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Spaciousness in Music: the Tonmeister's Intention and the Listener's Perception

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Abstract

Tonmeisters tune the sound of music productions. Besides aspects like spectral balance, loudness and dynamics, spaciousness plays an important role. Music of different genres tends towards different degrees of spaciousness due to generic aesthetic ideals and practical reasons. In this paper, we compare the degree of spaciousness as intended by the Tonmeister and perceived by the listener. 150 music excerpts from 5 different genres (electronica, classical, jazz, rock and ethno) are analyzed. The Tonmeister's intention is derived from the literature and from analysis with a goniometer. The listener's perception is obtained from a listening test with 13 participants. The listening test revealed different adjectives for each genre relating to a spacious perception. We found that general rules as suggested in the literature are barely reflected in the goniometer results or the subjective impressions. Subjective impressions are largely contradictory.

1 Introduction

Spaciousness refers to the feeling of the sound arriving from several different directions [1, p. 325]. It "means that auditory events, in a characteristic way, are themselves perceived as being spread out in an extended region of space." [2, p. 348] The opposite monophonic impression is the feeling that the sound is coming from a narrow gap [1, p. 325].
Many Tonmeisters claim that a mixer's main task is to increase the spaciousness of sound [3, p. 49][4], often referred to as "dimensionality" [5, p. 145]. It has been found that most review comments on music mixes deal with aspects of loudness and spaciousness [6]. Spaciousness is the most important criteria for the evaluation of concert hall acoustics [7, p. 29]. It turned out to be a valuable parameter in content-based music recommendation [19] and is of increasing importance in audio systems [19, 8]. There are certain aesthetic ideals of overall sound, spaciousness perception and intimacy in different communities and domains [10, p. 145][11, p. 119].

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Electronic dance music tends to exhibit little spaciousness. The dominant kickdrum and bass are monophonic with a panning to the center. In the literature, it is furthermore recommended to keep mixes narrow [10, p. 139]. As the stereo loudspeakers in nightclubs are far apart, a hard-panned sound may be inaudible in a wide region of the dancefloor, which is undesired [3, p. 22]. However, especially for melodic and harmonic parts, auditory scene may be larger than life [12, p. 14]. Traditionalists sing and play in real-time [13] and ethnographic recordings tend to conserve the natural auditory scene instead of adding spaciousness effects [14]. Often, music is performed outside with little reverberation. Jazz makes little use of overdubbing techniques but sometimes uses hard panning [3, p. 10][12, pp. 6, 8 and 13][5, p. 153]. When applying hard panning, mono recordings are often used [5, p. 185]. Classical music tends to be recorded with conventional stereo recording techniques in a room with appropriate reverberation [15, pp. 153, 157 and 163][5, p. 156]. These recordings are kept natural [3, pp. 2 and 10]. In contrast to that, rock music recordings co-evolved with recording studio technology and the acoustic spaces are unnatural and often larger than the natural sound scene [3, p. 2][12, p. 13][16, pp. 43-47][5, p. 150]. Guitars are in the foreground and exhibit echo effects [17, pp. 74f.], strong channel decorrelation, and an additional widening of voices and hard panning of instruments is common practice [3, p. 89][10, p. 140][18, pp. 116f., 128f. and 152].
To monitor stereo width, Tonmeisters tend to consult goniometers (also referred to as phase scope or vector scope) that plot the left over the right channel and display Pearson's correlation coefficient between the stereo channels [19, pp. 313f.]. We calculate the entropy of the pseudo phase space and use box-counting to quantify its complexity and the mean correlation coefficient to quantify what the audio engineer saw when monitoring the stereo mix.
What Tonmeisters do when mixing a sound is creating a physical sound event. Perception means the processing of a sound arriving at a listener's ears into electrical signals that are further transferred into the brain. A chain of processes between the physical event in the external world and its perceptual registration by the listener take place [20, p. 21][21]. Thus, the internal representation after the processes can differ from the physical event. Wellek (1982) differentiates the spaces experienced while listening to music by separating the physical space from the psychological space. The auditory information processing of spatial hearing consists of three different aspects according to Blauert's model (1997) : the physical, psychophysical, and the psychological aspect.
In the present study, we analyze 150 music excerpts of 5 different genres, namely electronic dance music, world (ethno) music, jazz, classical and rock music. From the literature review indicated above, we assume that the spaciousness of these genres may increase in this very order from electronic dance music to rock. We investigate whether this order is reflected in the output of audio analyzing tools that Tonmeisters tend to use for mixing and mastering. We furthermore test whether the subjective impression of listeners reveals a similar ranking by letting them rate the perceived spaciousness of each song by several spatial terms. Finally, we investigate the agreement between the statements from the literature, the outcome of the audio analyzers and the subjective rankings.

