# Eighth-Notes Performances: Kinds of Inégalité

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## ABSTRACT

From a technical perspective the impression of inégalité in musical pulse mainly refers to aspects of timing, loudness, and duration. Musicians tend to model these performance parameters intuitively and listeners seem to perceive them, to a certain degree, unconsciously.

Expert musicians and non-experts were asked to interactively tune performance parameters in a short four-bar phrase. A recently developed performance synthesis tool furnished the technical base for this analysis. The results give insight into the relationships between performance parameters and give rise to discuss the role of expertise and skill in a slightly different light. Although the analysis of appropriate performance parameters is difficult, the need for it is still beyond question for the improvement of liveliness in synthetic performances.

## Keywords

Synthetic Performance, Notes Inégales, Timing, Articulation, Duration, Loudness, Dynamics

## 1. INTRODUCTION

The liveliness of a synthetic performance depends on the variability of performative features, such as timing, dynamics, and articulation. Beside the importance of large phrase units liveliness also refers to the pulse of the meter, particularly at a constant tempo. The French term inégalité is borrowed from a historical discussion referring to a timing phenomenon in the Baroque era. But in the present study inégalité is seen more widely as a phenomenon, of which timing, loudness, and tone-duration are three dimensions of its entirety. Articulation contains more than the duration of a tone [11, 12], but the duration in particular is of interest in the present context.

Timing still seems to be a core feature of expression. One of the pioneering researchers in timing was Gabrielsson, who analyzed ratios of beats or frequent notes at the sub-beat level [8]. In short, he found various degrees of differences between notes of equal value—but no constant pulse in music performances at all. His observations derived from analyses of a broad stylistic range reaching from Swedish folk songs to the Viennese Waltz. Similar phenomena were also discovered in more remote cultures, as Gerischer demonstrated [9], or in diverse Western music styles, as analyzed by Langner [13].

While research in the 20th century contributed to the scientific description of this phenomenon, the fact itself has been known in theory and practise since the rise of notes of definite values. The most prominent example in European history is the note inégale in Baroque music (Hefling discussed this in detail [10]). Referring to original sources like Quantz' treatise [15], inégalité has always included aspects of loudness and articulation. The most important difference between the historical meaning of notes inégales and today's non-equal playing of eighths is that notes inégales always prolongate the notes occurring on metrical accents, whereas in other times, styles, and cultures the prolongation can also fall on notes between.

This paper analyzes the impression of inégalité with respect to different performance parameters. With the help of an interactive performance rendering tool, participants could adjust three performance parameters separately or in combination (see Section 3). Interdependencies between different parameters are uncovered in Section 4. As the results also show, an important aspect is he ability of listeners to identify performance parameters. Since this turned out to be difficult, Section 5 includes a discussion of this aspect and other findings, e.g., the correlation of different parameters and the effects of expertise.

## 2. HYPOTHESES

The main assumption was that any of the three performance parameters timing, loudness, and duration may emphasize a tone. Considering this, one might ask whether those multiple means for emphasis are cumulative. This would entail that an intensive use of a single performance parameter causes the same emphasis—and therefore the same impression of inégalité—as a slight use of multiple performance parameters. To avoid an overemphasis, the musician or music producer must balance out these parameters, which leads to a compensation effect.performance parameters Following Gabrielsson's approach [7] a further question was whether specialized performers or listeners prefer a different degree of inéalité than non-specialists. These considerations led to the following hypotheses:

1. When controlled separately, the parameters of timing, loudness, and duration are used to a larger extend than in combination.
2. Assuming a cumulative effect, there should be a negative correlation between all parameters when used in combination.
3. The results are more distinct or only significant for participants who are experts. Experts should also be more correct in identifying a parameter by listening.


