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# Perceived Roughness - a Recent Psycho-Acoustic Measurement

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**ABSTRACT**

This paper relates to an investigation on perceived roughness from Aures in 1984 where findings are based on psycho-acoustic tests with synthetic sounds and a small group of people. The related results have repeatedly been used for modelling roughness perception since then, for instance in the context of noise perception. Roughness is again an issue when investigating the perceived quality or timbre of musical sounds. In this context, roughness is one among some ten mid-level features to be extracted. Here, perceived roughness is measured again, but on a wider basis than in the earlier investigation. This paper outlines the psycho-acoustic investigation, basically following the method of Aures, but modifying some of the issues under question. The results are reasonable and differ from the earlier findings in various aspects.

## 1. MOTIVATION

This paper strictly relates to the investigation on perceived roughness from Aures in 1984 [2]. There, modulation intensity, carrier- and modulation-frequency were varied in synthetic sounds and used in listening tests. Since then the related findings have repeatedly been used for modelling roughness perception [1] [3] [9], e.g. in the context of noise perception [6] [8]. Roughness is also an issue when investigating the perceived quality of musical sounds. In the context of a research project on violin sound quality, roughness is one among some ten mid-level features to be extracted. During their modelling approach, the authors were hesitant to use the data base of Aures for a number of reasons. Therefore, the original psychoacoustic test has been repeated with some alterations to obtain alternative raw data on perceived roughness. The community may wish to use this alternative data set when working on perception models. This paper outlines where the test method of Aures has been followed and where issues under question have been addressed by modifications. It also describes the true test conditions for presented results.

## 2. METHOD USED AND ALTERATIONS

In principle the method employed here follows the basic idea already used by Aures [2]: in a first test phase, two tones of same carrier frequency are presented, and individuals have to adjust the modulation intensity for specific modulation frequencies until the perceived roughness matches that of a reference sound of different modulation frequency. This first test phase therefore delivers sensitivity of perceived roughness against variations of modulation frequency. In a second phase, roughness across different carrier frequencies is compared within sound pairs, maintaining the modulation frequency for both sounds, and, again, adjusting the modulation intensity until the perceived roughness matches. This second phase delivers sensitivity of perceived roughness against variations of carrier frequency. Finally, results from the two phases are roughly brought into a common context, and the perceived roughness is mapped against the three parameters used. This investigation uses the same sequence of test phases and the same final context map. It also employs the same test procedure, using the method of adjustment on sound pairs. Most of the parameters of the synthetic sounds are also identical.

The few modifications of our test approach are fully conform with the general recommendations for psychophysical tests from Hellbrück et al. [5].

a) The number of sound pairs to be adjusted by individuals is 18 for the first test phase and 12 for the second test phase, compared to 124 and 112 sound pairs in the respective Aures test. The authors felt more confident when requesting only some 20 minutes of attention from individuals, rather than hours.

b) The group size is more than doubled compared to the former test, 20 instead of eight individuals. This larger group size should deliver an improved statistical basis.

c) According to Aures' method for the final context mapping, results for sound pairs with a carrier frequency of 1 kHz are specifically important. Here this circumstance is appreciated in particular by defining an anchor parameter set. As this set is important for linking the results of the two phases, the group size has been enlarged to 50 individuals. The larger group on this parameter set also helps to estimate confidence levels for the other parameter sets with only 20 participants.

Apart from these modifications, there are a few other issues where the Aures publication does not fully outline details of interest to the reader or of relevance to the procedure:

a) The Aures investigation says nothing about the eight individuals involved in the test. In this investigation, the 50 individuals are randomly chosen people, mainly from the faculty environment. None of the individuals has been involved in the research questions behind the test. None of the individuals has specifically been trained.

b) Individuals have been interviewed on musical skills or training after execution of the test. Therefore, individuals have not been biased prior to the test, nor have they been under pressure in terms of expected performance. The subsequent questionnaire allows for classification across individuals and for meaningful evaluation of data, e.g. perception of musicians vs. non-musicians.

c) The sound pairs are randomly permutated. However, the permutation has been manually re-edited to maximize options for cross checking the obtained raw data between groups and between parameter sets.

d) The authors expected that individuals would need the first few sound pairs for adapting to the test environment and for finding some confidence when adjusting the modulation intensity. Therefore three sounds were presented to individuals prior to the test phase: a slightly vibrating tone, a rough tone, and a rather rough tone.

e) In addition, the uncertainty of the early test phase is addressed by allocating a larger group size for the first few sound pairs. The permutation has been adjusted in a way that parameter sets with a larger group size are likely to be presented in the early test phase.