2 Methods

2.1 Goniometer Analysis/ Objective Measures

Goniometers, also referred to as *phase scope* or *vector scope*, simply plot the left over the right channel of the stereo master output. A mono signal yields one line, no matter where on the loudspeaker base it is panned by means of amplitude panning. Completely incoherent channel signals create a chaotic plot. Tonmeisters monitor the goniometer to ensure that the mix has the desired balance between these two extremes. As this visual monitoring is qualitative rather than quantitative, we applied two methods to quantify the goniometer output. The box counting dimension is often used to analyze data scatter, e.g. to determine the fractal dimensions of sampled continuous functions. Some details and an application on to automatic speech recognition can be found in [23]. First, the two-dimensional plot is divided into a number of equal sized squares. Then, the number of squares that contain a sample is counted. The more widespread the plot, the higher the number of counted squares. We counted all squares that occurred in the excerpt. That means if for example an autopan-effect was used on a mono source file, the complexity would be comparably high. We refer to this quantity as the complexity of the goniometer plot. Another quantity to describe the two-dimensional goniometer with a single number is the entropy. Entropy of signals is often used in music analysis and music information retrieval [24, e.g. ch. 4]. It is a logarithmic measure, which basically gives the number of coordinate pairs that occur with significant probability. Again, the higher the entropy, the less predictable the plot coordinates and the higher the apparent randomness. In addition to the two-dimensional plot, goniometers show Pearson's correlation coefficient of the left and right stereo channel .

2.2 Experiment

For this study, we used the data of a former listening test that took place at the Institute of Systematic Musicology, University of Hamburg [25].

13 subjects listened to the 150 music excerpts of 5 musical genres through two EV Sentry 500 studio monitors and evaluated each excerpt on a scale from 1 (least) to 10 (most) how "artificial", "big", "close", "infinite", "intimate", "low", "open", "narrow", "wide", "rough", "hollow" and "soft", it sounded to them. All participants were either musicology students or research staff of the institute and had prior experiences in listening tests. The music excerpts of the genres electronica, ethno, classical, jazz and rock were derived from cd and saved as .wav-files. They comprised no musical change in dynamic, instrumentation and vocals for an unvarying amount of spaciousness to ensure a coherent judgement [25, p. 13].

During the listening test, the subjects were located in front of the two studio monitors. They listened to the genres in the order: classic, electronic music, jazz, ethno, rock and had about 1min to evaluate each music excerpt according to the twelve adjectives. During that time, the subjects listened to each music excerpt four times. Music excerpts of one genre were played in a row. There was a short break during the listening test for the subjects to refresh.

According to the arithmetic mean, classic is perceived as "big", "open", "wide", "low" and "intimate", rock is allocated to "big", "open", "wide" and "low". Ethno sounded rather "big" and "open" and jazz "big", "open" and "close" (see Figure 1). Electro was perceived as "big", "wide" and "artificial" [25].

More results are described in the next section that also include an analysis of the goniometer results.