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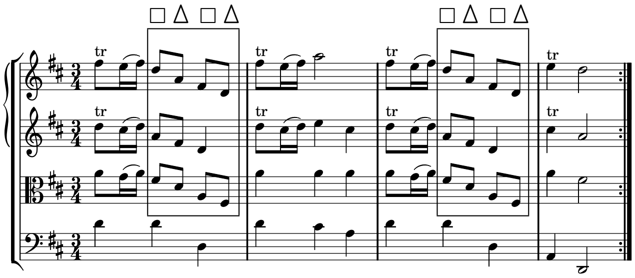

**Figure 1: First bars of the Polonoise taken from the overture in d-major "La Gaillarde" TWV 55:D13 for strings & b.c., composed by G. P. Telemann.**

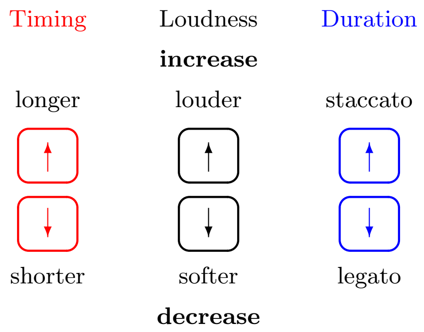


**Figure 2: Instructions for the modification of eighth notes occurring on the beat.**

# 3. METHODOLOGY

The "Analysis-by-Synthesis" approach used in this study reaches back to Seashore and his colleagues, like Metfessel,[16, 14] but was outlined in detail by Bengtsson and Gabrielsson [1]. Normally, various stimuli were presented to listeners, who were then asked to judge them. These stimuli comprised synthetic performances that differed in the characteristic of some particular performance parameters and the listener's judgements indicate which of them are most appropriate.

In the present study this approach was modified for the following reason: the total amount of stimuli depends on the number of grades a parameters is subdivided into and increases to the power of parameters used. A combination of three parameters of 21 grades each would result in $21^3 = 9261$ stimuli, which are impossible to be presented to listeners. The problem was to provide all stimuli but at the same time reduce them to a minimum. This was solved by letting the participants manipulate these three parameters independently and interactively until they approved the parameter combination they preferred.

The whole procedure, the technical setup and the participants are described in the following Sections.

## 3.1 Procedure

The appropriate degree of inégalité strongly depends on musical structure and may change from bar to bar. This made it necessary to minimize the stimulus. Another constraint of the stimulus was based on the question about whether there is a difference between experts on Baroque performances and non experts.

The stimulus comprised the first four bars of a Polonoise composed by G. P. Telemann, which are shown in Figure 1.

Two tests were carried out, first a *separate parameter test* and then a *combined parameter test*. In the first test the participants were asked to modify the performance of the eighth notes of the stimulus, which was presented in a loop. With the Arrow-Up key the eighth notes on the beat (□ in Figure 1) were emphasized. A decrease of this emphasis or even an emphasis of the eighths between the beats (△ in Figure 1) was set by pressing the Arrow-Down key. If the limit of the parameter spectrum was reached, a beep signaled that no further modification was possible in that direction.

The first test consisted of two tasks: First, the participants were asked to identify the means by which they emphasized the notes, i.e., to identify the parameter they set. Then they had to tune the relation of the eighths as they supposed to sound best and confirm with the Enter-key. The participants were not influenced by a visual feedback indicating the parameter value. They only saw the score including the squares and triangles as shown in Figure 1 and therefore depended completely on the auditive feedback.

In the second test the same stimulus was presented to the participants, who now had the opportunity to tune all three parameters independently. All parameters were set by the array of six control-keys above the arrow keys, which were labelled with up and down arrows in red, black and blue. In this test the participants were handed an instruction referring to the parameters and the keys as shown in Figure 2.

## 3.2 Technical Setup

Technically, an expressive performance is a series of features that set and modify certain properties. We developed and implemented mathematical models to describe those features. This includes

**Timing:** tempo (macro timing), rubato (self-compensating micro deviations), asynchrony, and random imprecision [3, 4]

**Dynamics:** macro dynamics and metrical accentuation [5]

**Articulation:** Articulation instructions can be freely defined regarding their effects on tone loudness, duration, and timbre [11, 12].