## 3. TEST SETUP

### 3.1. Parameters Sets, Group Size and Allocation

The sounds consist of a carrier with carrier frequency $f_c$, $AM$ modulated with modulation frequency $f_m$ and modulation intensity $m$. Sounds are synthesized according to

$$y_m = \sin(2\pi f_m \cdot t) \quad (1)$$

$$y_c = \sin(2\pi f_c \cdot t) \quad (2)$$

$$y_{AM} = (1 + m \cdot y_m) \cdot y_c. \quad (3)$$

Sampling rate is always $f_s = 44.1\ kHz$ and the signal duration is $t_{sig} = 1\ s$.

This test uses the same set of carrier frequencies as Aures did for his investigation:

| **index** | **a** | **b** | **c** | **d** | **e** | **f** |
|---|---|---|---|---|---|---|
| $f_c$ **in Hz** | 125 | 250 | 500 | 1000 | 2000 | 4000 |

**Table 1:** set of carrier frequencies used

The set of modulation frequencies is reduced compared with the Aures approach in order to reduce the number of parameters and to enhance the test quality for the parameters of interest:

| **index** | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| $f_m$ **in Hz** | 40 | 55 | 65 | 75 | 90 | 120 |

**Table 2:** set of modulation frequencies used

Sound pairs always consist of a sound under investigation and a corresponding reference sound, predefined according to table 3. The modulation frequency $f_m$ is chosen roughly in the area of an expected maximum for the perceived roughness.

50 individuals have been organized in five test groups (TG). Test groups one to five are allocated across the different carrier frequencies:

| $f_c$ **in Hz** | 125 | 250 | 500 | 1000 | 2000 | 4000 |
|---|---|---|---|---|---|---|
| $f_m$ **in Hz** | 50 | 50 | 50 | 70 | 70 | 70 |

**Table 3:** predefined reference sounds for test phase one

| **index** $f_c$ | **a** | **b** | **c** | **d** | **e** | **f** |
|---|---|---|---|---|---|---|
| **TG1** | x | | x | x | | |
| **TG2** | | x | | x | x | |
| **TG3** | | | x | x | | x |
| **TG4** | x | | | x | x | |
| **TG5** | | x | | x | | x |

**Table 4:** Allocation of test groups (TG) across carrier frequencies $f_c$ (see table 1)

According to this allocation, the carrier frequency 1 kHz is presented to 50 individuals, whereas all other carriers are presented to only 20 individuals.

### 3.2. Permutation

Table 5 lists the permutation map for test group two. Letter and number for each entry correspond to the indices of carrier and modulation frequency according to Tables 1 and 2. For example, the sound $c1$ represents a 500 $Hz$ carrier which is modulated with 40 $Hz$. In the first test phase the respective reference sound is a signal with the same carrier frequency. Specifically, the carrier is again $f_c = 500\ Hz$, modulated with $f_m = 50\ Hz$, according to Table 3. Sounds under investigation are always modulated with $m = 0.7$, whereas the modulation intensity of the reference sound is to be adjusted. Sound pairs number four to 18 are randomly permutated with some manual correction to avoid long sequences of always the same carrier frequencies. The early sound pairs number one to three employ two distinct sequences to allow for cross checking raw data within and between test groups.

In test phase two the reference sound always consists of a 1 $kHz$ carrier using the same modulation frequency as the sound under investigation

| | VP 2.1 | VP 2.2 | VP 2.3 | VP 2.4 | VP 2.5 | VP 2.6 | VP 2.7 | VP 2.8 | VP 2.9 | VP 2.10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | d1 | d1 | d1 | d1 | d1 | d6 | d6 | d6 | d6 | d6 |
| **2** | d5 | d5 | d5 | d5 | d5 | d3 | d3 | d3 | d3 | d3 |
| **3** | d2 | d2 | d2 | d2 | d2 | d4 | d4 | d4 | d4 | d4 |
| **4** | e5 | b2 | b1 | e6 | e6 | b5 | b4 | e2 | b1 | e3 |
| **5** | e4 | d6 | b3 | e1 | b5 | e5 | b5 | e6 | b4 | e2 |
| **6** | b1 | b6 | e5 | b5 | b6 | e6 | d5 | b6 | b2 | b1 |
| **7** | b4 | b5 | b2 | b1 | b3 | b6 | e5 | d1 | d2 | b2 |
| **8** | e6 | e4 | d3 | d6 | e5 | b4 | e3 | d2 | e2 | b3 |
| **9** | e3 | b3 | d4 | b4 | e1 | e3 | b1 | e1 | e3 | e4 |
| **10** | e1 | d4 | e4 | e3 | e4 | d1 | b3 | e4 | d1 | d5 |
| **11** | d3 | d3 | e2 | e2 | d3 | d2 | b2 | b2 | d5 | d2 |
| **12** | d4 | e1 | e3 | e4 | d6 | d5 | e4 | b3 | e4 | d1 |
| **13** | b3 | e3 | b4 | d4 | e3 | e4 | e1 | b1 | e1 | e1 |
| **14** | e2 | e6 | d6 | d3 | e2 | b3 | d2 | e3 | e5 | b4 |
| **15** | b5 | b4 | b6 | b2 | d4 | b2 | d1 | e5 | b3 | b6 |
| **16** | b6 | b1 | b5 | e5 | b2 | b1 | b6 | d5 | b6 | e6 |
| **17** | d6 | e2 | e1 | b3 | b4 | e2 | e6 | b5 | b5 | e5 |
| **18** | b2 | e5 | e6 | b6 | b1 | e1 | e2 | b4 | e6 | b5 |

**Table 5:** Permutation map for TG 2 in phase one

and a modulation intensity $m = 0.7$. This allows evaluation of perceived roughness across different carrier frequencies.

