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Fakultät I - Sprache und Kommunikation
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Master's Thesis:

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 set high demands in terms of low reverberation times to account for speech intelligibility. This raises questions regarding the reasons for this discrepancy between recommendations by scholars, national standards and anecdotal evidence of low acoustic quality in the context of restaurants. Furthermore, it raises the question of whether poor acoustics or desirable auditive characteristics have a measurable effect on restaurant quality itself and other quality factors. Therefore, the subject of this master's thesis is to carry out a correlational field study involving a sample of 15 restaurant settings. The purpose of this study is to investigate the effect of reverberation time and sound pressure level on customers' perceived affective quality of the soundscape. In addition, the relationship between auditive variables and the overall satisfaction with the restaurant is analysed statistically using linear mixed-effects models due to the hierarchical structure of the assessed data. The relative impact of auditive variables is measured in comparison to other (non-acoustic) features of the restaurant. The results show that reverberation time and Soundscape Pleasantness are correlated with overall restaurant quality ratings. These results imply that the auditive perception does play a significant role in restaurant atmosphere and high reverberation times should be avoided. Considering the results and limitation of this thesis theoretical and practical implications for the acoustical design of restaurants will be discussed.

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1 Introduction

1.1 Hospitality industry

Consumer behaviour entails "all activities associated with the purchase, use and disposal of goods and services, including the consumer's emotional, mental and behavioural responses that precede or follow these activities."(Kardes, Cline, & Cronley, 2011)
Food service marketing is a special case of consumer behaviour and is often subsumed under the generalized term of hospitality.

> The food service industry exemplifies two aspects of postmodern consumer culture. As Peacock (1992) notes, it is flexible, artisan-focused and context-dependent enough to offer a high degree of customisation. Thus it can provide an ultimately short-lived fashion product in a highly simulated environment: typical criteria of postmodernism (Jameson, 1984). At the same time, this is the industry that has seen the most blatant operationalisation of service, Ritzer's (1996) phenomenon of McDonaldisation, which he claims to be the other face of postmodern consumer society. (Johns & Pine, 2002, p. 120)

Multiple disciplines have been concerned with consumer studies in foodservice, yielding a diverse body of knowledge. Studies including surveys, experiments as well as qualitative research have provided insights into the restaurant experience. In his eclectic review of food service consumer research, Johns and Pine (2002) distinguished 4 areas originating from different disciplines, practical focus and used methods within food service research. These areas are termed "Experimental Research", "Economics and geography", "Sociology and anthropology" and "Survey research" and are briefly explained subsequently.

The experimental research tradition is often focused on customer preferences and "regards eating out as a function of the food itself and the situation in which it is eaten" (Johns & Pine, 2002, p. 124). Accordingly, the methods used are experiments with control for specific variables.
The survey research approach is generally based on marketing strategies of segmentation, targeting and positioning. Frameworks are often based on geodemographic, attitude and behaviour-based surveys in conjunction with modelling techniques.
In contrast, in the sociological and anthropological view, "the cornerstones of marketing psychology, are (...) replaced by societal pressures of fashion, power relationships, rationalised service and signs"(Johns & Pine, 2002, p. 129). The Individual experience and the wider social context are of specific interest. The methods used are in-depth interviews, observations and literature reviews.
Finally, economics and geography approaches regard the spatial and socioeconomic location of gastronomy and often analyse secondary data.
This literature review is focused on empirical studies of environmental psychology in the restaurant context and thus mainly considers the survey research approach. However, arguments and findings from other disciplines are also considered, as diverse perspectives can potentially reveal gaps and weaknesses within a uniform discipline. Commonalities, differences and potential reasons for the latter will be discussed.

1.1.1 Theories for assessing customer satisfaction in restaurant field surveys

In the field of food service research, several theories have been used for assessing and measuring potential dimensions of consumer satisfaction or dissatisfaction. Subsequently the three widely-used theories of "expectancy-confirmation theory", "coherence theory" and "attribute-value theory", are briefly explained. Scientific opinions as to which one is the most suitable for food service research are at odds, as can be seen from the citations below. In many studies a combination of several theories is applied, for example investigating the importance of several attributes as well as their coherence with other dimensions as in Ryu and Han (2011)

Expectancy-(dis)confirmation theory

Disconfirmation relates to a mental comparison between expectation and reality (in this case performance). The Expectancy-(dis)confirmatiion theory suggests that consumers have expectations about a product in mind before consuming it. According to if these expectations have been met, missed or exceeded the product is being rated by the consumer. Respectively, three general types of outcomes can be expected: zero disconfirmation, negative disconfirmation, and positive disconfirmation (Ryu & Han, 2011, pp. 601-602).
Within survey research "(m)any studies use expectancy–disconfirmation theory and the relationship between the quality of the offering and likelihood of repeat custom has been demonstrated using sophisticated multivariate techniques" (Johns & Pine, 2002, p. 130).

Coherence theory

Coherence, also referred to as "Compatibility" or "Appropriateness" refers to the perceived suitability of a product or service to the place of consumption. "In natural settings it refers to how well a place blends in with its surroundings and is related inversely to contrasts (in color, texture, size, and shape) with the natural background; in urban settings compatibility results from replication of features such as materials, style, and overall shapes" (Bitner, 1992, p. 63)
It is reported, that measures of appropriateness outperform conventional preference scales and it is suggested that context has a bigger influence on the choice of food than hedonic factors (Johns & Pine, 2002, p. 125).

Attribute-Value theory

According to the Attribute-Value theory, consumers rate a service such as a restaurant meal in terms of a set of attributes. Each of these attributes has a certain level of importance to the customer, which can vary considerably by market segment. For example some consumers might be attracted by a restaurant's low price, while others by a restaurant's upscale image and its food quality. The overall value is weighed up according to the individual importance of attributes and finally leads to the decision which restaurant is chosen by the consumer (Johns & Pine, 2002, p. 121).

Concluding, the theory as to how a consumer evaluates a restaurant's quality is important in the context of customer satisfaction. It may be hypothesized that consumers rate restaurant quality with a mix of the mentioned concepts. Thus, in order to cover all possible rating factors, a mix of theories would need to be used when using a questionnaire instrument for restaurant quality ratings.