Their flexible parameterization allows to create a huge bandwidth of characteristics—typical (as can be observed in human performances) and even atypical. The models were applied to render expressive MIDI sequences. Our performance engine implements a standard MIDI output mode and additionally some specialized functionalities for the output over the software sampler *Vienna Instruments*. In this study, however, we applied the software *VSampler 3* that runs smoothly on laptops, allowing for more flexibility and mobility.

Using three controllers (see also figure 2) the participants of the study could steer certain parameters that influence the timing (rubato), dynamics (metrical accentuation), and articulation (tone duration). The parameter space was discretized into 21 steps (controller states) reaching from -10 (minimal setting) to 10 (maximal setting).

**Rubato:** While the basic tempo remains unchanged at 120 bpm the intensity of micro deviations could be controlled. The rubato frame was of the length of a quarter note. Thus, for each quarter note a swing-like distortion could be created. This distortion is modelled by a potential function in the unity square. The timing relation between first and second eighth is:

$$\Big((0.5^i)\,0.98 : (1 - 0.5^i)\,0.98\Big) \quad | \quad i \in [0.4, 1.6]$$

The parameter $i$ was set by the timing controller. Values between $10 \to (i = 0.4)$ and $-10 \to (i = 1.6)$ were linearly interpolated.

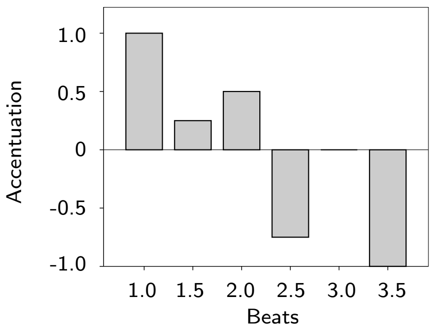


**Figure 3: The accentuation scheme could interactively be scaled.**

**Metrical Accentuation:** A predefined accentuation (see figure 3) scheme was applied to each measure. The user could set the intensity, that is the loudness scale of the scheme, ranging -60 up to 60 MIDI velocity units. The maximal controller setting created a pianissimo for the softest and a fortissimo for the strongest accentuations (a range of 107 MIDI velocity units). By a negative intensity setting the scheme could also be inverted.

**Articulation:** The durations of two eighth notes under a quarter beat could be changed from legato to a very short staccato. Thereby, a very cantabile or more rhythmical performance could be created, but the duration of the second eighth note decreases faster than the first so that the emphatic relation between both notes shifts accordingly. Three sampling points were defined and linearly interpolated.

| controller state | Duration of | |
|---|---|---|
| | 1st eighth | 2nd eighth |
| 10 | 0.35 | 0.2 |
| 0 | 0.7 | 0.4 |
| -10 | 1.0 | 1.0 |

The positive controller settings for rubato and metrical accentuation cover the scope that could be observed within human performances. Negative settings create inverse characteristics. This does not apply to articulation, of course, as negative durations are practically impossible. In the *separate parameter test* the controllers were randomly initialized at the extremes, i.e. -10 or 10. In the *combined parameter test* the initialization was also random but over the full parameter space.

All manipulations could be done directly while the music was playing. The music engine [2] updated the performance within a latency frame of 500 milliseconds after interaction. This inertia allowed the engine to collect multiple inputs and align the changes with the next beat or barline to produce a more homogenous musical output.

Furthermore, the system tracked all interactions. The protocol recorded the time of interaction and the controller settings. At the end of the test the users had to approve the setting. The complete test duration was also protocolled. This allows insights into how the users explored the search space (there was no visual output, only the music to listen to) and how long they listened to certain settings until they made a decision and interaction.

## 3.3 Participants

In order to analyse the expertise of the participants, diverse skills were captured in more detail.