## 3.3. Test Environment and Conditions

Individuals executed the test alone in an acoustically dry and silent room. They were given enough time to comfortably do the test. Short steady-state sounds of one second duration were automatically generated on a computer and binaurally presented via external sound board ($UA - 25$) and a headset ($HD$ 202). Individuals had the free choice to repeatedly listen to the sounds and to jump between the reference sound and the sound under investigation in order to adjust the level of modulation intensity m. Control and adjustment were done via a MATLAB-based graphical user interface and mouse. The control bar for the modulation intensity allowed for adjusting m continuously between zero - no modulation at all - and one - maximum depth. Therefore, the technically limited parameter space was much wider, than the space needed for the task. Each sound pair was presented on a separate page and adjustment results were captured from individuals with each step through the sequence of pages. There was no way back in reverse direction of the sequence to lean on earlier decisions. Individuals were always aware of their work progress.

Before the test, individuals were allowed to set their favoured loudness level for comfortable listening, but they were also instructed to maintain the loudness level over the test. Three learning sounds were presented to individuals prior to the test: ($i$) a slightly vibrating tone, $f_c = 1\ kHz$, $f_m = 10\ Hz$, $m = 0.4$, ($ii$) a rough tone d1 with $m = 0.6$ and ($iii$) a rather rough tone $d4$ with $m = 0.9$. Prior to the test, individuals were also introduced to the use of the very simple GUI. They were encouraged to settle all questions before they were left alone with the test. Questions on the purpose of the test or the related research questions have not been answered. Individuals were encouraged to take a break between the two test phases.

## 3.4. Test Log Book

The mean working duration was 13.4 $min$ with a deviation of 4.0 $min$ for the first test phase (18 sound pairs), and was 12.9 $min$ with a 3.9 $min$ deviation for the second test phase (12 sound pairs) after an average break of 10 $min$. From 50 individuals nine persons set the loudness to a slightly lower level and one person to a slightly higher level.

## 4. RESULTS

### 4.1. Reasoning Raw Data

Raw data from the tests consist of 1650 individual adjustments of modulation intensity. Reasoning this data raises confidence: $(i)$ only eleven adjustments used the technical limit $m = 1$, $(ii)$ quartiles do not vary much from group to group, $(iii)$ quartiles do not vary much across parameter sets, $(iv)$ quartiles are the same for both group sizes, confidently showing that the group size of 20 already delivers trustworthy data, $(v)$ quartiles do not vary for different sequences of the early sound pairs number one to three. These and other cross checks build confidence in the obtained data base.

Raw data has been cleared by one out of 50 test persons after careful check. One reason for this clearance are loose and volatile individual decisions in combination with an extended working duration. Another reason is that the test person admitted a hearing defect during the subsequent interview. The remaining 49 data sets are rated trustworthy, even though another seven individuals reported minor hearing deficiencies, see appendix.

### 4.2. Results on Perceived Roughness

The data sets from the remaining 49 test persons deliver median and quartile for investigated parameter sets of equally perceived roughness. Figure 1 shows the adjusted modulation intensity versus modulation frequency for different carriers. Results in each plot are related to the reference sound - the entry without quartiles. For example, with the 250 $Hz$ carrier, a sound under investigation with $f_m = 120\ Hz$ and $m = 0.7$ provoked the same roughness perception as the reference sound at $f_m = 50\ Hz$ and $m = 0.32$. This definition of Aures might seem irritating in the first place, but it is reasonable since now the plot can be read as a sensitivity map: at which modulation frequencies are people particularly sensitive when it comes to roughness? In this example, people seem less sensitive at higher modulation frequencies. The medians agree well with the results from Aures. Quartiles are larger here than in the Aures investigation.

A very satisfying result is that quartiles increase when modulation frequencies of the two sounds become distant. This result is in full accordance with the expectation that roughness assessments become less precise with increasing distance between the characters of the sound. On the contrary, entries close to the reference point deliver small quartiles, since investigated sounds have a modulation frequency similar to the reference sound. This is true for all carriers, but it is not even generally the case in the Aures investigation.

Results from the second test phase are shown in Figure 2. Again, the graphs identify modulation intensity versus modulation frequency, however, the reference point is not within the same graph, it is always the 1 kHz carrier of same modulation frequency. For example, the 250 $Hz$ carrier with $m = 0.7$ and the 1 $kHz$ carrier with $m = 0.22$ - both modulated with $f_m = 75\ Hz$ - are perceived equally rough. Medians differ from the result in the Aures investigation. They are in particular smaller for the 250 $Hz$ and the 500 $Hz$ carrier, and larger for the 4 $kHz$ carrier. Quartiles are again larger in this investigation.