1.1.2 Dimensions of restaurant quality

Within the food service research there is not much consensus on the definition and importance of the individual quality dimensions. This can be traced back to the divergent approaches in the analyses. In his review on the literature relating to food service consumers Johns and Pine (2002) identified the principal dimensions to be choice and quality of food and drink, the price or value, service, atmosphere, location and convenience. In contrast, Antun, Frash, Costen, and Runyan (2010) state that "what is important to restaurant patrons is primarily conceptualized in three generally identifiable quality domains: the restaurant's food, service and atmosphere" and add a social factor and a healthfulness dimension.
Below, the aforementioned five dimensions and their diverse definitions are addressed:

Food Quality

Definitions of food quality vary considerably (Blose et al., 2017). It can include food presentation, food variety, taste of food, or cuisine (Antun et al., 2010). "Sulek and Hensley's (2004) definition of food quality refers to the 'safety, appeal and dietary acceptability of the food'" (Antun et al., 2010, p. 362). In contrast, Antun et al. (2010) define dietary acceptability with a distinct construct termed healthfulness.

Service

The definitions of service dimensions are partially convoluted (Antun et al., 2010, pp. 362-363). Stevens and Colleagues (1995) suggest five dimensions of service: reliability (dependable and accurate), responsiveness (willingness and promptness), assurance (knowledgeable and courteous), empathy (caring and attentive), and tangibility (facility and employee appearance).

Atmosphere

At this point solely some of the multiple used definitions in the empirical studies are presented. "According to Sulek and Hensley (2004), a restaurant dining room's atmosphere is impacted by the facility's décor, lighting, cleanliness, temperature, odours, and music" (Antun et al., 2010, p.363).
Raajpoot (2002) conceptualized the TANGSERV instrument on the base of all tangible attributes within a restaurant. This scale considers design/layout factors, social factors, product/service-related factors and ambient factors and thus overlaps with other attributes. Ryu and Han (2011) developed the DINESCAPE scale and identified 6 factors: facility aesthetics, ambience, lighting, service product, layout, and social factors. More considerations regarding the atmosphere dimension will follow in the next chapter.

Social Aspects

Antun et al. (2010) proposed that social factors such as the internal sense of belonging to the social environment (social homophily) and the social connectedness to the restaurant staff have a significant role in consumer's feelings, thoughts and behaviour. However, recent studies have shown that this factor is not as important as the three main factors: "Using the DinEX scale, DiPietro and Partlow (2014) found that several social items were relatively unimportant. Only one social construct item was moderately important — not feeling out of place." (Blose et al., 2017, p. 5)

Healthfulness

This dimension is not commonly found in the literature, yet some studies suggest that restaurants could increase restaurant visitation and willingness to pay by including healthy items on the menu (Blose et al., 2017, pp. 4-5).

1.1.3 Relative importance of restaurant quality dimensions

Since the definitions of restaurant quality dimensions are already ambiguous among scholars, consequently research has also revealed conflicting evidence about their relative importance. Food quality is mostly considered to be a leading area of importance for restaurant diners , while some scholars argue that the perception of a restaurant's service quality is the decisive factor for diners' intentions to return (Blose et al., 2017).
Pettijohn, Pettijohn, and Luke (1997) found that food quality, cleanliness, price and value have the greatest impact on the customer's perception in fast food restaurants. These factors were recognized as the fundamental requirements, while atmosphere and menu variety had a lesser impact on customer satisfaction. Amongst the crucial factors, Food quality was the most important factor, followed by cleanliness.
Johns and Pine (2002, p. 122) perspective on the question on importance of restaurant quality dimensions reads:

> Clark and Wood (1998) comment that the available evidence suggests food quality and value to be the most significant restaurant attributes, and question the assumption of classic texts such as that of Campbell-Smith (1967) that the total package of attributes making up the "meal experience" determines consumer behaviour.

A scale to measure restaurant guests' expectations of importance in dining experiences is the DinEX scale. It was developed by Antun et al. (2010) and originally contained 5 factors (food, service, atmosphere, social, and health). A recent study by Blose et al. (2017) adopted the DinEX instrument. In this study the factor 'social' was divided into 'social homophily' (being like the other guests) and 'social connectedness'(familiarity with staff). Additionally, the meal period and restaurant category were assessed to investigate potential differences between these variables. Data was analysed by a Top-Box approach, only considering items being answered on the maximum of the scale (labelled as 'extremely important'). Results have shown that food quality was clearly the most important factor across all meal times and restaurant categories, followed by service standards. However, service standards came close to food quality within the higher priced segment. The third most important dimension was atmospherics, which had been rated as 'extremely important' by more than 40% of the participants. In comparison, healthfulness and social factors have been notably rated as less important.

