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Room acoustics, soundscapes and customer satisfaction in restaurants – a field study

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ABSTRACT

Studies of the hospitality industry on restaurant quality only partially consider the acoustical side of atmosphere. In contrast, studies on restaurant acoustics make high demands in terms of low reverberation times to account for speech intelligibility. This raises questions regarding the reasons for this discrepancy and desirable auditive characteristics in the context of restaurants. We thus carried out a correlational field study involving a sample of 12 restaurant settings. In this study, we investigated the effect of reverberation time and sound pressure level on customers' perceived affective quality of the soundscape. In addition, the relationship between soundscape pleasantness and the overall satisfaction with the restaurant was analyzed. Analyses using linear mixed-effects models revealed that the soundscape indicators pleasantness and eventfulness are related to the (room) acoustical parameters sound pressure level and reverberation time. Moreover, soundscape pleasantness judgments were shown to predict overall customer satisfaction. Theoretical and practical implications for the acoustical design of restaurants are discussed.

Keywords: Soundscape, Restaurant Acoustics, Gastronomy Acoustics

1. INTRODUCTION

In most human cultures, people get together while dining and have conversations. Therefore, visiting a restaurant is a highly social experience. Also, a restaurant visit can be regarded a highly multisensory experience as the quality and comfort of a restaurant visit is not only determined by the taste of food, but also by many other factors, such as service quality, odors, lighting, and furniture. While previous hospitality industry research found robust relationships between atmosphere and consumer behavioral intentions in restaurants (e.g., Jang and Namkung (1)), little attention has been paid to the contribution of acoustical factors on atmosphere and overall customer satisfaction. However, a recent American survey (2) amongst 13.000 restaurant guests suggests that the acoustic environment the visitor experiences during their visit might be one of the crucial factors influencing customer satisfaction. In this survey, participants rated noise (24%) as the highest ranked disturbance, followed by service (23%), crowds (15%) and high prices (12%). The importance of acoustics is highlighted further by studies on cross-modal perception which have shown that auditory stimuli can affect our sense of taste (3,4). For example, Woods et al. observed that gustatory cues are diminished by loud background noise (3). Another experiment report in the same paper revealed that the liking of sounds heard while eating was associated with the liking of the food itself. Finally, North et al. showed that the taste of wine can reflect the semantic connotation of the background music listened to while drinking (5).

National standards have defined acoustical parameters that should be accounted for to enable a comfortable stay in public spaces, such as dining rooms in terms of recommended reverberation times or minimum equivalent absorption area. More concretely, the German institute for standardization DIN (6) proposes the following formula for rooms with fairly long-term stay (class B3) including dining spaces (the formula was dissolved for T by the authors):

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$$T \leq 0.163 \cdot (3.13 + 4.69 \cdot \lg(h/1\ \mathrm{m})) \qquad (1)$$

with h being the room height and T the reverberation time.

Moreover, Rindel (7) suggested a classification system with requirements concerning reverberation time and volume of restaurants to achieve sufficient quality of communication. The suggested requirement is expressed by

$$T \leq 0.063 \cdot (V/N) \qquad (2)$$

Following Formula 2, a restaurant with a volume of 300 m^2 and 50 seats would require a reverberation time of less than 0.38 s. In contrast, according to Formula 1 (DIN), a room of the same volume with a ceiling height of 2.8 m would require a reverberation time of 0.85 s. Finally, considering Battaglia's study on restaurant acoustics (8), a specific narrow range of reverberation time between 0.5 and 0.7s would be optimal to provide acoustical comfort for restaurant guests of all ages.

Clearly, there are considerable differences between these recommendations. While standards and classifications offer a first orientation regarding basic acoustical requirements, there still seems to be a lack of consensus amongst both scientists and practitioners concerning the question what ‚good' restaurant acoustics is at all. In addition, anecdotal evidence suggests that many restaurants do not meet any of these suggested recommendations, but instead exceed reverberation times beyond 1s. This discrepancy raises the question if restaurant acoustics is underestimated by restaurant owners or overestimated by consultants.

