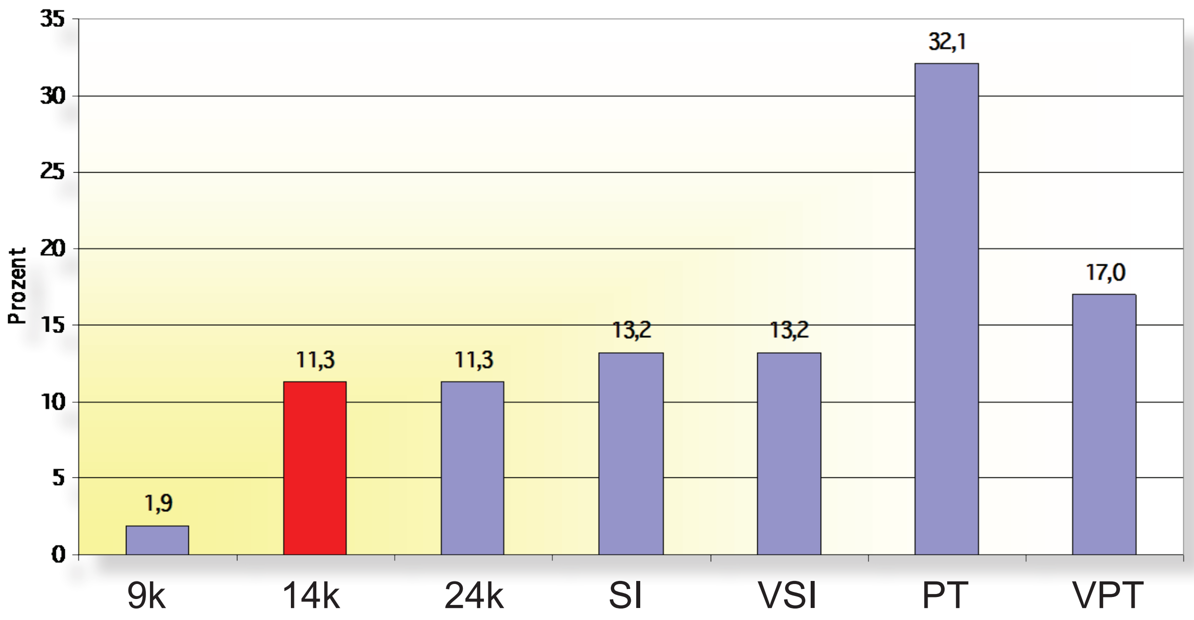
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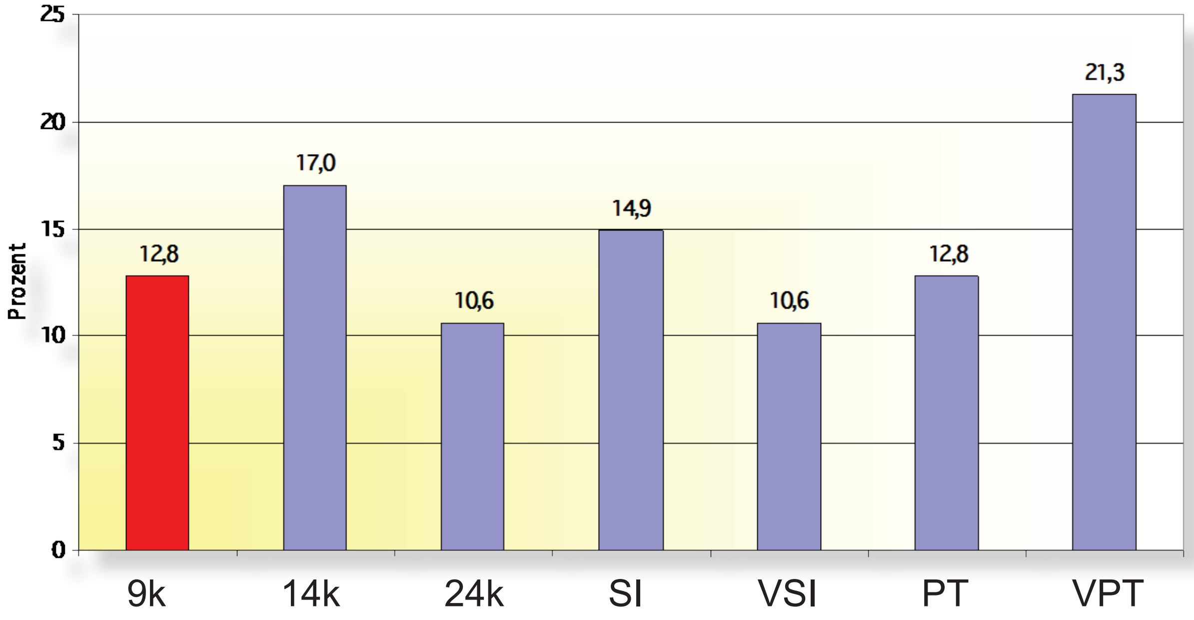
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