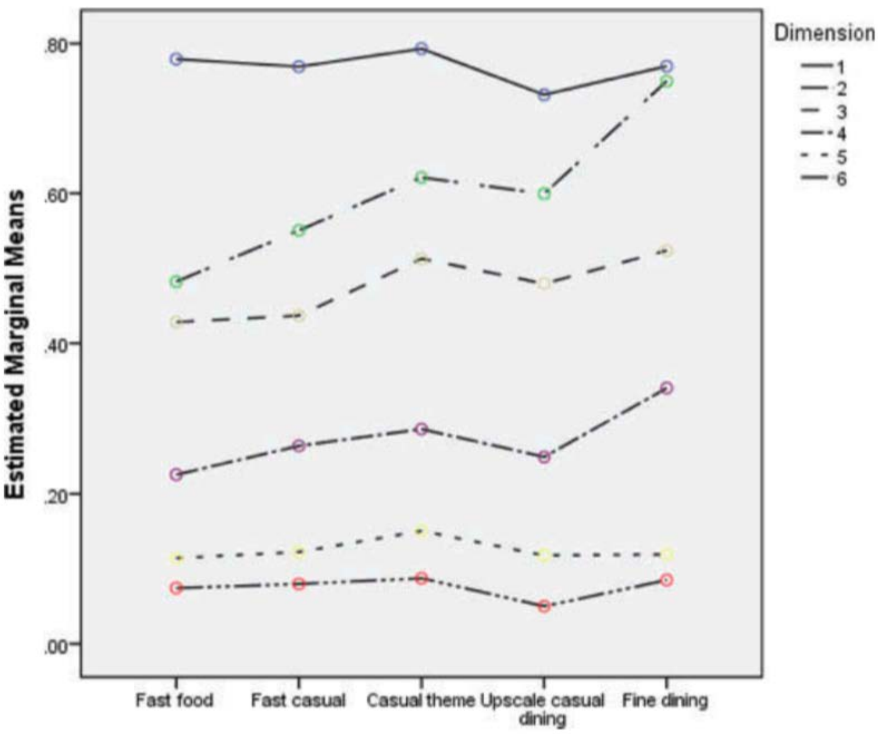

Figure 1: Top box percentages across dimensions by restaurant category as found in Blose et al. (2017). Dimensions: 1: Food Quality 2: Service Standards 3: Atmospherics 4 : Healthfulness 5: Social Homophily 6: Social Connectedness

In conclusion, the mentioned studies investigating the dimensions of restaurant quality and customer satisfaction show that atmospherics are amongst the significant factors for restaurant quality ratings. The question remains how atmosphere can be defined and disaggregated. Since acoustics can be considered a part of atmospherics it is worth taking a closer look at the definitions of this dimension and whether and how acoustics is involved in atmospherics by scholars of food industry service.

1.1.4 The role of atmospherics in food service research

Considering Pine et al. (1998) claim that the Western economy is changing from a service base to an "experience" base, atmospherics is also gaining importance in the food service industry. It is recommended to "(e)ngage all five senses. The sensory stimulants that accompany an experience should support and enhance its theme. The more senses an experience engages, the more effective and memorable it can be." (Pine et al., 1998, p. 104)

In consideration of lifestyle as a marketing strategy for eating out, Riley (1994) even claims

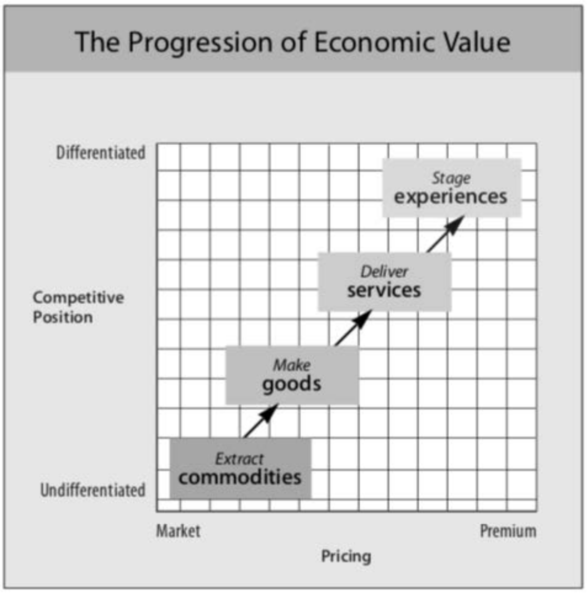

Figure 2: The progression of economic value to selling experiences as found in Pine et al. (1998).

that atmosphere and environment are influential attributes for preference and it is "the holistic and intangible that really matter" (Riley, 1994, p. 16).

The question of whether and how the environment affects our mood, behaviour and evaluation can be contextualized under the more generalized science of environmental psychology.
Pioneering work in this field was created by Mehrabian and Russell (1974), who suggest that individuals react to places with two general, and opposing, forms of behaviour: approach and avoidance. Environmental perception is described by three dimensions: pleasure, arousal and dominance. However, often a two-dimensional model (pleasure and arousal), as depicted in figure 3, is used in the literature (Bakker, van der Voordt, Vink, & de Boon, 2014) This framework, known as the Mehrabian-Russel (or M-R) -model has also been cited and used frequently within service environments, e.g. by Bitner (1992, p. 63):

> In a long stream of research, Mehrabian and Russell and their colleagues have programmatically explored emotional responses to environments (e.g., Mehrabian and Russell 1974; Russell and Lanius 1984; Russell and Pratt 1980; Russell and Snodgrass 1987). Through their research they have concluded that the emotion-eliciting qualities of environments are captured by two dimensions: pleasure-displeasure and degree of arousal (i.e., amount of stimulation or excitement). In other words, any environment, whether natural or manmade, can be located in a two-dimensional space reflecting peoples' emotional response to the place. Re-

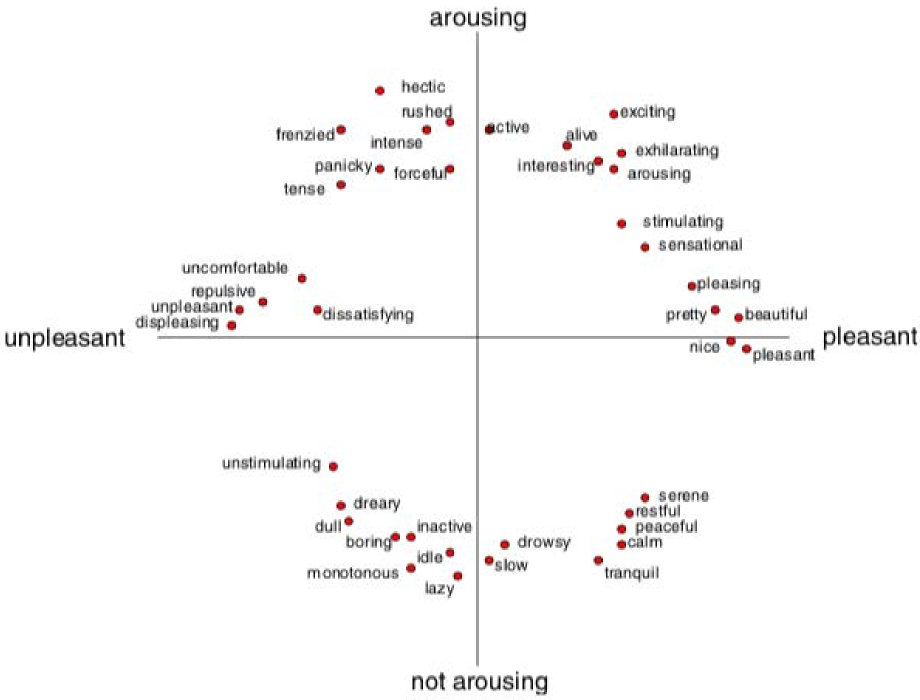

Figure 3: Example of an environmental psychology model with two axes that shows various adjectives to indicate the level of pleasure (X-axis) and arousal (Y-axis) (Russell and Lanius 1984)

> search shows that emotional response measured on those dimensions can predict behaviors with respect to the environment.