Since it was important for this task to gain musicians with high skills and knowledge about the Baroque performance of notes inégales the test included musicologists, musicians, music teachers, and professional musicians specialized in *Historically Informed Performance* (HIP).

The participants comprised 36 western socialized adults, including 21 women and 15 men. To ascertain their expertise they were asked for how many years they were playing an instrument, if they had a degree in music, musicology, music education or similar subjects, how much they liked classical and Baroque music, and whether they were working as a professional musician. The answers to these questions were used in the later analysis to test which expertise factor influenced the particular results most.

10 participants were professional musicians, 16 had a degree in music, 20 played an instrument for more than 10 years, 14 of which for more than 20 years. 25 stated to be interested in classical music or Baroque music in particular. 22 were acquainted with the term HIP.

# 4. RESULTS

The difficulties the participants had were more pronounced than expected. Hence, 11 participants had to be excluded from the second task. The remaining 25 participants included 19 playing an instrument for more than 10 years, 15 with a degree in a music related subject and all 10 professional musicians.

## 4.1 Separate Parameter Test

The answers given in the first task were collected and manually classified as correct, ambivalent, or incorrect. A correct answer had to be unambiguous. This was a problem regarding the differentiation between timing and duration, for the term "length" is ambivalent (it might refer to the length of the inter-onset-interval (timing) or the tone duration). "Length" was correct for articulation only if the timing parameter was undoubtedly distinguished and vice versa, like in the combination of "length" and "articulation" or "tempo" and "length". It was otherwise ambivalent. If a participant wrote two times "length", he or she was asked to specify the difference. If impossible, no specification was made and both were ambivalent. The results of the first task are given in Table 3.

A Kolmogorov-Smirnov and Shapiro-Wilk test showed that the distribution of controller values from the second task was not normal, particularly for timing. To solve this problem the question was raised whether the participants did use a spectrum large enough to get an impression of the possibilities they had (it was also hardly possible to identify the parameter if it had not been modified to a certain degree). Therefore, data were excluded when the modification range during the test was below seven (regardless of the value finally approved). Under this condition four timing samples and two duration samples were excluded. The remaining samples showed a normal distribution and were used for further analyses.

## 4.2 Combined Parameter Test

In the second test, timing was the parameter modified most, as shown in Figure 4. A nonparametric test for independent samples (Friedman test) showed that the differences between the three groups were significant at the $\alpha = 0.001$ level.

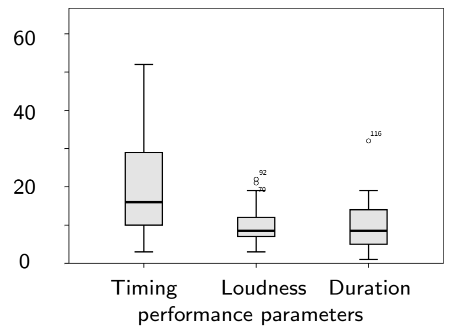


**Figure 4: Amount of modulations for each of the three parameters during the combination task.**

## 4.3 Hypothesis 1: Differences

The sample pairs of the controller values taken from the separate and combination test were tested for timing, loudness, and duration. The null hypotheses that the mean values and variances were the same were tested with a t-test and a Levine-test, respectively. None of the null hypotheses could be rejected so that there was no difference between a separate and a combined modulation of any parameter. Figure 5 shows the results of the controller values for both tests.

## 4.4 Hypothesis 2: Correlations

Timing and loudness were negatively correlated. The Pearson correlation coefficient of $r = -0.653$ was significant with a $p = 0.001$. The plot in Figure 6 shows every sample pair of timing and loudness values, and a regression line to illustrate the correlation. Both timing and loudness were independent of duration.