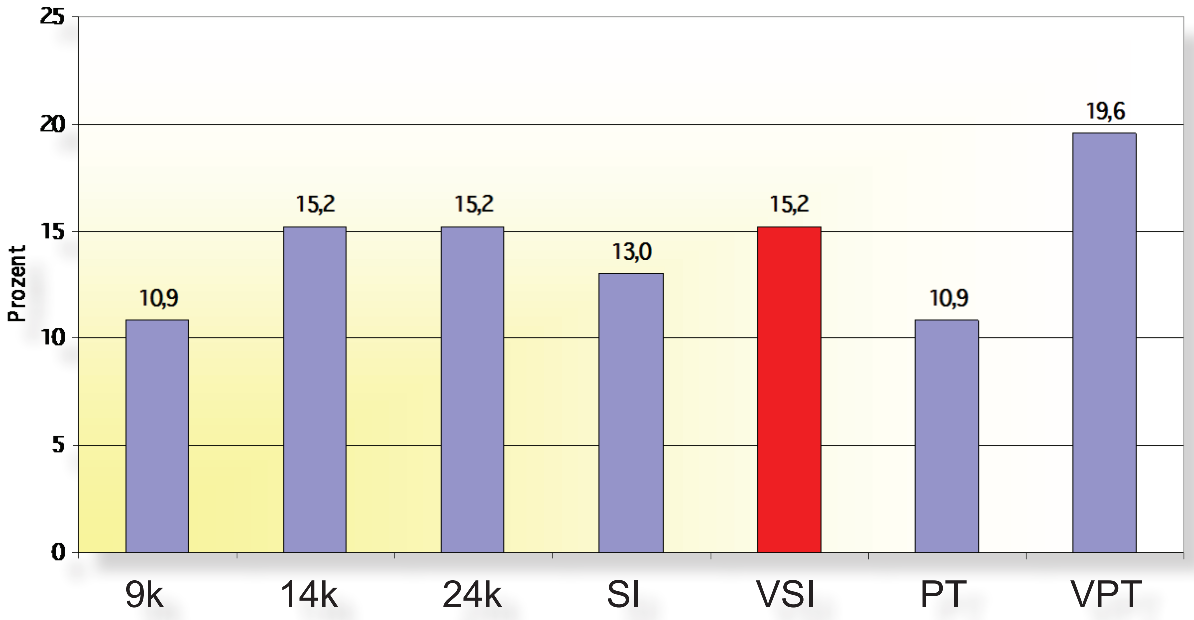
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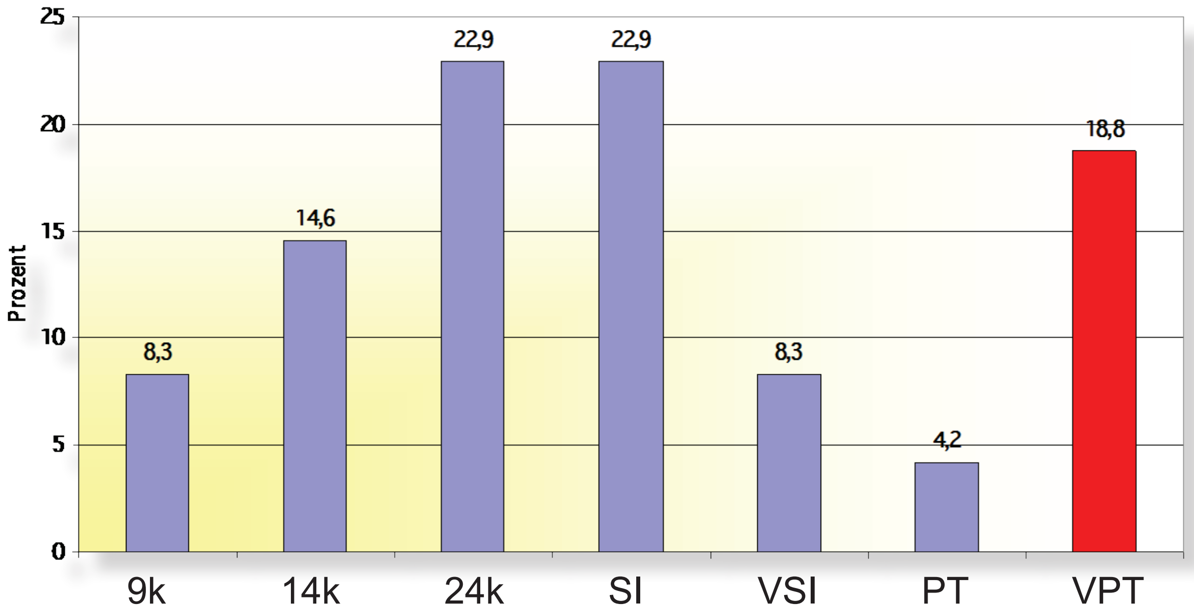
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SI
VSI
PT
VPT