A rich framework for exploring the role of physical environment in service organizations has been developed by Bitner (1992). In comparison to the M-R-model, this framework adds a cognitive and a physiological response by the customer to the environment. Furthermore, it is more specifically designed for commercial settings. The Servicescape framework is shown in figure **??**. In table 1, the customer's Internal Responses and Environmental Dimensions of the framework are explained. Particular attention is given to the dimension of 'ambient conditions'.

Jang and Namkung (2009) investigated the importance of atmosphere, product quality and service in four mid to upper-scale restaurants in the U.S., based on the M-R model. Atmosphere and service were found to enhance positive emotions while product attributes, such as food quality, acted to relieve negative emotional responses. The mediating role of emotions in the restaurant context on behaviour has (amongst other relations regarding food and service quality) empirically proven Bitner's proposals. The non-significant relationship between food quality and positive emotional response could, according to the authors, be explained by the assumption that a good meal is expected by the guest, but meeting the expectations does not elicit emotional responses. In this sense, it could be classified under the expectancy-disconfirmation theory. Following this argument, it could be hypothesized that exceeding the expectations and thus causing positive emotional responses could be met by high quality service and atmosphere. Furthermore, the results demonstrate, that positive emotions improve favourable behaviour intentions. However, the questionnaire only considered background music as an auditive aspect of atmosphere (besides colour, lighting, interior design and facility layout).
Another study addressing restaurant atmosphere was conducted by Heung and Gu (2012) in 10 upscale full-service restaurants in Hong Kong. Factor analysis of the aggregated data

Internal Response	
Emotion	"(T)he perceived servicescape may elicit emotional responses that in turn influence behaviors. (...) For example, environments that elicit feelings of pleasure are likely to be ones where people want to spend time and money (...), whereas unpleasant environments are avoided. Similarly, arousing environments are viewed positively unless the excitement is combined with unpleasantness (...). That is, unpleasant environments that are also high in arousal (lots of stimulation, noise, confusion) are particularly avoided" (Bitner, 1992, p. 63).
Cognition (Belief)	"(T)he perceived servicescape may elicit cognitive responses (...) influencing people's beliefs about a place and their beleifs about the people and products found in that place" (Bitner, 1992, p. 62) as well as give cues for the categorization of and distinction between restaurant categories. This influence is believed to be stronger the more unknown the place is to the customer. "In that sense, the environment can be viewed as a form of nonverbal communication (...), imparting meaning through (...) object language." (Bitner, 1992, p. 62)
Physiology	Physical responses to the servicescape affecting people in purely physiological ways. E.g. noise, temperature, glaring of lighting. May directly influence whether or not people stay in and enjoy a particular environment (Bitner, 1992).
Environmental Dimension	
Ambient conditions	"Ambient conditions include background characteristics of the environment such as temperature, lighting, noise, music, and scent. As a general rule, ambient conditions affect the five senses. However, sometimes such dimensions may be totally imperceptible (gases, chemicals, infrasound), yet may have profound effects (...), particularly on employees who spend long hours in the environment." (Bitner, 1992, p. 66)
Signs, symbols and artifacts	"Explicit or implicit signals that communicate about the place to its users. (...) Signage can play an important part in communicating firm image." (Bitner, 1992, p. 66)
Spatial layout and functionality	"Spatial layout refers to the ways in which machinery, equipment, and furnishings are arranged, the size and shape of those items, and the spatial relationships among them. Functionality refers to the ability of the same items to facilitate performance and the accomplishment of goals." (Bitner, 1992, p. 66)

Table 1: Definitions of Internal Responses to the Servicescape and underlying Dimensions within the Servicescape. From the Servicescape Framework by Bitner (1992)

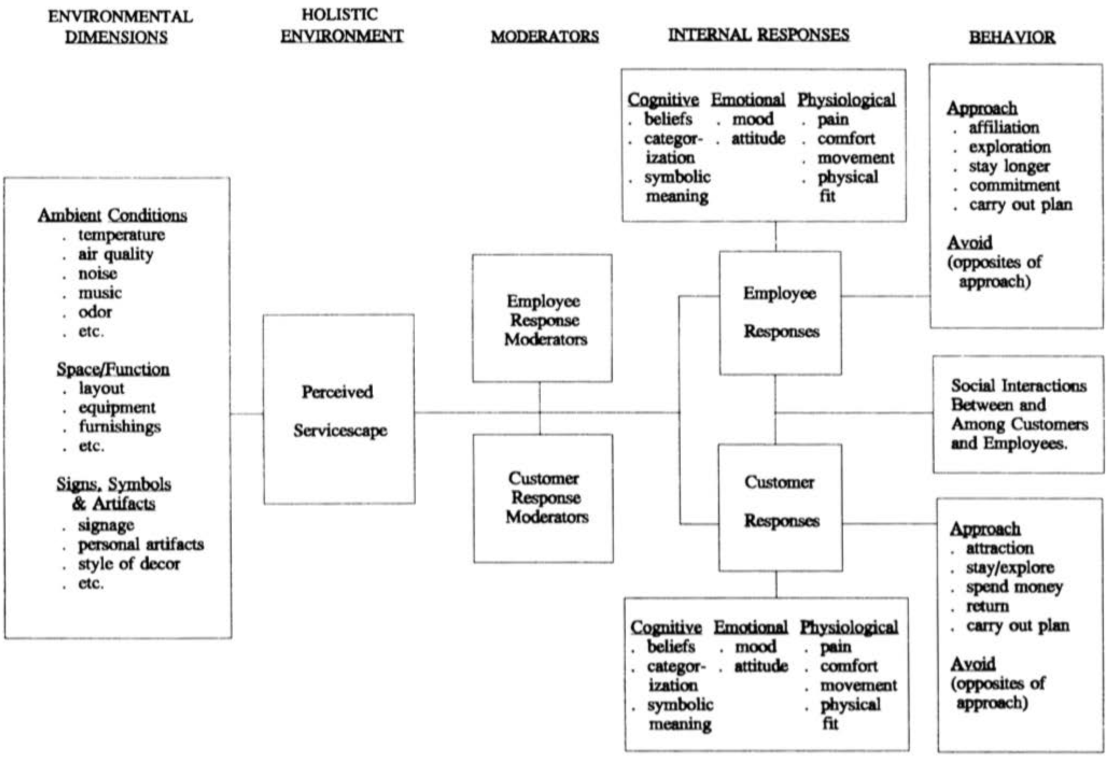

Figure 4: Servicescape Framework for understanding Environment-User relations in Service Organizations (Bitner, 1992)