It is reasonable to assume that the acoustical demands of a restaurant vary with its type and characteristics of its guests. For example, the manager of an urban lifestyle restaurant might aim at creating a different atmosphere than the manager of a fine dining restaurant. This hypothesis is supported by the study by Battaglia (8) who found that sound preferences differ by age group. The author observed that participants under 25 years seemed to be unaffected by loud background levels, whereas acoustical comfort of participants aged between 26–45 years decreased whenever they felt disturbed by conversations of other tables. In addition, participants aged between 46–65 years evaluated high acoustical comfort to rather quiet venues allowing for comfortable conversations.

Beyond (psycho-)acoustical metrics such as loudness, sharpness or roughness, the connotative associations evoked by sounds play an important role in people's preference. (9) An approach that does not merely measure certain physical values is given by the soundscape approach accounting for the holistic perception of sounds and highlighting the role of the listener, the context and meaning of a sound. There is a growing interest in soundscape research, especially in the US and UK (10). Numerous soundscape investigations carried out in outdoor spaces provide empirical evidence that people are influenced by the soundscape in terms of affective and behavioral processes (11,12,13). However, it is rather new to apply this approach to the built environment, and particularly few investigations on soundscapes have been carried out in dining spaces (14).

Our study therefore aimed to bridge the gap between classical acoustics, soundscape research and hospitality industry research, with the aim to mark a starting point for a systematic approach what characteristics of 'good' acoustics in restaurants might be, as well as what the actual impact of acoustics in the restaurant context is. More concretely, we investigated the effects of acoustical parameters on soundscape perception as well as the relationship between soundscape perception and quality rating of the restaurant. Therefore, we acquired a broader variety of perceptive and measurable data than earlier studies. In line with previous findings (15), we assumed that the averaged A-weighted equivalent continuous sound pressure level in restaurants measured over a 15 minute time interval ($L_{Aeq15'}$) would be negatively correlated with the perceived soundscape pleasantness (H1) but positively correlated with the perceived soundscape eventfulness as rated by restaurant guests (H2). These terms are described by the ISO standard (16), and their assessment is described in Chapter 2.5. Moreover, we hypothesized that reverberation time would be negatively correlated with perceived soundscape pleasantness (H3). In addition, we expected that the relationship between reverberation time and the rated soundscape eventfulness would follow an inverted U-shape (H4). This means we expect that highest eventfulness ratings would be achieved for medium reverberation times where single sound scenarios are supported by early reflections but can still be discriminated as single events and do not perish in a swamp of noise resulting from long reverberation times. Finally, we assumed that the perceived soundscape pleasantness can significantly predict overall restaurant quality ratings (H5).

2. METHOD

2.1 Sample

We conducted a field survey in randomly picked restaurants in Berlin, Germany. Sixty restaurant managers were approached by personal inquiry, by email, or telephone. Refusals were obtained due to the managers not wanting to disturb their guests, skepticism toward the study, or managers not being available for a personal inquiry. This resulted in a total of 12 restaurants participating in our study.

Eight to 17 restaurant guests per restaurant filled out the questionnaire, yielding a total of 142 participants (mean age: 34.7 years, $SD = 13.0$). Fifty-one participants were male, 88 were female, 2 'divers' and one person preferred not to disclose their gender. Eighty-seven participants had an academic degree, 40 had a general qualification for university entrance, 11 had a general certificate for secondary education, and four persons had no official certificate of education.

2.2 Questionnaire Design

The questionnaire consisted of four sections and a total of 55 items:

- 10 person-related items (age, gender, education, noise sensitivity, hearing impairment, mealtime, visitation motifs, frequency of visits)
- 23 restaurant quality items (10 quality items each as 'importance' and 'performance', willingness to recommend restaurant and repeat visit, recommendations)
- 16 soundscape items
- 6 personality traits items (Extraversion and neuroticism)

Soundscape parameters were assessed by means of the recommended items suggested in the ISO standard (17) and translated into German by the authors. Here, a two-dimensional 5-step Likert scale was used, labelled with the symbols [--] [-] [0] [+] [++]. Items for restaurant quality and visitation motives were gathered from Ponnam & Balji (18) and also translated into German by the authors. The Big Five personality traits Extraversion and Neuroticism were measured through the German short inventory BFI-S by Gerlitz & Schupp (19) on a 7-step Likert scale. All other items were constructed by the authors using 5-step Likert scales.