TEST B

In this listening test, each flute was assigned a letter, which neither the test director nor the testing subjects knew. The test persons heard for example the flute „A“ played by all 7 players and had to describe the sound in keywords and additionally grade it (1=very good, 5=bad). On an optional basis, the test subjects could state if they recognized which flute was played and name it. As sound samples the Carmen solo and the solo of the Brahms symphony were used.

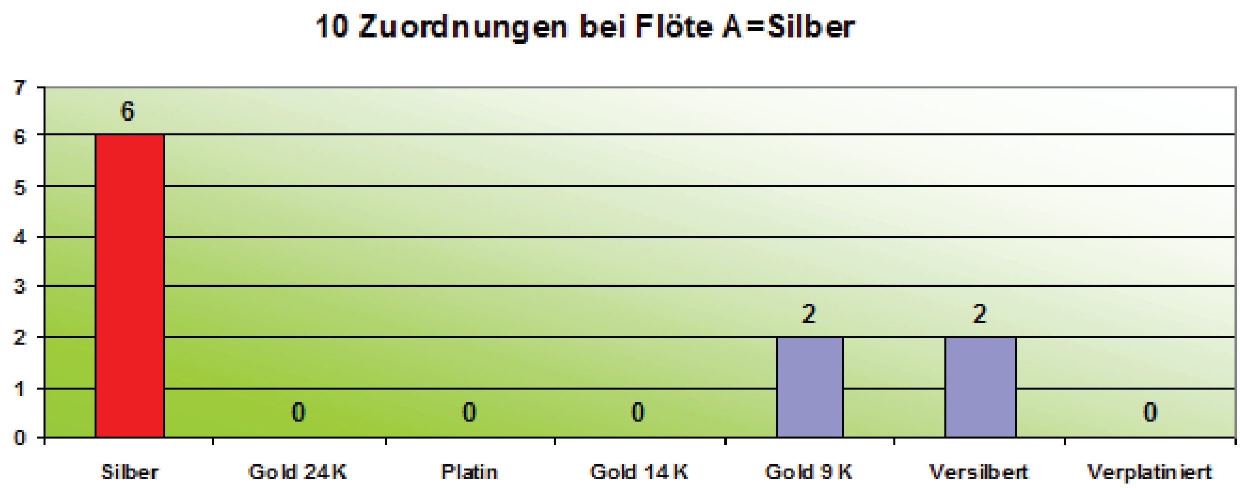
As an example here the description of the sound of the **24k gold flute** by the 15 test persons. *(Please take into account that the translation of technical terms commonly used in the German language into English may not always have been successful):*