These graphs already indicate that humans are most sensitive for roughness perception in the 1 to 2 $kHz$ range. This can be made clearer when mapping the results into one chart, following the same scaling procedure as in the Aures investigation. Aures did not explicitely mention the scaling function, but it can easily be figured out as

$$\tilde{m}_i(k) = \frac{m_i^{\{2\}}(k) \cdot m_{1kHz}^{\{1\}}(k)}{0.7^2}, \tag{4}$$

where $i = f_c$, (see table 1), $k = f_m$ (see table 2) and $^{\{p\}}$ with $p = 1, 2$ (test phase one and two).

Figure 3 maps the results from both phases together and can be interpreted as the sensitivity of perceived roughness against carrier frequency and modulation frequency. The desired scaling on the abscissa would probably be an absolute measure of roughness for everyone. However, the relation between roughness and modulation intensity is not linear in the first place and in addition it is not the same across different carriers [7] [11]. Therefore, interpretations of the early Aures result and likewise the interpretation of this graph should bear in mind the underlying wrong assumption of linear relationship. We follow the general conviction that the perceived roughness

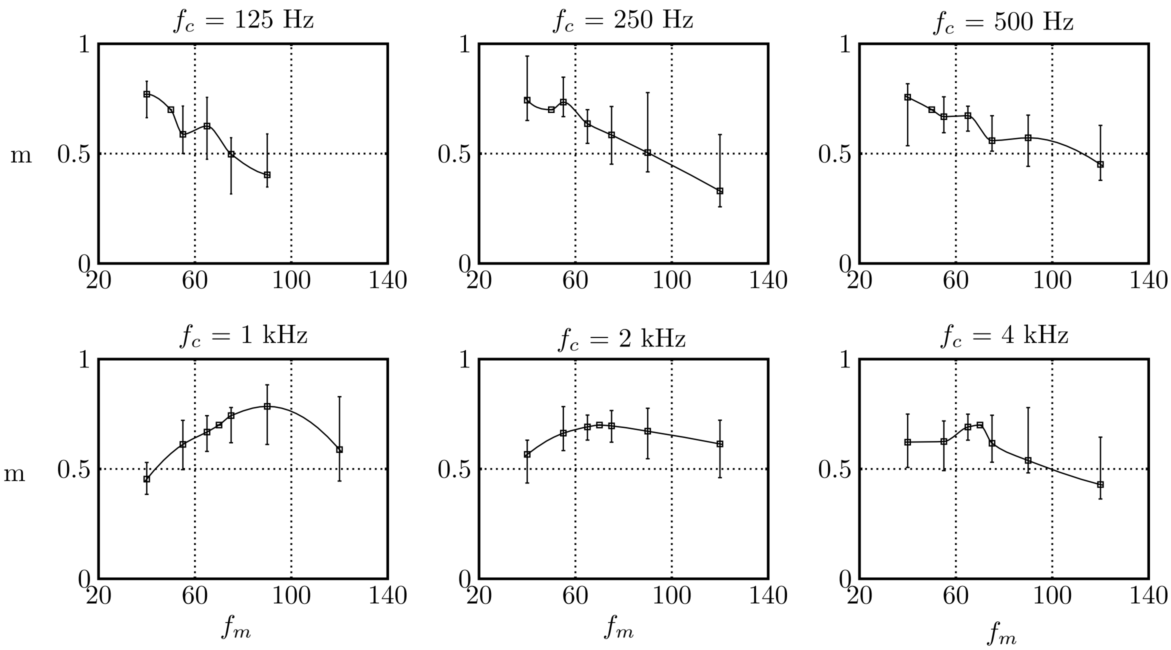


**Fig. 1:** Results from the first test phase - comparison of different modulation frequencies for individual carriers - graphs represent modulation intensity versus modulation frequency