2.3 Acoustical measurements and restaurant attributes

For the $L_{Aeq15'}$ measurements, a NTI XL2 acoustic analyzer with M2210 microphone was used. The acoustical scenes were recorded in first order ambisonics format using a Sennheiser Ambeo VR Mic to allow for acoustical simulation of the restaurant soundscape in the laboratory. Both microphones were placed in the guest room next to each other and close to a regular table on head height.

Room acoustical measurements were conducted according to the short measurement defined in empty condition using a self-constructed omnidirectional source (with reverse-horn principle), 'DBX DriveRack RTA-M' microphone, 'Focusrite Scarlett 2i2' interface and 'Room EQ Wizard 5.19' software. The measurement signal was a logarithmic sweep with a length of 256k samples at a sampling rate of 44.1 kHz. Cooling aggregates and other noise sources were switched off where possible. To obtain values of $T_{20,m,empty}$, octave band measurements from 400 to 1250 Hz have been arithmetically averaged. The reverberation time in occupied state $T_{20,m,occup}$ was calculated for 80% occupancy according to (6) and used for statistical analyses. These values and further assessed restaurant attributes such as capacity, volume and area of the guestrooms are shown in Table 1.

In addition to the acoustical parameters and the restaurant attributes, the number of guests was assessed by manual count approximately every 15 minutes. Depending on the speed of fluctuation, the interval of count was shortened to 5 minutes or extended to 30 minutes. Occupancy in between these measurement intervals was estimated by means of linear interpolation.

Table 1: Restaurant attributes and requirements according to (6) and (7)

ID	Type	$T_{20,m,empty}$ / s	Capacity	Volume V / m³	Area A / m²	T_{DIN} / s	T_{Rindel} / s	$T_{20,m,occup}$ / s
1	French cuisine	0.70	47	152	54	0.85	0.20	0.48
2	Swiss Fondue	0.53	72	392	119	0.91	0.34	0.44
3	Steaks	0.80	36	142	44	0.90	0.25	0.56
4	Restaurant-Café mix	1.01	75	354	111	0.90	0.29	0.69

5	Italian cuisine	0.64	70	302	97	0.89	0.27	0.49
6	Lifestyle / healthy food	n.A.	37	n.A.	n.A.	n.A.	n.A.	n.A.
7	Indian cuisine	0.54	44	202	61	0.91	0.29	0.43
8	Breakfast and Brunch	1.03	23	338	80	0.99	0.29	0.90
9	Indian cuisine	0.70	72	430	119	0.90	0.37	0.56
10	Indian cuisine	0.74	58	194	63	0.81	0.21	0.50
11	Hip Brunch / Café	0.68	33	184	56	0.91	0.35	0.54
12	German cuisine	0.97	195	793	240	0.91	0.25	0.64

2.4 Procedure

Restaurant guests were asked to fill out the questionnaire during a period of three to four hours on a regular service day. Depending on the manager’s preference, guests were either approached by the first author or the restaurant’s staff. Participants filled out the questionnaire on a tablet PC provided by the authors or on their own smartphone using the browser-based platform LimeSurvey.

$L_{Aeq15'}$ measurements were conducted during the distribution of the questionnaire, and measurements of the room acoustics were performed before or after opening hours under empty conditions.

2.5 Data analysis

$L_{Aeq15'}$ measurements failed in one restaurant (ID 1) due to technical problems, and one restaurant declined the room acoustical measurement (ID 6). In addition, one restaurant (ID 8) behaved differently than the rest of the sample, and was thus considered an outlier. Accordingly, it was not included in the analysis.