2.3 Analysis of Goniometer Results and Listeners' Perception

The results of the complexity, entropy and the listening test are listed in Table 1. The adjectives are sorted by their standard deviation. N is the number the overall ratings for number of $subjects \cdot 112$ *music excerpts*. If N is smaller than $N = 1456$ it means, that subjects missed rating a few music excerpts. In order to ensure to only use clipping-free examples, we excluded some music excerpts and used 112 examples for the analysis. The minimum and the

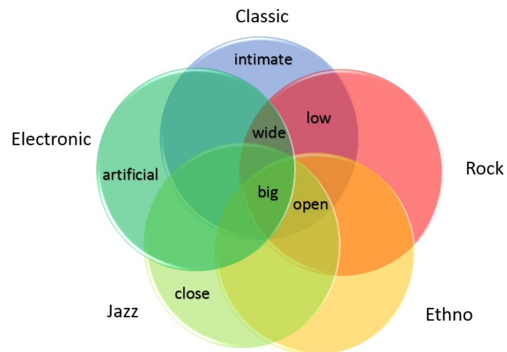

Figure 1: Venn diagram of genres and their adjectives being evaluated > 5 [26].

maximum are the lowest and the highest score evaluated within the whole listening test and goniometer values. The table shows that "big" was rated overall the highest ($\oslash_{\text{big}} \approx 5.41$) followed by "open" ($\oslash_{\text{open}} \approx 5.11$) and "wide" ($\oslash_{\text{wide}} \approx 4.93$). "Hollow" received the lowest ratings ($\oslash_{\text{hollow}} \approx 3.82$) followed by "rough" ($\oslash_{\text{rough}} \approx 3.85$) and "intimate" ($\oslash_{\text{intimate}} \approx 3.94$). According to the standard deviation, "rough", "close" and "narrow" are the adjectives the subjects agreed the most among all adjectives even though the standard deviation is still relatively high. The analysis revealed complexity ($\oslash_{\text{compl}} \approx 0.37$) having a moderately high standard deviation ($\sigma_{\text{compl}} \approx 0.20$) and entropy ($\oslash_{\text{ent}} \approx 13.24$) containing a low standard deviation ($\sigma_{\text{ent}} \approx 0.52$).

	N	Min.	Max.	$\oslash$	σ
Rough	1439	1	9	3.85	2.050
Close	1448	1	10	4.57	2.167
Narrow	1418	1	10	4.15	2.180
Intimate	1443	1	10	3.94	2.226
Hollow	1431	1	10	3.82	2.228
Low	1451	1	10	4.78	2.231
Big	1455	1	10	5.41	2.240
Open	1455	1	10	5.11	2.290
Infinite	1455	1	10	4.04	2.307
Wide	1455	1	10	4.93	2.319
Soft	1451	1	10	4.18	2.324
Artificial	1434	0	10	4.12	2.594
Complexity	1456	0.0037	0.9735	0.3164	0.2034
Entropy	1456	10.1347	13.4012	13.2379	0.5165

Table 1: Descriptive statistic of the adjectives, complexity and entropy that shows the minimum (min.), maximum (max.), the arithmetic mean ($\oslash$) and the standard deviation (σ). The adjectives are sorted by their standard deviation.

A more detailed analysis of each genre's complexity (compl) reveals a ranking listed in Table 2. Rock shows the highest mean value ($\oslash_{\text{compl,rock}} \approx 0.49$) followed by electronica ($\oslash_{\text{compl,electro}} \approx 0.35$), jazz ($\oslash_{\text{compl,jazz}} \approx 0.28$) and classic ($\oslash_{\text{compl,classic}} \approx 0.24$). Ethno contains the lowest complexity ($\oslash_{\text{compl,ethno}} \approx 0.20$).