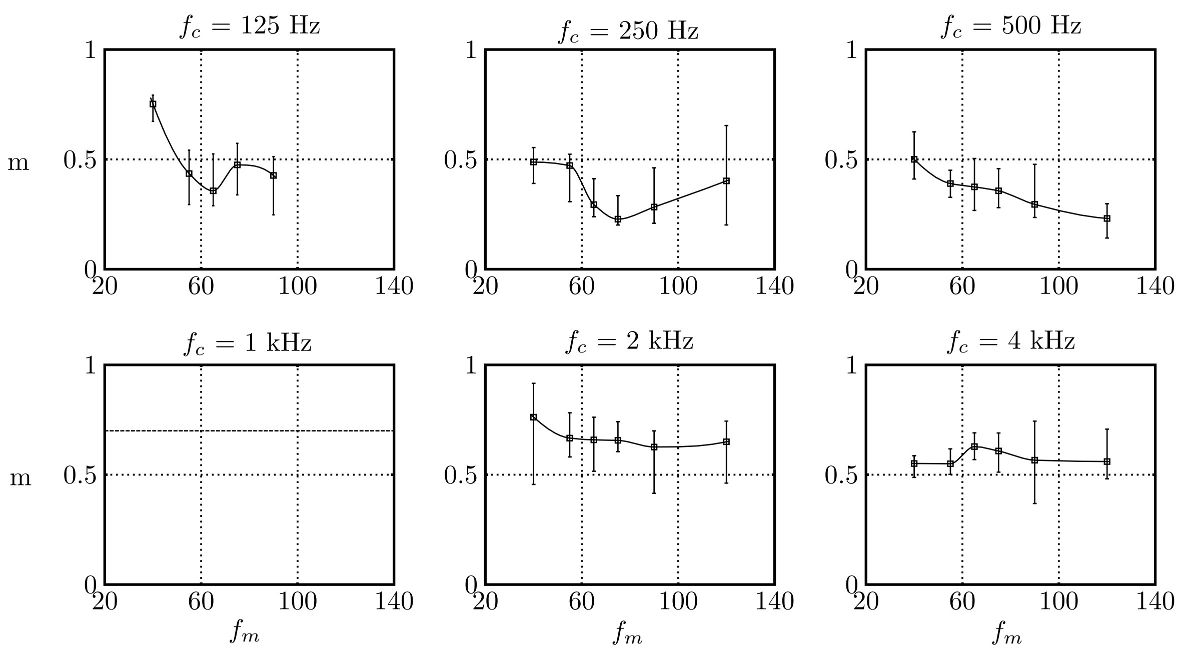


**Fig. 2:** Results from the second test phase - comparison of different carriers for individual modulation frequencies - graphs represent modulation intensity versus modulation frequency

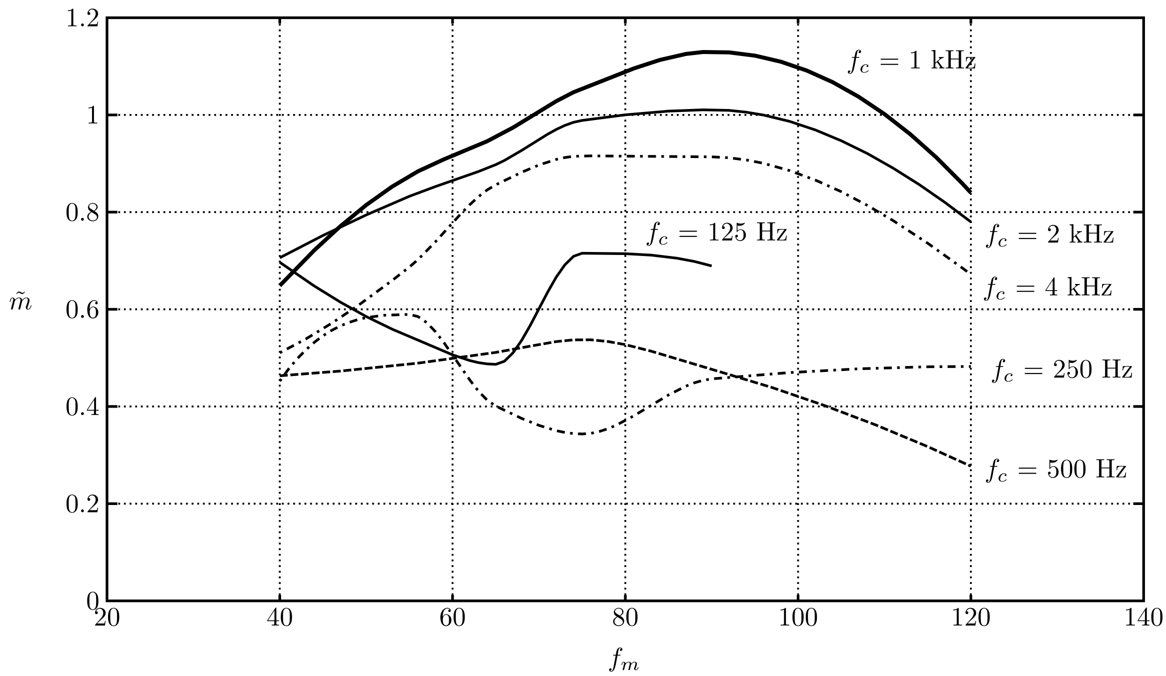


**Fig. 3:** Sensitivity of perceived roughness against carrier frequency and modulation frequency

$R = m^{\alpha}$, where $\alpha$ ranges from roughly 1 to 2 in the literature, and is not necessarily considered as constant over carrier frequency. Therefore the abscissa represents a qualitative measure rather than a quantitative measure. Reading the figure appropriately, the scaling still reflects the method from the test, where parameter sets match for equally perceived roughness. Absolute measures for the perceived roughness would require further investigations.