For each participant visiting one of the remaining restaurants used in our analysis, the timestamp of the questionnaire transfer was assigned to the respective $L_{Aeq15'}$. In a similar manner, the present occupancy was assigned to each questionnaire, as well as the particular restaurant’s room acoustical measures.

Robust values for soundscape pleasantness P and eventfulness E were calculated from eight soundscape items using the following formulas according to (16):

$$P = (p - a) + \cos 45° \cdot (ca - ch) + \cos 45° \cdot (v - m) \quad (1)$$
$$E = (e - u) + \cos 45° \cdot (ch - ca) + \cos 45° \cdot (v - m) \quad (2)$$

with p = pleasant, a = annoying, ca = calm, ch = chaotic, v = vibrant, m = monotonous.
Subsequently, P and E were divided by $(4 + \sqrt{32})$ to obtain normalized values as suggested by (16).

Statistical analyses were carried out using IBM SPSS 25.0. As the data was hierarchically structured (i.e., containing multiple repeated measures per restaurants), several linear mixed-effects models (LMM) were computed to test our hypotheses, estimating both fixed and random effects. More concretely, we computed random intercept models including a random intercept for each restaurant. Fixed effects were $L_{Aeq15'}$, reverberation time, and soundscape pleasantness, respectively. To test for a non-linear, U-shaped relationship, the LMM was calculated with T and T^2 as fixed effects. Tests of significance were carried out with Type III tests of fixed effects via Satterthwaite’s degrees of freedom method. In addition, marginal R^2 were computed to obtain the variance in the respective dependent variable explained by the fixed effects (20).

Before testing the five hypotheses, a principal component analysis (PCA) of the ‘non-acoustical’ restaurant quality items was carried out, using orthogonal Varimax rotation. The Kaiser-Meyer-Olkin measure of sampling adequacy (= .683) and Bartlett’s test of sphericity (χ^2 = 369.2; df = 36; p < .001) indicated substantial correlations amongst items to warrant a PCA. Three factors with an eigenvalue over 1.0 were extracted explaining 63% of the total variance. The three resulting factors were interpreted as ‘product’, ‘’ and ‘service’.

Table 2 – Factor loadings of the restaurant quality items

Factor	Item (factor loadings)
product	gourmet taste (.806); variety-in-menu (.693); menu price (.680); food presentation (.657)
atmosphere	design & decor (.890); ambience (.758); upscale image (.570)
service	responsiveness (.911); hospitality (.819)

3. RESULTS

3.1 The influence of $L_{Aeq15'}$ on soundscape perception

As assumed by H1, results of a LMM revealed a significant negative association between the $L_{Aeq15'}$ on soundscape pleasantness, $F(1, 11.10) = 8.58$, $b = -0.12$, $p < .05$. Moreover, calculating the $R^2_{marginal}$ reveals that 15.6 % of the variance in the pleasantness judgments was explained by the SPL. The results are shown in Figure 1.

Another LMM further supports our second hypothesis (H2) that the $L_{Aeq15'}$ was positively related to soundscape eventfulness ratings performed by the restaurant guests, $F(1, 11.49) = 27.20$, $b = 0.02$, $p < .001$ (see Figure 2). Here, 30.5 % of the variance in the perceived eventfulness was explained by the SPL ($R^2_{marginal} = .305$).