A more detailed analysis of each genre's entropy (ent) reveals a ranking shown in Table 3. Rock contains the highest mean value ($\oslash_{\text{ent,rock}} \approx 13.39$) followed by classic

Ranking	Genre	N	⊘	σ
1	Rock	325	0.489	0.161
2	Electronica	273	0.351	0.246
3	Jazz	286	0.280	0.166
4	Classic	312	0.237	0.164
5	Ethno	260	0.201	0.111

Table 2: Complexity rankings of genres sorted by the arithmetic mean (⊘).

($\oslash_{\text{ent,classic}} \approx 13.35$), electronica ($\oslash_{\text{ent,electro}} \approx 13.29$) and ethno ($\oslash_{\text{ent,ethno}} \approx 13.13$). Jazz ($\oslash_{\text{ent,jazz}} \approx 13.00$) reveals the lowest entropy.

Ranking	Genre	N	⊘	σ
1	Rock	325	13.391	0.018
2	Classic	312	13.348	0.076
3	Electronica	273	13.291	0.236
4	Ethno	260	13.126	0.694
5	Jazz	286	12.996	0.867

Table 3: Entropy rankings of genres sorted by the arithmetic mean (⊘).

According to the listeners' evaluation, the genres are ranked as followed: infinite is the least represented in jazz, followed by ethno, rock, electronica and it received the highest ratings for classic (Table 4). The ranking for wide is from least to most: ethno, jazz, electronica, rock and classic (Table 5). And the ranking for narrow is from least to most: rock, ethno, jazz, electronica and classic (Table 6).

Ranking	Genre	N	⊘	σ
1	Classic	312	5.00	2.448
2	Electronica	272	4.47	2.472
3	Rock	325	3.64	1.963
4	Ethno	260	3.55	2.196
5	Jazz	286	3.50	2.040

Table 4: Ranking list of genres according to "infinite"-ratings.

In order to check if there is a link between the objective data of the goniometer and the listener's ratings, we calculated the Pearson's correlation coefficients that are shown in Table 7. The results reveal only (very) small correlation coefficients when correlating the adjectives with the genres that were labelled with categoric numbers for the analysis. The most relevant adjectives of our interest for spaciousness "big", "open", "infinite", "wide" and "narrow" reveal highly significant ($p < 0.01$) and not significant ($p > 0.05$) correlations. "Big" and "open" correlate with genre not significantly. "Infinite" ($r = -0.227$), "wide" ($r = -0.083$) and "narrow" ($r = -0.101$) show negative correlations that are highly significant. These low correlations mean that there is only a small link between each adjective and the order of the genre categorization. Also the correlation between the adjectives and entropy (ent) as well as between adjectives and complexity (compl) only reveal (very) small correlation coefficients. Entropy correlates the highest, positively with "big" ($r_{\text{ent,big}} = 0.128$), "infinite" ($r_{\text{ent,infinite}} = 0.109$) and "wide" ($r_{\text{ent,wide}} = 0.100$) highly significant ($p < 0.01$). Complexity correlates the highest, positively

Ranking	Genre	N	⊘	σ
1	Classic	312	5.51	2.253
2	Rock	325	5.24	2.252
3	Electronica	273	5.08	2.317
4	Jazz	286	4.55	2.223
5	Ethno	259	4.14	2.314

Table 5: Ranking list of genres according to "wide"-ratings.

Ranking	Genre	N	⊘	σ
1	Classic	282	4.46	2.364
2	Electronica	267	4.32	2.269
3	Jazz	285	4.18	2.191
4	Ethno	260	4.00	2.039
5	Rock	324	3.85	1.994

Table 6: Ranking list of genres according to "narrow"-ratings.

with "big" ($r_{\text{compl,big}} = 0.329$), negatively with "intimate" ($r_{\text{compl,intimate}} = -0.252$) and "soft" ($r_{\text{compl,soft}} = 0.206$). These correlations for complexity are highly significant ($p < 0.01$). If correlations were (quite) big it would be possible to find indications to predict the perception of an adjective by the entropy and/or the complexity.