## 4.5 Hypothesis 3: Expertise

The influence of expertise on the parameter identification was analyzed with a $\chi^2$ test. The results are listed in Table 3. From a strict statistical view expertise had only an influence on the identification of duration. There may be two considerations mentioned in this context: First, participants with a degree in a music related subject are to the better half represented in the group of participants playing an instrument for more than 10 years. And second, professional musicians are both a subgroup of participants playing

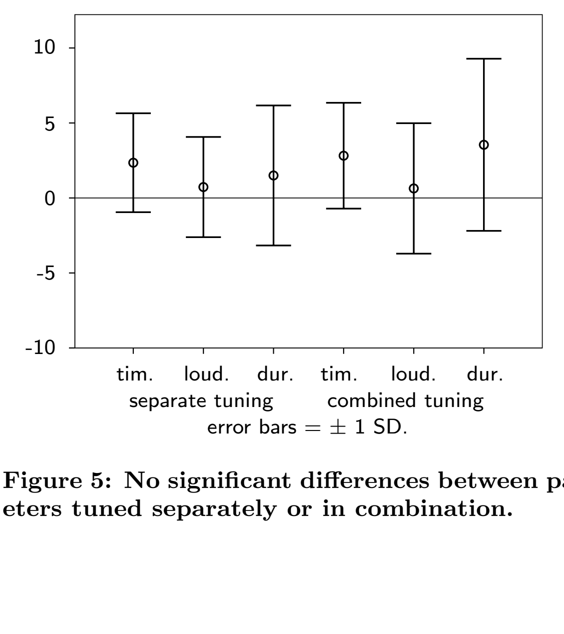


**Figure 5: No significant differences between parameters tuned separately or in combination.**

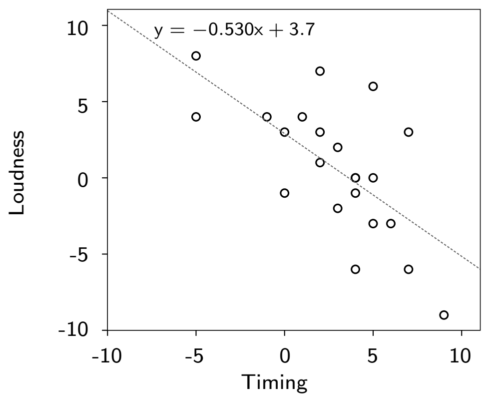


**Figure 6: The regression line demonstrates the negative correlation between timing and loudness values.**

an instrument for more than 10 years and participants with a degree in music. Only the professional musicians just missed the significance for the remaining parameters.

The influence of personal factors (including the expertise factors) on the distribution and mean values of the controller values were analyzed with an ANOVA and a Levine-test. For every expertise factor both null hypotheses were confirmed, i.e., the mean values and variances did not differ, which meant that the expertise had no effect upon the controller values.

Only in the first test did gender have an effect on duration and timing, which is shown in Table 1.

Another group of experts was discovered by a comparison between participants who could identify the parameters and those who could not. Although the mean values did not differ, the null hypothesis that the variances were equal was rejected for timing and loudness, as shown in Table 2. These differences are also plotted in Figure 7.

## 5. DISCUSSION

According to the rules of HIP, all performance parameters should be manipulated slightly in a positive direction. This was the case for the mean values of every of the three parameters timing, loudness, and duration, regardless of the participant's expertise (see Figure 5). The different distributions plotted in Figure 7 can be interpreted in two directions: The negative interpretation is that there is no definite proper characteristic for the particular stimulus when parameters are modelled just intuitively. The other, more positive interpretation, is the observation that even if participants do not know what they control, their results do not differ from expert's results regarding the mean value.