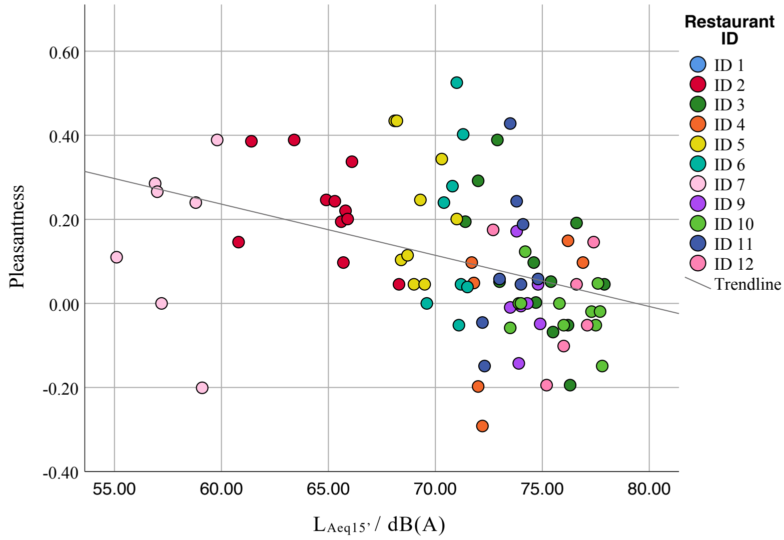

Figure 1: Soundscape pleasantness ratings dependent on the $L_{Aeq15'}$, trendline of linear regression included

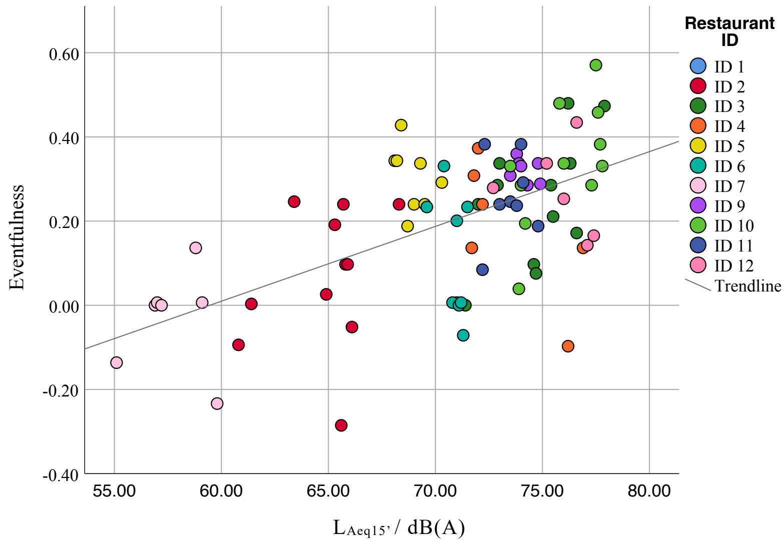

Figure 2: Soundscape eventfulness ratings dependent on the averaged $L_{Aeq15'}$, trendline of linear regression included

3.2 The influence of reverberation time on soundscape perception

Results of a third LMM revealed that reverberation time was significantly related to soundscape pleasantness, confirming H3, $F(1, 9.70) = 6.73$, $b = -0.78$, $p < .05$. Calculating the $R^2_{marginal}$ revealed that 12.3 % of the variance in the pleasantness judgments could be explained by the reverberation time.

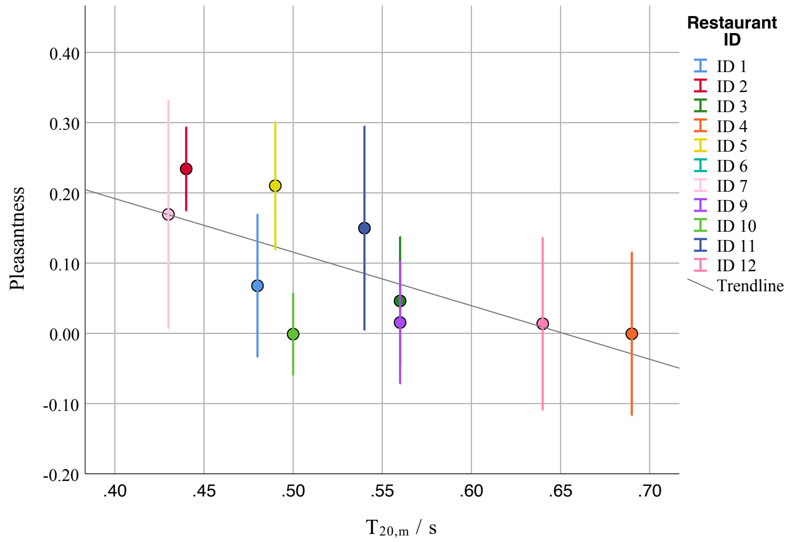

Figure 3: Averaged soundscape pleasantness ratings (with 95% Confidence Interval) dependent on reverberation time $T_{20,m}$ in seconds, trendline of linear regression included