yielded four factors ‘Spatial layout & employee factor’, ‘Ambience’ , ‘Facility aesthetics’ and ‘View from the window’. All factors were found to have a significant influence on dining satisfaction and behavioural intentions. But, again, among all items in the questionnaire only one considered auditive sensation (background music is pleasing).
The relative impact of physical surroundings on customers’ emotions and satisfaction has also been investigated by Lin and Mattila (2010) by interviewing guests in a Japanese restaurant in Taiwan. In line with Riley (1994) the authors talk about the need for pleasant servicescapes to create “the consumer experience”. Additional attention is drawn to the perceived congruency between servicescape and the core product, providing support to the authors’ theory that it is the holistic experience that has an impact on pleasure. The servicescape was represented by 11 items based on (Hightower, Brady, & Baker, 2002), who did include a noise and background music item. However, it is not clear if both items have been considered in the reduced instrument, as it had been reduced from 26 items in the original.
Summarizing the literature presented in this chapter, although noise appears as one of the environmental dimensions of Bitner’s framework (a fundamental reference in environmental perception within service environments), it is often neglected in other studies of the hospitality industry. This observation includes studies particularly concerning restaurant atmospherics. In the same manner, the possibility to converse easily within the restaurant environment has not been considered in past studies of restaurant environments. Both are factors that are crucially determined by the room acoustics of the facility. In the next chapter the principles of room acoustics will be discussed.

1.2 Acoustics in restaurants

As already mentioned above, research in the field of hospitality industry has rarely been dedicated to acoustic aspects. While music is indeed more often considered, room acoustics and

speech intelligibility are hardly ever within the question. This is surprising, considering the fact, that in a recent survey among 13,000 Americans noise was rated as the most bothersome irritation in restaurants across the US (24%) followed by service (23%) high prices (12%) and parking (10%) (*Zagat Releases 2018 Dining Trends Survey*, 2018). On the other hand, many studies in the field of acoustics have shown, that noise may have negative effects concentration, well-being and health (Reinten, Braat-Eggen, Hornikx, Kort, & Kohlrausch, 2017; Kryter, 2013).
However, until now the science of acoustics has not been a subject of investigation in restaurants. Yet, interest in the field seems to grow. "Restaurant Acoustics" was the topic of a session for the first time during the 177th meeting of the Acoustic Society of America (ASA, 2019). The next chapter therefore is meant to give an introduction into room acoustics in general, as well as an overview of what is known in the field of acoustics considering the service and hospitality industry.

1.2.1 Room acoustics basics

This section will give a short introduction into the physical basics of room acoustics.
Whenever a sound is emitted into a room containing acoustically hard surfaces, the sound is reflected by these surfaces (Reflection). If there are soft and porous surfaces or obstacles in the room, the sound is (entirely or partly) being absorbed (Absorption). Most surfaces are neither fully absorbant, nor fully reflective. The ratio of a surface's sound absorption is defined as the absorption coefficient (between 0 and 1). To put it simply, the more surfaces of a room are rather reflective than absorbant, the more reverberant it is.
The basic parameter used to determine the reverberation of a room is known as the *reverberation time*. It is measured by emitting sound across all frequencies into the room (e.g. an impulse, white noise or sinus sweep) and measuring the time until the sound level inside the room drops below 60 dB from the original sound level. Examples for very long reverberation times are churches and bathrooms (about 2 - 6 s), whereas examples for very short reverberation times (dry acoustics) are bedrooms which contain many textiles or sound studios (about 0.2 - 0.8 s). With a simple formula (Sabine Formula) it is possible to calculate the corresponding absorption area of the room.

$$T_{60} = 0.163 \cdot \frac{V}{A} \tag{1}$$

T_{60} = Reverberation Time (frequency dependent)
V = air volume in m^3
A = equivalent sound absorption area (frequency dependent)
In more reverberant rooms, sounds like voices, noises and music are amplified by the reflections. More specifically, if the absorption area inside the room is lowered by a half, the sound energy in the room rises by 3 dB. A reason for a bathroom to be one of the favourite places for singing might therefore be that it is a place where you hear your own voice with an energy level many times higher (compared to free-field or highly absorbing conditions) due to the present reverberation.

Other than that, highly reverberant rooms are lower in speech intelligibility, because the reflected sounds mask information in the original speech signal. Reflections can support or interfere with the intelligibility of speech, depending on their delay to the original speech signal. Reflections arriving 0.01 to 0.05 s after the direct sound support intelligibility, which equals a travel distance of 17 m. On the contrary, reflections arriving 0.05 to 0.1 s after the direct signal lead to a decline of intelligibility (equalling 17 to 34 m of travel distance). Finally, delays of more than 0.05 s are perceived as echoes and likewise worsen intelligibility. Hence, for enhancing speech intelligibility, reflections delayed by more than 0.05 seconds need to be reduced by room acoustical measures in the form of absorbing surfaces (Willems et al.,

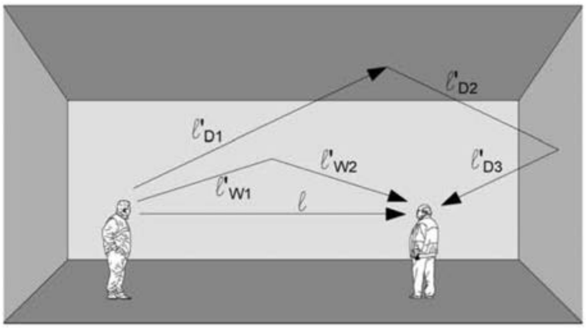

Figure 5: Schematic propagation of sound in a closed room as found in Willems et al. (2010)