Darker, less background noise and rounder than flute A (Person 1)
Full, round tone, bright, few overtones (Person 2)
Slightly heavier and thinner than flute A, nice high register, bright (Person 3)
Brighter and thinner than flute A (Person 4)
Softer and darker than flute A, for player 4 lighter (Person 5)
Warm beautiful sound, balanced, with silver thread (Person 6)
Somewhat dull, little bright (Person 7)
Full sound (Person 8)
More background noise than flute A, nice high register (Person 9)
Bright and narrow sound in the high register, low register duller than high register, for one player low and high register well balanced (Person 10)
Sounds harsh, too direct, too much brassy (Person 11)
With Brahms rounder than flute A, brighter than A, much colour (Person 12)
Heavy sound, better vibrating than A, intonation better (Person 13)
Warm sound, more center than A (Person 14)
Warmer than A, more intensity, intonation difficult for one player (Person 15)

Mean value of the grading: 2.38

As can be seen from this example, there are positive, neutral, negative and numerous conflicting assessments. Therefore, the magnitudes of these categories were also examined for each instrument.

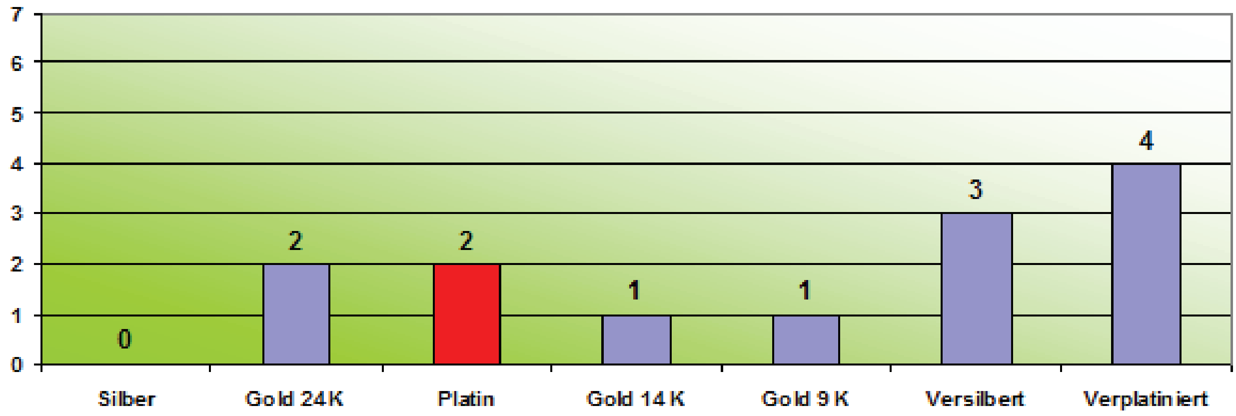
The following diagrams show the allocations made for each instrument. A correct allocation is indicated by red colour. The numbers above the bars indicate the number of allocations. Since the option “I have recognized and allocate the instrument” is voluntary, not all test persons have always used it.