Concerning H4, another LMM confirmed our hypothesized non-linear relationship between the reverberation time and soundscape eventfulness, with the linear term T, F (1, 8.18) = 11.49, b = 13.50, $p < .01$, and the squared term T^2: F (1, 8.21) = 10.47, b = -11.55, $p < .05$. The assumed inverted U-shaped association is depicted in Figure 4, indicating that the highest averaged eventfulness ratings were achieved for medium reverberation times around 0.7–0.8s. Calculating the R^2_{marginal} reveals that the model explained 23.7 % of the variance in the eventfulness judgments.

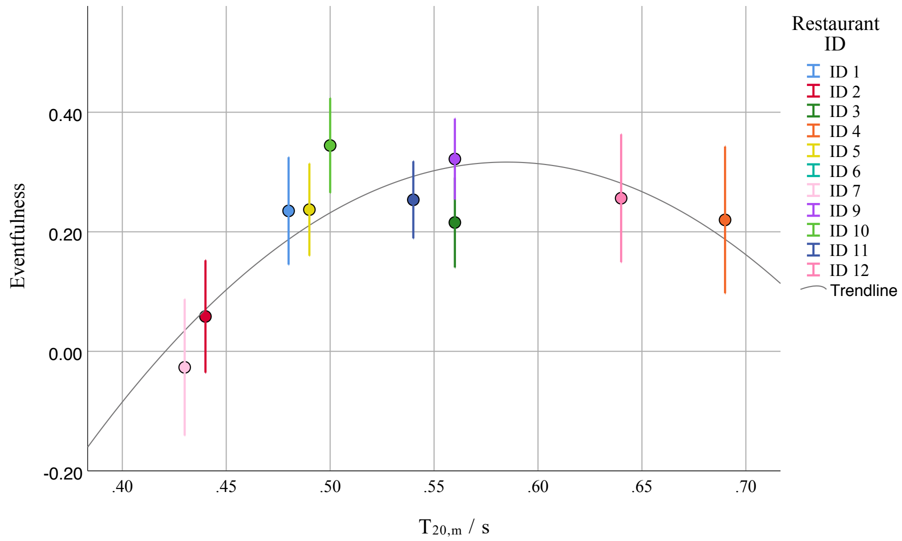

Figure 4: Averaged soundscape eventfulness ratings (with 95% Confidence Interval) dependent on reverberation time $T_{20,m}$ in seconds, trendline of quadratic function included

3.3 The influence of soundscape perception on overall quality

Finally, results of a LMM also showed a significant positive association between the soundscape pleasantness and the guests' overall quality ratings, F (1, 130.00) = 13.46, b = 1.06, $p < .001$, confirming H5. Moreover, the statistical analysis indicated that 9.4 % of the variance in the overall quality judgments was explained by soundscape pleasantness as rated by the restaurant visitors ($R^2_{\text{marginal}} = .094$).

4. DISCUSSION

We carried out a correlational field study investigating the soundscapes in restaurants and their relationship with (room-) acoustical parameters. Firstly, we found that the perceived soundscape pleasantness of a restaurant is strongly connected to the ratings of its overall quality, explaining more than 15% of their variance. Our results further suggest that both the averaged A-weighted equivalent continuous sound pressure level in restaurants measured over a 15-minute time interval ($L_{Aeq15'}$) as well as the reverberation time negatively affect soundscape pleasantness. In contrast, $L_{Aeq15'}$ was positively related to the visitors' perception of soundscape eventfulness, and the relationship between reverberation time and soundscape eventfulness was shown to follow a non-linear relationship (inverted U-shape).