2010, p.346).
A parameter for quantifying speech intelligibility is known as the Speech Transmission Index (STI). It has been shown that a decline of speech intelligibility causes people to raise their voice level and pitch them higher in order to be better understood by their conversational partner. This "behavioural feedback" is known as the Lombard effect and has proven to double the noise level in rooms from 3 to 6 dB, if the absorption area is lowered by a half. 6 dB correspond to an energy level present in the room that is four times higher.
Many studies have investigated the effects of sound environment on humans and presented evidence that noise can significantly lower children's learning abilities, reduce task performance, disturb sleep, and cause daytime sleepiness. Noise exposure leads to annoyance, affects patient recovery and staff performance in hospitals and increases the occurrence of hypertension and cardiovascular disease (Reinten et al., 2017; Kryter, 2013; Basner et al., 2014).
Since the echo of a reverberant room raises the noise level and reduces the ability to converse, it is abundantly clear that reducing reverberation time leads to enhancing the acoustic quality of a room and supports well-being. The subsequent chapter will be dealing with room acoustic requirements and measures to improve room acoustic quality in general, specifically within restaurants.

1.2.2 Requirements for room acoustic quality in restaurants

Depending on a room's type of use, the requirements in respect of its acoustic properties differ. These requirements are set in national standards such as the German standard "Acoustic quality in rooms" (DIN, 2016). For example, the acoustic requirements for classrooms for pupils that include hearing-impaired children have been set high, whereas areas of short-term stay logically have not. Within the categories of this standard, restaurants can be assigned to category B3 (rooms for long-term stay) , yielding the requirement for reverberation time to be calculated with the following formula:

$$\frac{A}{V} \geq (3.13 + 4.69 \log(\frac{h}{1m}))^{-1} \tag{2}$$

Dissolving this formula for T this leads to the equation
Maximum Reverberation time for rooms with longterm stay according to (DIN, 2016)

$$T_{DIN,B3} \leq 0.163 \cdot (3.13 + 4.69 \log(\frac{h}{1m})) \tag{3}$$

according to formula 3, a room with a volume of $300m^2$ and a ceiling height of $2.8m$ would require a reverberation time of $T_{DIN,B3} = 0.85s$.
One researcher who has extensively examined verbal communication within the room acoustics of dining spaces is J.H. Rindel. In his paper (Rindel, 2010) a prediction model is developed considering the feedback-loop of the Lombard effect as well as the estimated absorption area

that is added to the room by each person. In this paper the evaluation for acoustic quality of eating establishments is suggested by considering the quality of verbal communication. To evaluate the latter it is suggested to consider the signal-to-noise-ratio (SNR). Verbal communication is considered "insufficient" when SNR ≤ -3 dB. Hence, according to the prediction model, an absorption area of 8m^2 per person is required for "satisfactory" verbal communication and at least 17m^2 is required for "good" verbal communication. It is stated that the latter is very hard to achieve, especially with dense table and seating arrangements, making it necessary to include absorptive material on walls, ceiling and floor. A higher ceiling would also help to achieve this goal if the walls are implemented sound absorbing. In a recent paper, this model for room acoustical quality within dining spaces has been further developed. The approach based on speech intelligibility results in a formula for the borderline between sufficient and insufficient quality of vocal communication (Rindel, 2010).

$$T_{Rin} \leq 0.063 \cdot \frac{V}{N} \tag{4}$$

where V is the volume of the room and N is the capacity of guests. According to this study the requirement for Class A acoustic quality is given when $\frac{V}{NT} \geq 40, (m3/s)$ This means that for a dining space with a volume of 200m3 and a capacity of 50 seats, the requirement for class A would be a reverberation time of 0.1 s or less, which is practically impossible. It is thus open to discussion, whether these requirements might have been too stringently chosen.

The importance of these findings should not be underestimated. However, the fact that speech intelligibility have until now been overlooked in the studies which consider atmospherics in the restaurant context so far, entails the question of whether this concept is as relevant as proposed. Especially considering the extensive costs for restaurant managers to achieve the suggested classifications. Moreover, findings from other disciplines, which will be discussed in the soundscape chapter below, lend support to the assumption, that speech intelligibility enhancement and noise reduction are not sufficient parameters when it comes to acoustic comfort in restaurants. Privacy in between tables, which is contradictory to speech intelligibility, as well as atmospherics by means of acoustical background sounds, have not been considered. Another aspect is that a stimulating environment might boost social activity. Thus, higher levels of ambient and masking noise might be desirable for certain restaurant categories with a stimulus-seeking tendency.
Comparing formula 4 with the recommendation of the German standard yields considerable differences when assuming the same physical values of the room and number of seats. A restaurant with a volume of 300 m2 and 50 seats would require a reverberation time of less than 0.38 s. As every model, this model has its simplifications and assumptions, such as the threshold for sufficient speech intelligibility, source directivity and diffuse sound field, which will be discussed next.
Considering the threshold for sufficient verbal communication , anecdotal evidence suggests that speech intelligibility is possible in restaurants that do not fulfil the mentioned requirements. In fact, visitors of crowded restaurants are still able to communicate with each other to a certain extent (even if possibly under high cognitive effort). This could be explained by the factors improving speech intelligibility shown in figure 6. Herein the strategies of our hearing system for handling hard listening environments are analysed e.g. in situations with multiple simultaneous talkers, in which a listener (without hearing impairment) can concentrate on one single speech signal only. This is the so-called, cocktail party effect. (Bronkhorst, 2000).