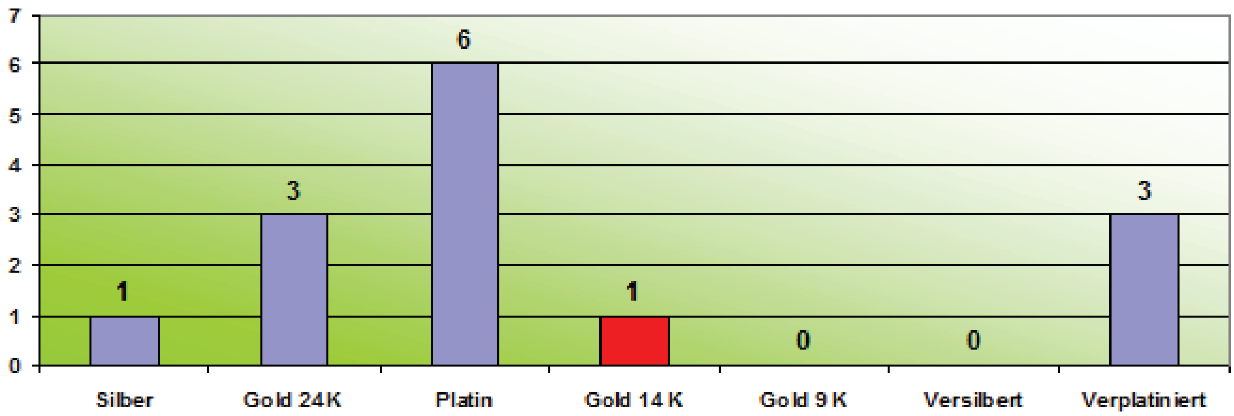
Silver 24k Gold Platinum 14k Gold 9k Gold Silver coated Platinum coated