The result that $L_{Aeq15'}$ is negatively related to soundscape pleasantness is in line with the findings by Gozalo (15), and partly in line with Battaglia who found week correspondence between background noise and the subjective impression of acoustical comfort in restaurants (8). By contrast, it contradicts findings by Zhang et al. (21) who observed positive relationships between L_{Aeq} and acoustic comfort in urban open public spaces. A possible explanation for these discrepancies might be that other demands are made on soundscapes in closed compared to open spaces. In addition, soundscape pleasantness might be dependent on behavioral motifs within the soundscape. For example, guests with the intention to socialize and interact with other guests might prefer a louder and more eventful soundscape than those whose motive is to enjoy an exquisite meal or relax.

The observed positive association between $L_{Aeq15'}$ and soundscape eventfulness corroborates earlier findings by Axelsson (22). Furthermore, our results suggest, that lower reverberation times lead to higher soundscape pleasantness. This is in line with Battaglia's findings who found that lower reverberation times correlate with acoustical comfort (8).

The effect of reverberation time on soundscape eventfulness was found to follow an inverted U-shape. This means that visitors rated the soundscape eventfulness lowest under very dry and very reverberant conditions whereas medium reverberation time led to highest eventfulness ratings. We interpret these findings such that speech intelligibility among communication partners and therefore short reverberation times are not the only dominating factor that needs to be considered when it comes to 'good' restaurant acoustics. In contrast, an eventful soundscape with medium reverberation times might create an acoustic ambience that is stimulating and not achievable in acoustically dry rooms. Moreover, privacy in terms of low speech intelligibility to neighboring tables is assumed to be promoted by longer reverberation times in the course of masking effects. Therefore, very short reverberation times as suggested by (7) might be appropriate for guestrooms primarily intended to be calm and relaxing (e.g., for guests of higher age), whereas guestrooms intended to be vibrant and exciting might need to be dimensioned differently. Here, the recommendations found in the German standards (6) might be interpreted as an upper boundary for reverberation time in average restaurants. However, for varying categories of restaurants, divers reverberation times may be appropriate.

As every empirical study, our field experiment brings about certain limitations addressed in the following. First, our restaurant sample did not contain values of very high and very low reverberation times and sound pressure levels. Therefore, the results are only valid in the measured range between 0.55–1.03 seconds. Moreover, general limitations of empirical studies apply, such as the fact, that a parametric (frequency-based) significance test was used implying that the sample was picked randomly out of the population. However, as the questionnaires were only filled out by those people who wanted to participate at a study, the sample was "filtered" by a not-randomly self-selection process (Non-response error) (23). The same holds true for the actual participants filling out our questionnaires which could only be recruited from a group of people who actually chose to visit the respective restaurant. Therefore, potential differences in restaurant preferences, demands and habits across persons could not be taken into account by our design. For example, a person disliking loud restaurants might not choose a busy restaurant with high SPL at all and therefore their evaluation would be systematically missing in our data.

In addition, due to the correlational approach of the study, we cannot exclude that some causal relationships might go (at least partly) in the opposite direction than assumed. For instance, a negative restaurant quality (e.g., caused by a bad service) might have led to a bad mood in our participants which affected soundscape pleasantness ratings. Our results thus need validation in the course of further experimental studies. Finally, listening experiments under laboratory conditions (i.e., auralizing the restaurant environments) could investigate whether pleasantness and eventfulness behave similarly when the environment and sound sources remain unchanged, but reverberation times and loudness are experimentally manipulated.

5. CONCLUSIONS

In conclusion, our study clearly suggests that auditive factors have an impact on our holistic perception of restaurants and can predict overall customer satisfaction. Therefore, we emphasized the need of designing dining spaces as acoustically comfortable zones and aimed on demonstrating that it most likely would pay off for restaurant managers to invest in comfortable acoustics of their guestrooms. Here, our study provides potential measures in terms of loudness and reverberation time and target values to do so. Finally, when applying such target values, we highlight the need to categorize restaurant types to give advice for what is 'good' restaurant acoustics. Here, the soundscape approach was found to be a suitable method to tackle this question in the course of future investigations.

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