Another aspect for consideration is that it is not clear whether the directivity of sound sources has been considered or not. Thus, the total sound energy within the room might be lower, if the voice level was transferred from speech direction to omnidirectional emission. What is more, the rise in the voice level has also not been considered in the model.
Secondly, Sabine's formula assumes a diffuse sound field. This simplification is not valid if

Factor	SRT change (dB)
Spectral differences	-2 ... 2
Fluctuations (“listening into the dips”)	-10 ... -6
Voice similarity	3 ... 9
Spatial separation (single words)	-11 ... 0
Spatial separation (multiple sources)	-8 ... 0
Best ear vs. binaural – Distinct binaural benefit of “better ear”	-7 ... -1
Reverberation	0 ... 9
Moderate hearing impairment	0 ... 10

SRT Speech reception threshold,
better performance (more noise tolerable) when negative

Figure 6: Factors affecting speech intelligibility as found in Bronkhorst (2000)

the room has sound absorbing noise barriers or a “flat” shape. Furthermore, it is not clear, to which room sizes the model applies. In small rooms with low capacity, acoustical events could be perceived very differently than in large dining halls. The model has been verified by acoustical measurements for large dining halls only.
Another factor that has been disregarded is the atmosphere created by a certain degree of room-acoustical response. The sounds are uniquely seen as “noise” which needs to be reduced. The ambience created by the present conversations at other tables is not considered. In a similar manner, other effects of very low reverberation time need to be looked at, such as the lack of privacy in between tables, since very low reverberation might interfere with social activity. If the given acoustics lead to the understanding of every word spoken at another table, guests might feel uncomfortable about speaking freely.
All in all, it has not yet been shown whether the mentioned requirements for speech intelligibility within restaurants account for a rise in the overall comfort of the customer.
Battaglia (2015) investigated acoustical comfort in restaurants in a survey including 11 restaurants and a total of 825 patrons. Acoustical comfort was defined by four parameters, as shown in table 2 (*Privacy, Comfort, Quietude* and *Communication*). Reverberation time and Background noise (at 80 % occupancy) was measured. The results show, that reverberation time is correlated with each one of the four subjective categories of acoustical comfort. *Comfort* was additionally correlated with sound pressure level. Besides this, differences between age groups could be observed: While the youngest age group (under 25) seemed unaffected by a loud background level, the oldest age group preferred quiet settings with the ability to easily converse. While this study provides a lot of useful information, there are some drawbacks, leaving open questions: Unfortunately, only the values of r^2 have been reported within the statistics, leading to an uncertainty of significance values. Occupancy has not been controlled for within the data aggregation, since managers were asked to only distribute the questionnaire during busy times (75% occupancy or more). Similarly, sound level was a fixed parameter within the restaurant level, as it had only been measured once during well-occupied business times. Factors of acoustical comfort were measured by one item per factor only with a mix of uni-dimensional and bi-dimensional 4-point scales.

Factor	Item	Scale (4-point)
Privacy:	How disturbing are sound of conversations from other tables?	(Disturbing ... Not Disturbing)
Comfort:	What is your comfort level with the way this restaurant sounds?	(Uncomfortable .. Comfortable)
Quietude:	How noisy does this restaurant sound to you?	(Noisy .. Quiet)
Communication:	How difficult is it to converse with other diners at your table?	(Difficult ... Easy)

Table 2: Factors and items used in the questionnaire for assessing acoustic comfort in eating establishments in Battaglia (2015)

An interesting observation that can be drawn from the data is, that restaurants with reverberation times over 1 s seem to be perceived as considerably more disturbing, noisy, and that it is more difficult to have a conversation. This can also be drawn from figure 7. The limitations described above could, however, have led to biasing the results and limiting the possibilities of fully interpreting the results statistically. Due to the above-mentioned observations, the

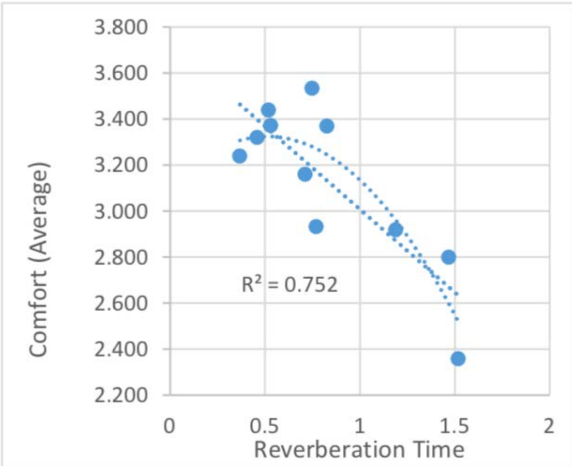

Figure 7: Correlation between acoustical comfort and reverberation time as found in Battaglia (2015)

author draws the conclusion that reverberation times of 0.5 to 0.7 seconds are within the optimal range for perceived acoustical comfort of all age groups. However, the data does not include reverberation times under 0.5 s, so the question remains as to whether or not a further lowering of the reverberation time does lead to an increase of acoustical comfort.
It can therefore be concluded that the recommendations for achieving room acoustical quality in restaurants are ambiguous (as it can further be interferred from figure 10). The perception of auditive senses in interdependence with gustatory senses and well-being shall thus be further analysed in the next paragraph.

1.3 Psychology and physiology of the auditive senses

It is indisputable that individual human beings perceive their environment very differently. Whether or not an event is perceived as pleasant or not, may depend on culture, character, state of mind and many other factors. While the differentiation between sensitivity ratings concerning physiological stimuli (e.g. loudness) might be easier to determine, individual preferences of events, feelings objects etc. usually follow more complex rules (W. J. Davies et al., 2013).