When summarizing the remaining results of the previous Section three pairs of conflicting statements occur, which can be discussed:

**Table 1: Differences between participants in the first test.**

| | Gender | N | Mean | SD | ANOVA F | ANOVA p |
|---|---|---|---|---|---|---|
| loudness | women | 20 | **3.00** | 4.801 | 7.777 | 0.009 |
| | men | 13 | **-1.31** | 3.473 | | |
| timing | women | 15 | **1.74** | 3.679 | 4.526 | 0.042 |
| | men | 17 | **0.46** | 2.537 | | |

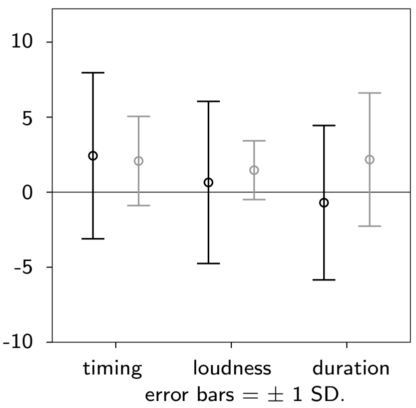


**Figure 7: Results of separate tuning. Values tuned by participants identifying parameters correctly (gray bars) compared to others (=black bars).**

1. Timing was the most frequently used performance parameter to gain the impression of inégalité; but the extent of the timing parameter did not differ significantly to loudness or tone-duration.

2. Timing and loudness seem to be cumulative, for they showed a negative correlation; but, on the other hand, the extent of performance parameters did not differ between the separate or combined test.

3. There were no differences between experts and non-experts referring to their statements. But the variance in the first task differed between participants who identified the parameter correctly by listening and those who failed. Furthermore, the only personal factor with an effect on the results was gender.

The first point indicates that timing was the most difficult parameter. Until the participants approved their timing adjustment they pressed the arrow- keys about twice as much as they did for loudness and duration. Interestingly, timing was also the parameter most participants identified correctly. Because timing was the first parameter used in the test, there is the additional factor that the participants still had to become acquainted with the task and get a feeling for the parameter space available. It remains unclear whether or not this playful approach contributed to the correctness of justification. A separate test of this hypothesis should furnish some interesting aspects of interfaces being as goal-directed as intuitive.

The second statement is not as conflicting as it seems at first sight. While the correlation refers to the parameter pairs, the mean values refer to the distribution of all values independently. The negative correlation states that participants increasing the timing parameter are quite likely to decrease the loudness parameter. Timing and loudness are therefore like two elements on a see-saw. This dependency also causes a mirroring of the distribution of both parameters. An equal mean value indicates that this see-saw is balanced out and that both timing and loudness might be equal to emphasize notes for the impression of inégalité, for it remains unclear which one is dominant.

That, additionally, the mean values did not differ between both tests indicates that timing and loudness are not only equals for an emphasis but also interchangeable. This would indeed be a surprising result that should be investigated in more detail.

Less expected were the results referring to the expertise that led to the third statement. Of course, the results of participants identifying parameters by listening clearly showed a smaller variance for timing and loudness. The ability to identify the parameters correctly is a factor of expertise. Moreover, it is the most influencing factor but at the same time not represented by any other expertise factor of the participants. Although the results in Table 3 are non significant they furnish another hypothesis: The fact that only the professional musicians just missed the significance may be due to the small amount of professional musicians included in this study. No professional musician failed in identifying timing and only two failed in loudness-identification. Therefore, the group of professional musicians gained a much higher $\chi^2$ and a much lower $p$ value than the other groups. This may lead to a hypothesis of a twofold expertise: a motor-expertise and a knowledge-expertise. Participants with a degree in music related subjects, e.g. musicologists, have an expert knowledge but may lack motor skills (simply because of a lack of time to practise etc.). Participants playing an instrument for more than ten or twenty years may have motor skills but a lack of knowledge about special topics like HIP. Both groups did not differ from other participants (see Table 3).