A correlation analysis provides information about a link's strength between two variables such as the adjectives, entropy and complexity. One step further, a regression analysis reveals information about the type of relationship between the variables [27, p. 333]. In addition to Pearson's correlation, we checked whether we could find more details about the link between the adjectives and entropy respectively complexity using multiple linear regression. We found that only complexity could be included in the regression analysis. As an example, the analysis for "big" revealed a coefficient of determination of $R^2 = 0.108$ that gives information about the result's meaningfulness. It is the highest coefficient of determination among all adjectives. Checking the result with the Durbin Watson value ($dw = 1.393$), it is in a reasonable range. The highly significant regression function ($p < 0.01$) is the output of how "big" can be explained by complexity:

$$\text{big} = 4.26 + 3.63 \cdot \text{complexity}. \tag{1}$$

Note that this output is quite unaccurate as R^2 is very low. An accurate and meaningful output is achieved if R^2 is close to 1. Figure 2 shows the scatter diagram of the ratings for "big" and complexity. Although R^2 is very low, the scatter diagram reveals an interesting result in the extremes. A complexity close to 0 displays only few "big"-ratings over 7. In addition, a complexity between 0.5 and 1 shows the "big"-ratings disappearing from 1 firstly and later from 2 and 3, too. Thus, at least the complexity is linked to the extremes in the perception ratings.

In addition, we analyzed Pearson's correlation between genre, entropy and complexity (Table 8). Genre correlates positively with complexity ($r_{\text{genre,compl}} = 0.284$) highly significant ($p < 0.01$) but not significant ($p > 0.05$) with entropy. Complexity and entropy reveal a moderate correlation with a highly significant ($p < 0.01$) correlation coefficient ($r_{\text{compl,entropy}} = 0.425$).

Adjective	Genre	Entropy	Complexity	N
Low	-0.035 (n.s.)	0.066*	0.153**	1451
Open	-0.035 (n.s.)	0.052*	0.101**	1455
Infinite	-0.227**	0.109**	0.120**	1455
Soft	-0.218**	-0.055*	-0.206**	1451
Intimate	-0.079**	-0.086**	-0.252**	1443
Hollow	0.109**	-0.044 (n.s.)	-0.046 (n.s.)	1431
Wide	-0.083**	0.100**	0.167**	1455
Rough	0.247**	-0.019 (n.s.)	0.190**	1439
Artificial	-0.118**	0.036 (n.s.)	0.080**	1434
Close	-0.069**	-0.084**	-0.180**	1448
Narrow	-0.101**	-0.043 (n.s.)	-0.090**	1418

Table 7: Pearson's Correlations between adjective ratings and genre, complexity and entropy.
*** Correlation's significance $p < 0.01$ (two-tailed).
** Correlation's significance $p < 0.05$ (two-tailed).
n.s. Correlation is not significant, $p > 0.05$.

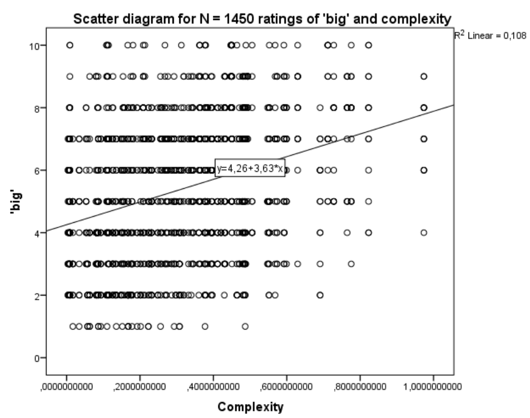

Figure 2: Scatter diagram for regression output between "big" and complexity.