9 Zuordnungen bei Flöte B=Gold 24 K

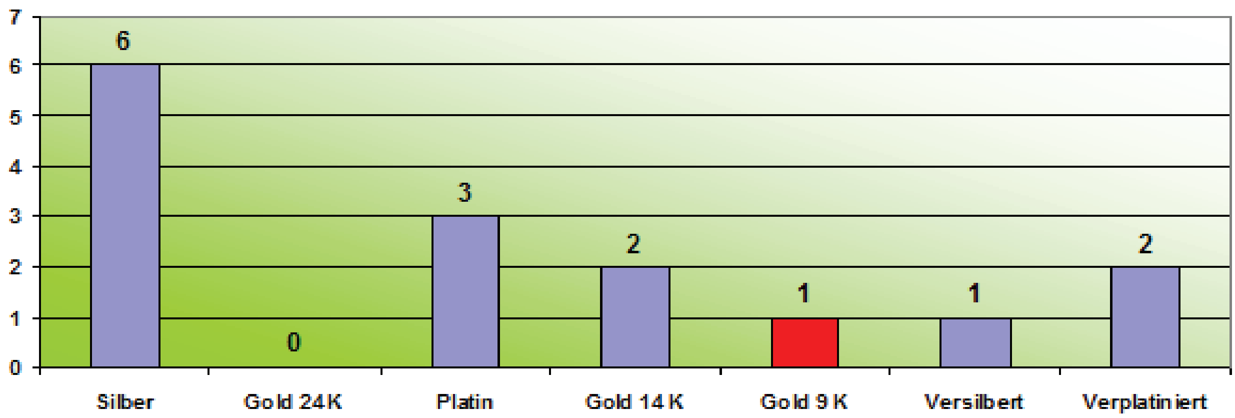
13 Zuordnungen bei Flöte C=Platin

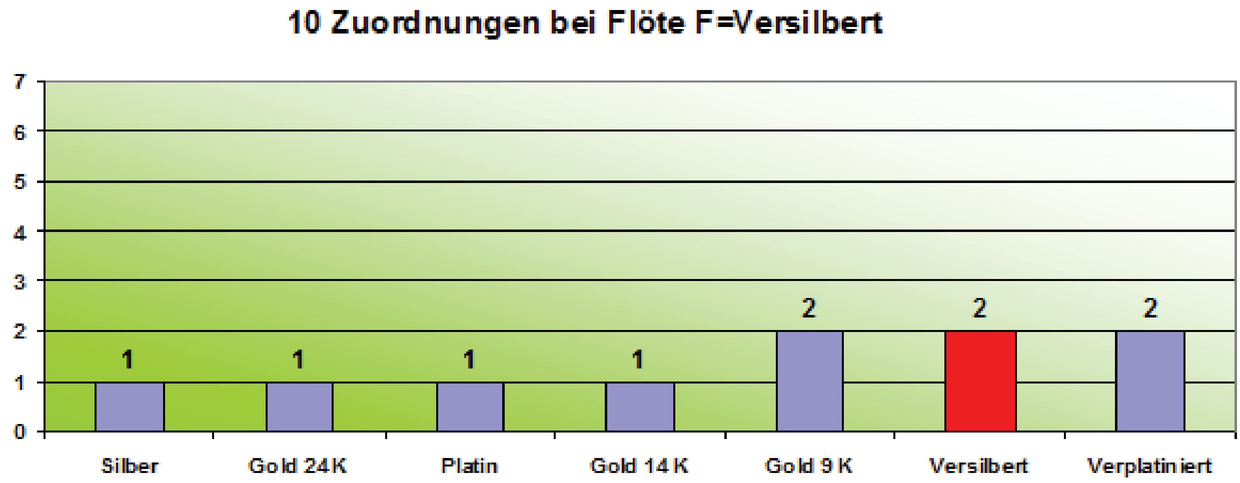


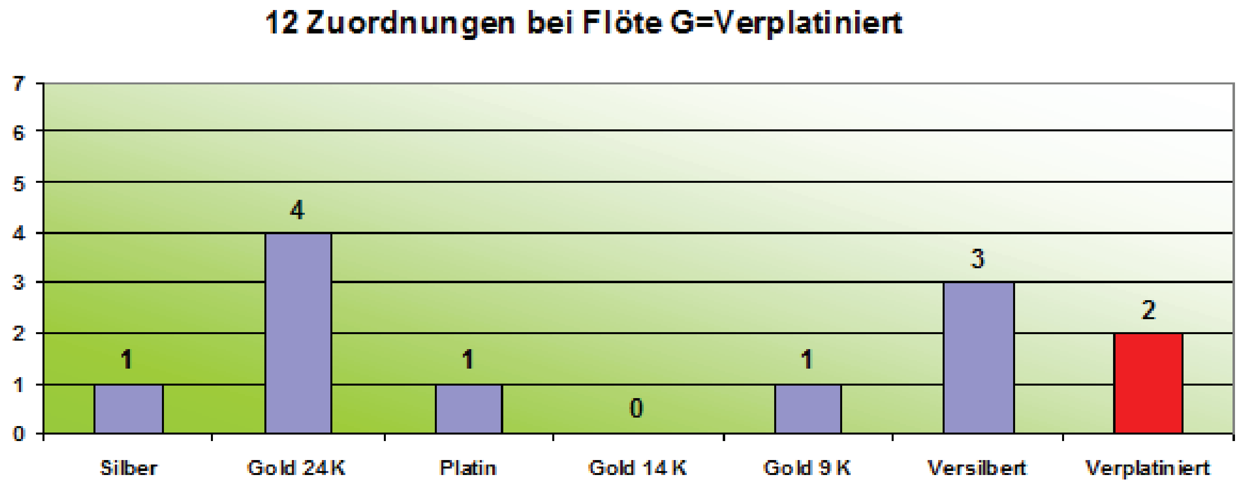
14 Zuordnungen bei Flöte D=Gold 14 K



15 Zuordnungen bei Flöte E=Gold 9 K







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 solid silver instrument, the 14 k gold flute was identified as the solid 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 sound color for each instrument were separated into 5 categories:
positive occupied expressions
negative occupied expressions
from all persons assigned expressions
contradictionary expressions and
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 table on the next page shows an interesting result:
The sum of all evaluations (1=very good, 5= bad) shows with 2.16 - 2.92 a rather small bandwidth. Interesting is the ranking: the most popular and most played solid silver flute scores worst regarding timbre! Surprisingly, the result also shows which instrument is better suited for the Carmen or Brahms solo: the 9k Gold and the silver coated are clearly in the lead, although the latter has very contradictionary evaluations for Carmen.
While the Platinum flute can succeed with reservations with Carmen, it is almost uniformly rejected in the high register with Brahms. However, the 24k gold flute, which generally ranks second in the listening tests, is perceived very contradictorily in both solo passages.

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	+ - -	++ - - - -

THE SURVEY

A comprehensive survey of 110 professional flutists in the Vienna area was conducted to gather their opinions on the influence of the material on the sound and the recognisability of the instruments due to the material used. The table shows which instruments are played by the orchestra musicians, the students (University) in the second stage of study and one amateur.

	Berufsmusiker	Studierende	Amateure
Silber	21	44	0
Gold 14 K	14	1	0
Versilbert	0	8	1
Gold 9 K	6	0	0
Gold 5 K	1	4	0
Gold 24 K	3	0	0
Verplatiniert	1	2	0
Gold 18 K	2	0	0
Holz	2	0	0
Platin	1	0	0
Summe	**51**	**59**	**1**

The questions were:

- Which instrument do you use?
- What material is your flute made of ?
- Why did you choose this instrument?
- What sound characteristics do you attribute to the material of your flute ?
- Which other flutes do you play or have you played before?
- If money is no object; Which material would you prefer - why?