The main result is that humans are most sensitive in the 1 $kHz$ region. Perceived roughness declines with higher carrier frequency. It declines for lower carrier frequencies and even stronger when the modulation frequency rises. For the 1 $kHz$ carrier the maximum roughness is not confirmed at 70 $Hz$ modulation. Our tests deliver a sensitivity maximum at a higher frequency, approximately at 90 Hz. While maintaining Aures scaling function (Fig. 3), $\tilde{m}$ becomes slightly larger than unity.

### 4.3. Results across Classes

Perceived roughness seems to be independent from the fact, whether an individual has been actively exercising a musical instrument or not. For this comparison, the participants have been interviewed about their musical practice, instruments and time spent. The classification was done after the test, there was no pre-selection or call for musicians. Participants without any skills on musical instruments are classified as non-musicians, whereas all participants with training on at least one musical instrument are classified as musicians. By pure chance, the two groups have almost equal size: 23 non-musicians and 26 musicians.

Figures 4 and 5 show the results for the group of musicians and non-musicians, respectively. There are only few minor differences in the results. Quartiles are slightly smaller for many entries in the group of musicians. There are minor differences for the 125 $Hz$ and 250 $Hz$ carriers at low modulation frequencies. However, this seems to be an area of general uncertainty. It is the same parameter range where the results here differ from Aures' results. Apart from this area, the difference between medians from the two groups is always significantly smaller than the uncertainty of the entire approach, expressed in the quartiles. Therefore it seems, that

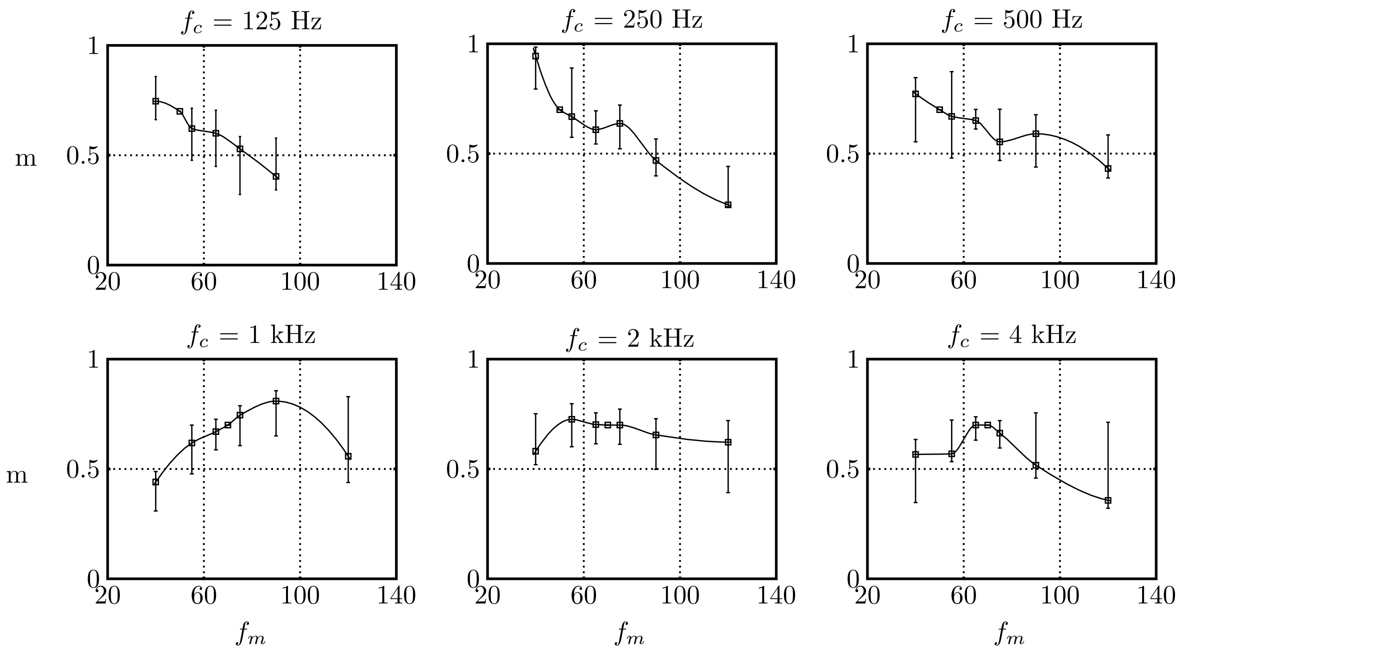


**Fig. 4:** Results from the first test phase - comparison of different modulation frequencies for individual carriers - non-musicians