3 Discussion

The ranking by phase scope entropy is rather comprehensible. Rock music using decorrelation methods and classical music having a rather strong reverberation exhibit the highest entropy, followed by electronic dance music which makes use of channel decorrelation in the medium and upper frequency region. Ethno music is relatively dry, as it is often recorded outside with little reverberation. Jazz, using narrow instrument recording but hard panning, has the lowest entropy. The complexity ranking seems to be closely related to the naturalness of the auditory scene. Rock and electronic music, creating unnatural sound scenes, have the highest complexity. Classical music and ethnic recordings which conserve the natural room acoustics, have the lowest complexity. Jazz, which is kept relatively natural except the hard panning and some audio effects, lies somewhere in between.

As the perception of listeners can differ from the actual physical sound it is not remarkable that the results of the listening test reveal a different ranking than the intention of the Tonmeisters according to the literature does. More research is needed in order to find a way to being able to

	Genre	Entropy	Complexity
Genre	1	-0.011 (n.s.)	0.284**
Entropy	-0.011 (n.s.)	1	0.425**
Complexity	0.284**	0.425**	1

Table 8: Pearson's Correlations between Genre, Entropy and Complexity.
*** Correlation's significance $p < 0.01$ (two-tailed).
n.s. Correlation is not significant, $p > 0.05$.

better predict the listeners' experience by the Tonmeister when mixing a sound. The listening test contains different adjectives to describe spaciousness more detailed. It makes sense that the adjectives' ratings reveal different rankings as they represent different characteristics of spaciousness. However, the genres' ranking according to the literature is surprisingly different to the entropy's and complexity's ranking as well as to our most relevant adjectives.
Rock and jazz are the only genres that match in the literature's ranking and the complexity ranking. Rock received the highest ranking and jazz is placed in the middle. Ethno is represented quite well in the lower rankings in both cases. But electronica and classic are described very differently in the literature as found in the complexity rating.
The entropy ranking corresponds to the literature ranking quite well. Rock, classic and ethno share the same rank in both rankings. Only jazz and electronica have different ranks. In the literature, jazz is placed in the middle and electronica on the lowest rank. On the other hand, electronica's rank is in the middle and jazz' rank on the bottom.
Looking at the "infinite" rankings, only ethno is ranked the same. Classic is ranked on the top places in both rankings but the ranks for electronica, rock and jazz are different. "Wide" ranking differs from the literature's ranking, too, but only because of small changes. Rock and classic both share the same top ranks. Jazz is placed in the lower, middle ranks and ethno in the lower part of the rankings. Only electronica's rank is more apart in both rankings. Lastly, comparing "narrow's" ranking with the literature's ranking, jazz and ethno share the same ranks in the middle, lower part. Classic is in the top places in both rankings but electronica and rock are very different. In "narrow's" ranking electronica is on the second and rock is on the last rank, it is the opposite in the literature ranking. Thus, the genres show at least some commonalities although the rankings seem very different at first.
Taking the Pearson's correlation analysis into account, it should be noticed that there is only a weak, statistically significant ($p < 0.01$) relationship between the ratings of "infinite", "wide" and "narrow" and the genre, entropy and complexity. Thus, further meaningful analysis such as a function explaining the results is hardly possible.

4 Conclusion

The spaciousness ranking according to the literature (from least to most: electronica, ethno, jazz, classical, rock) is neither represented in the evaluation of the listeners (e.g. "infinite": jazz, ethno, rock, electronica, classic) nor found in the complexity of the goniometer (ethno, classic, jazz, electronica, rock). Still, genre correlates lowly but statistically significant ($p < 0.01$) with the evaluation of the listeners in respect to the adjectives "infinite", "wide" and "narrow" and the complexity of the goniometer. Also, the subjective ratings can be explained by the complexity of the goniometer statistically significant ($p < 0.01$). Concluding, spaciousness recommended by Tonmeisters can be recognized in different genres, but the genres reveal large overlapping in respect to their amount of spaciousness. Thus, these recommendations serve as rough orientation but are not supposed to be universal guidelines.

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