The survey provided a wealth of material and a relatively good overview of the views prevailing in the Viennese flute community on the material properties and the supposedly resulting sound, with contraindications being considerably high. All details can be found in the original master thesis in German language.

CONCLUSION

● The sound analyses showed that each flutist was able to realize his or her individual conception of an ideal sound almost 100% with each instrument.

● The examination of the RMS values for the scales played over 3 octaves impressively proves that the characteristic pattern of the „envelope“ for a player is clearly recognizable on all instruments, but that no pattern typical of an instrument was present on different players.

● A statistical analysis of averaged sound spectra (cepstrum with 128 coefficients up to 16 kHz) showed that the spectra of the players differ from each other by up to 7 dB at various frequency regions, while the maximum difference caused by the played instruments was only 0.5 dB at most.

● An even clearer picture shows the evaluation of the „dynamic range“, that is for each of the 4 notes a4, f5, d6 and bb6, the difference between the lowest possible and highest possible volume.

The achieved dynamic range by each flutist, averaged over the four tones and over all flutes is between 7 dB and 19.6 dB. Therefore the highest obtained dynamic is three times as much as the lowest.
In contrary to that the mean value of all players and the 4 above mentioned notes 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 1.57 dB. The possibility that this difference becomes zero with an increased number of test players cannot be excluded.

● It must not be forgotten, however, that the analysed sounds represent the product of musician and instrument, i.e. what the audience gets to hear! This doesn‘t say anything about whether one or the other flutist can reach his ideal sound more easily (or only with difficulty) with one or the other flute. To investigate this, a different setting would be required.

● The common stereotypes regarding the timbre caused by the material, which are persistently held by flutists and flute makers, have been exposed as „stereotypes“.

Although the test subjects were very experienced flutists from top international orchestras with an average of 20 years of professional experience and were all firmly convinced that they could immediately tell from the sound whether it was a silver, gold or platinum flute, the results of the instrument recognition tests were a complete disaster. Even those people who recorded the sounds themselves were not able to identify the instruments correctly when listening to their own sounds.

[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)