The crucial aspect of motor planning and motor control

**Table 2: Levine-Test of equal variances. Results of participants correctly identifying the parameter they are tuning show a smaller standard deviation (SD).* including ambivalent answers.**

| | Correct | N | Mean | SD | Levine-Test F | p |
|---|---|---|---|---|---|---|
| loudness | no* | 20 | 0.65 | **5.40** | 13.831 | 0.001 |
| | yes | 15 | 1.47 | **1.96** | | |
| timing | no | 7 | 2.43 | **5.53** | 5.478 | 0.026 |
| | yes* | 25 | 2.08 | **2.97** | | |

**Table 3: Parameter identification: Differences between participants playing an instrument for more than 10 years (=instr.), with a degree in music (=degr.) and professional musicians (=music.) are compared to each remaining with a $\chi^2$ test.**

| | | all | instr. | | degr. | | music. | |
|---|---|---|---|---|---|---|---|---|
| | | | yes | no | yes | no | yes | no |
| | $\sum$ | 36 | 20 | 16 | 16 | 20 | 10 | 26 |
| Timing | correct | 21 | 12 | 9 | 8 | 13 | 6 | 15 |
| | ambivalent | 7 | 5 | 2 | 5 | 2 | 4 | 3 |
| | incorrect | 8 | 3 | 5 | 3 | 5 | 0 | 8 |
| | $\chi^2$ | — | 1.792 | | 2.563 | | 6.092 | |
| | $p$ | — | 0.383 | | 0.336 | | 0.053 | |
| Loudness | correct | 15 | 11 | 4 | 8 | 7 | 7 | 8 |
| | ambivalent | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| | incorrect | 19 | 8 | 11 | 7 | 12 | 2 | 17 |
| | $\chi^2$ | — | 3.337 | | 0.950 | | 5.979 | |
| | $p$ | — | 0.193 | | 0.740 | | 0.051 | |
| Duration | correct | 17 | 12 | 5 | 9 | 8 | 7 | 10 |
| | ambivalent | 7 | 5 | 2 | 5 | 2 | 3 | 4 |
| | incorrect | 12 | 3 | 9 | 2 | 10 | 0 | 12 |
| | $\chi^2$ | — | 6.808 | | 6.311 | | 6.930 | |
| | $p$ | — | 0.032 | | 0.049 | | 0.030 | |

is known since the early studies of Clynes and Walker [6] and Shaffer [17]. A motor program allows storing a single movement consisting of temporal and spatial parameters. Applied on an instrument, these movements cause certain effects on timing, loudness, and articulation. In a similar way these parameters seem to be perceived as a whole rather than as a combination of different parameters. Only the group of professional musicians was very close to identifying the parameters better than the other participants at a significance level of $\alpha < 0.05$. Although all professional musicians were included in both other groups these groups differed to the other participants quite remote from significance.

Professional musicians specialized in HIP have multiple skills: (i) the ability to mirror the motion of the stimulus, (ii) detailed theoretical knowledge about performance parameters and (iii) a knowledge about where to apply certain characteristics on a particular piece of music regarding advocations from historical sources. As students orally told, the conscious decomposition of these performance parameters is part of the practice at the department of early music of the UdK in Berlin. And experts are also acquainted with these parameters that are important aspects in the whole HIP discourse. The suggestions about motor-skill as an additional expert-"knowledge" beside theoretical knowledge are speculative, of course. But the consequences would be so far-reaching that a detailed analysis of this hypothesis should be one of the major tasks in future research.

The gender difference can be explained by the constitution of the participants. Separately analyzed, women did not significantly differ from men with respect to a degree in music, profession, or the time span they were playing an instrument. But they were to a larger degree represented in several expertise groups. In sum this might have had an effect in this particular case.

# 6. CONCLUSION

Notes at a sub-beat level were played inégal. Therefore, different means to reach this inégalité are loudness, timing and tone duration. Furthermore, loudness and timing are to a certain degree cumulative. The stimulus of this study was taken from a piece of Baroque music to test if expert knowledge on HIP had an effect on the degree of inégalité preferred. This was not the case. The results rather raised questions regarding musical expertise, which were discussed in Section 5.

One requirement of this study was that the participants could manipulate three parameters independently and interactively. Not only was this a technical problem to solve: to handle three parameters independently turned out a quite difficult task. A reason for this might be that humans tend to perceive (as well as produce) different performance parameters as one entirety.

# 7. ACKNOWLEDGMENTS

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