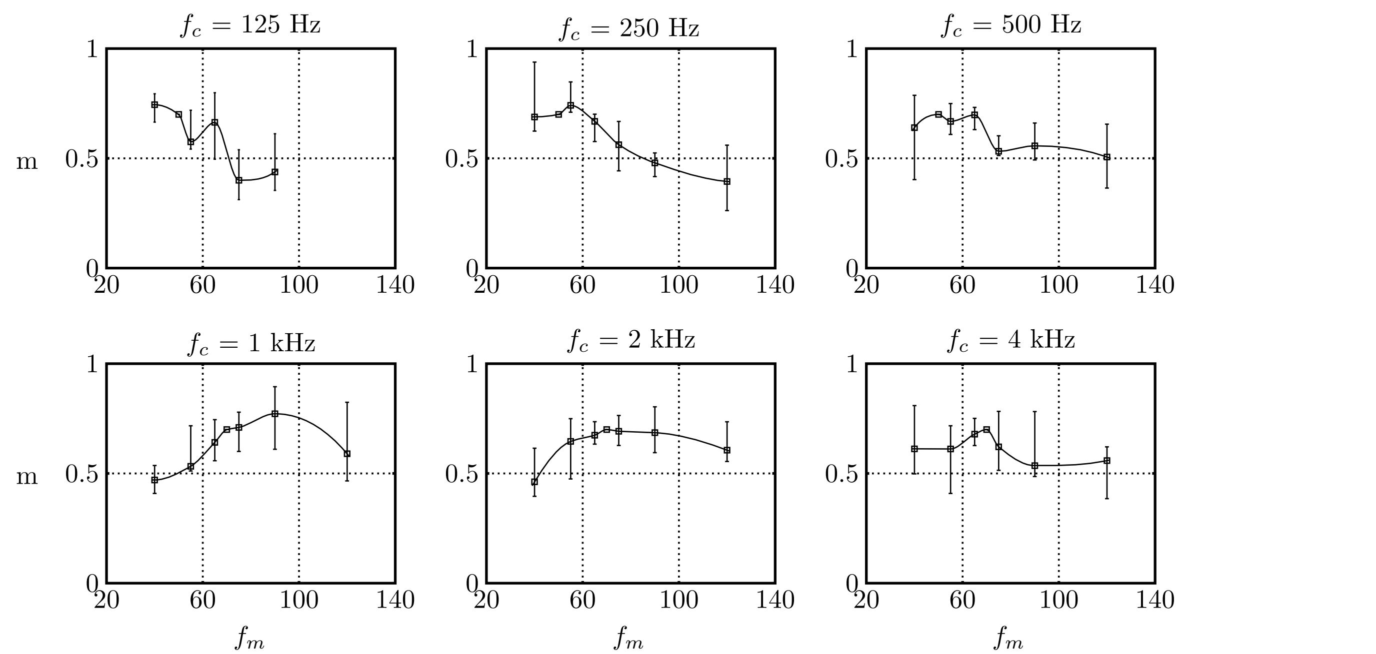


**Fig. 5:** Results from the first test phase - comparison of different modulation frequencies for individual carriers - musicians

there are no large differences in human perception of roughness, whether musician or not.

## 5. FINDINGS

There are four main findings in this contribution.

a) The findings of Aures can roughly be confirmed concerning the medians of raw data gained from both two test phases. Researchers can generally be reassured when trusting Aures' data for their perception model. However, anyone may feel free to use this alternative data set for tuning or conformance evaluation. Raw data under [12].

b) The precision of Aures' results, however, cannot be confirmed. Quartiles are generally larger here and are very reasonable as outlined. Looking back from the experience gained in this project, the sharp results are only obtainable with strongly preconditioned individuals.

c) Differences between medians of the two works are in many cases larger than the quartiles of the Aures results. This observation recommends that researchers should not overemphasize accuracy when using a solitary data basis only.

d) Musicians and non-musicians seem to perceive roughness in the same way. The method used here does not identify differences that would justify building separate perception models.

e) The results from a group with 50 participants did not deliver qualitatively different quartiles when compared to results from a group with 20 participants.

## 6. ACKNOWLEDGEMENTS

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[12] For raw data:
http://www.mt.haw-hamburg.de/home/mores/
→ Veröffentlichungen

| Test person | Musical instrument | Active years | Time spent hours/week | Listening to classical | Age | Hearing deficiency |
|---|---|---|---|---|---|---|
| **TP1.1** | - | - | - | y | 28 | n |
| **TP1.2** | guitar<br>bass guitar | 17<br>17 | abandoned<br>abandoned | n | 31 | n |
| **TP1.3** | guitar<br>bass guitar | 18<br>18 | 14<br>14 | n | 32 | y[1] |
| **TP1.4** | - | - | - | n | 26 | n |
| **TP1.5** | Trombone | 8 | abandoned | n | 27 | n |
| **TP1.6** | saxophone<br>guitar<br>piano | 12<br>4<br>2 | 3-4<br>2<br>abandoned | n | 27 | n |
| **TP1.7** | drums<br>piano | 6<br>3 | abandoned<br>abandoned | n | 27 | y[2] |
| **TP1.8** | - | - | - | n | 26 | n |
| **TP1.9** | - | - | - | y | 26 | n |
| **TP1.10** | - | - | - | n | 35 | n |

[1] Tinnitus both sides, right side twice
[2] Tinnitus left side

**Table 6:** Classifications of test participants (group 1)

| Test person | Musical instrument | Active years | Time spent hours/week | Listening to classical | Age | Hearing deficiency |
|---|---|---|---|---|---|---|
| **TP2.1** | guitar | 6 | 0.25 | n | 21 | n |
| **TP2.2** | - | - | - | n | 29 | n |
| **TP2.3** | - | - | - | n | 27 | n |
| **TP2.4** | - | - | - | n | 28 | n |
| **TP2.5** | guitar | 5 | 1 | n | 25 | n |
| **TP2.6** | piano | 20 | 2 | y | 52 | n |
| **TP2.7** | traverse fl. | 9 | 1 | n | 45 | n |
| **TP2.8** | - | - | - | n | 56 | n |
| **TP2.9** | piano<br>guitar<br>violine<br>cello | 1<br>15<br>17<br>4 | 2<br>1<br>1<br>1 | y | 45 | y[3] |
| **TP2.10** | guitar<br>bass guitar | 14<br>8 | 5<br>abandoned | n | 27 | n |

[3] -5dB at 1kHz and 6 kHz left side

**Table 7:** Classifications of test participants (group 2)

| Test person | Musical instrument | Active years | Time spent hours/week | Listening to classical | Age | Hearing deficiency |
|---|---|---|---|---|---|---|
| **TP3.1** | piano | 13 | 0.1 | n | 26 | y[4] |
| **TP3.2** | - | - | - | n | 23 | n |
| **TP3.3** | drums<br>piano | 30<br>n.a. | 3-4<br>n.a. | n | 45 | n |
| **TP3.4** | - | - | - | y | 58 | n |
| **TP3.5** | - | - | - | n | 29 | y[5] |
| **TP3.6** | trumpet<br>drums | 15<br>6 | 4<br>abandoned | n | 28 | n |
| **TP3.7** | - | - | - | n | 27 | n |
| **TP3.8** | vocals<br>piano | 19<br>12 | 3<br>1 | y | 28 | n |
| **TP3.9** | - | - | - | n | 22 | n |
| **TP3.10** | cello<br>guitar | 7<br>8 | 1<br>abandoned | n | 33 | n |

[4] Reduced hearing capability at high frequencies
[5] Reduced hearing capability at low frequencies, both sides

**Table 8:** Classifications of test participants (group 3)

| Test person | Musical instrument | Active years | Time spent hours/week | Listening to classical | Age | Hearing deficiency |
|---|---|---|---|---|---|---|
| TP4.1 | - | - | - | n | 27 | n |
| TP4.2 | guitar<br>piano<br>vocals | 15<br>2<br>1 | 0.1<br>0.25<br>abandoned | y | 26 | n |
| TP4.3 | guitar<br>vocals | 25<br>30 | abandoned<br>2 | y | 50 | n |
| TP4.4 | - | - | - | n | 30 | n |
| TP4.5 | - | - | - | n | 27 | y[6] |
| TP4.6 | - | - | - | n | 33 | n |
| TP4.7 | piano<br>saxophone<br>vocals | 20<br>10<br>15 | abandoned<br>3.5<br>1 | y | 27 | n |
| TP4.8 | vocals<br>violine | 2.5<br>8 | 3<br>abandoned | n | 25 | y[7] |
| TP4.9 | - | - | - | n | 28 | n |
| TP4.10 | guitar | 13 | 2 | n | 29 | n |

[6] Reduced hearing capability at high frequencies, left side
[7] Tinnitus both sides

**Table 9:** Classifications of test participants (group 4)

| Test person | Musical instrument | Active years | Time spent hours/week | Listening to classical | Age | Hearing deficiency |
|---|---|---|---|---|---|---|
| TP5.1 | - | - | - | n | 24 | n |
| TP5.2 | drums | 16 | 1 | n | 27 | n |
| TP5.3 | organ | 8 | abandoned | n | 31 | n |
| TP5.4 | - | - | - | n | 28 | n |
| TP5.5 | Cello<br>piano | 24<br>12 | 0.015<br>5 | n | 30 | n |
| TP5.6 | vocals | 20 | 0.5 | y | 33 | n |
| TP5.7 | - | - | - | n | 27 | n |
| TP5.8 | piano<br>vocals<br>guitar<br>trumpet | 28<br>24<br>20<br>6 | 8<br>5<br>5<br>abandoned | y | 25 | y[8] |
| TP5.9 | - | - | - | n | 27 | n |
| TP5.10 | bass guitar | 6 | 4 | n | 25 | n |

[8] Deficiency left side

**Table 10:** Classifications of test participants (group 5)