In this chapter, the psychological and physiological aspects of audition as well as their effect on each other are discussed. To anticipate, research has shown, that reciprocal effects, so called cross-modal effects between the senses of taste and audition exist and could be experimentally and statistically proven. As can be expected, music plays a crucial role within these effects, as it stimulates the brain differently than simpler sounds and noise. Nevertheless, an effect of background noise on taste perception has also been shown.
The effects of sound stimuli on human perception and sound quality evaluation are, amongst others, studied by the field of Psychoacoustics. Here, the properties of sound stimuli are being evaluated and measured in terms of their physical characteristics by so called psychoacoustical parameters. These metrics have been termed Loudness (perceived level), Tonality, Sharpness, Roughness, etc. They are common practice in sound design and a useful tool to predict perceived annoyance by environmental sounds. However, they "cannot (...) account for non-sensory influences entering into the judgement of a sound" (Ellermeier, Zeitler, & Fastl, 2004, p. 1). One of the major reasons for sounds being perceived differently than the psychoacoustic instruments would suggest, is their connotation to an event or feeling by the listener. In other words, the *meaning* of the sound ought to be considered, as it unambiguously influences the perception of the sound or sound environment (Fastl, 2005). This has been experimentally shown by (Ellermeier et al., 2004), where participants have been asked to evaluate sounds in regard to their annoyance. Sound stimuli were either played in their original state or were "neutralized" computationally, making it impossible to recognize the event that preceded the sound, yet keeping the psychoacoustic parameters constant. Results indicate that substantial differences exist between the ratings of recognizable (original) sounds and their neutralized counterparts exist. (Ellermeier et al., 2004)

1.3.1 Influence of music on taste

Sound stimuli that are heavily connected to their meaning and have extensively been studied are musical pieces. Moreover, studies of interactions with eating, drinking and dining out have been conducted and will be discussed subsequently.
North (2012) investigated the rating of red and white wine under 4 differing music conditions and one control group. The music tracks were selected in respect to their symbolic meaning and emotional connotations. The conditions' symbolic description of the 4 individual tracks was 'powerful and heavy', 'subtle and refined', 'zingy and refreshing' or 'mellow and soft'. Music was played in the background during the wine tasting, drawing no prior attention to it. For each music condition and from a total of 250 participating students, 25 were asked to rate their liking of the wine, the music, and to rate the character of the wine considering the four terms mentioned above. Results indicate that the character of background music has a significant effect on the perception of a wine's character. Every wine-character rating achieved its highest values under the congruent musical track playing. These results can be drawn from figure 8 below.

A possible explanation for this effect is the cognitive priming theory, which was found in commercial contexts of wine sales. It was demonstrated that the music of certain countries being played while buying wine raises salience and thus prime selection of the congruent wine (North, 2012).
These findings are coherent with the studies of sound-taste correspondences by Q. Wang (n.d.) who states that "soundtracks that are congruent with specific taste/ flavours are demonstrated to influence food/ drink evaluation." A more recent case study during wine tastings came to similar results: The same wines were rated significantly fruitier and smoother while a congruent soundtrack was playing than during silence. (Q. J. Wang, Frank, Houge, Spence, & LaTour, 2019)

Caldwell and Hibbert (2002) tested the effect of the tempo and preference of music being

	Music				
Rating	No music	Zingy/Fresh	Powerful/Heavy	Mellow/Soft	Subtle/Refined
Zingy/Fresh	4.91	6.91	5.25	5.51	5.47
Powerful/Heavy	4.38	4.71	6.78	4.35	5.88
Mellow/Soft	5.53	5.51	6.31	7.12	6.68
Subtle/Refined	4.96	4.86	5.61	4.78	6.47

Figure 8: Main effect of type of music played during a wine tasting on ratings of wine character (on a 10-point scale), showing that wines have been rated congruent to the background music (North, 2012)

played in a restaurant on the behaviour of guests in terms of time and money spent, enjoyment, future intentions and rating of the service encounter. Multiple regressions revealed that music tempo had a significant effect on time spent dining only in case musical preference was not controlled for . Musical preference, again, had a significant effect on time spent dining (r^2 = .28, sig. = .001) and enjoyment of dining (r^2 = .23, sig. = .001). What is more, time spent dining was correlated with money spent (r^2 = .60) yielding an indirect effect of musical preference on money spent. Also ratings of future intentions (revisiting the restaurant) and the restaurant encounter were positively correlated with the musical preference. These results indicate that a sound environment perceived as pleasant can have a positive effect on perception of other, non-auditive factors. More specifically, these findings point to a moderating role of the auditory sense in the food and restaurant context. This effect could be active beyond music, or as North (2012) put it: “It is, however, suspected that other non-musical sounds could be used similarly to create congruent ratings.”
A possible explanation for the effects described above could be crossmodal perception, which will be discussed in the subsequent paragraph.

1.3.2 Crossmodal perception

Crossmodal perception is perception that involves interactions between two or more different sensory modalities. It can be illustrated by this example from Lalanne and Lorenceau (2004, pp. 265-266):

> Imagine someone attending to his own occupations, and whose attention is suddenly drawn by the sound made by the boiling water of a saucepan in the kitchen; he looks towards the object in question, and it quickly appears that the saucepan must be taken away from the cooker. Now, what has to be done is to reach for the saucepan: crucial information about the object to be grasped are conveyed by vision (water steam), audition (sound of the boiling water), and haptics (heat and vibration of the handle). All of these perceptual cues, gained through different sensory modalities, concern the same object and, together, should influence the actor to perform this action carefully.

While this seems like a simple task, complex mechanisms are at work between sensory processing and cognitive interpretation or goal-directed motor action.
Crossmodal perception can also be observed in cases were one sensory cue produces stimuli on other sensory modalities. A prominent example is the phenomenon of synaesthesia among individual persons. Interestingly, evidence suggests that crossmodal effects also exist between gustatory and auditory cues: Woods et al. (2011) tested the taste of savoury and sweet snacks under 3 acoustic conditions (no noise, quiet noise (45 - 55 dB) and loud noise (75 - 85 dB)) in a repeated measures design among 48 students. Perceived sweetness and saltiness were

significantly lower under the noisy condition, thus noise seemed to dampen the gustatory cue intensity. In addition, the liking of background noise was correlated with the liking of the food itself (similar to the above-mentioned outcomes by (Caldwell & Hibbert, 2002)). Remarkably, gustatory ratings were only affected in the loud noise condition. It could thus be hypothesised, that the effect arises when noise exceeds a certain, critical level.

Another study by Yan and Dando (2015) further investigated taste-sound-correspondences in a crossover design with 48 participants over 2 days. 5 prototypic tastants (salty, sour, bitter, sweet and umami) as solutions in 3 different concentrations were tasted under sound and no sound conditions. Participants were asked to complete a questionnaire with taste intensity ratings. Statistical analysis (simple repeated student's t-test and Linear Mixed Models) yielded that sweetness was rated significantly lower under noisy conditions, while no difference in intensity rating was observed for salty, sour and bitter tastants. In contrast, umami was rated higher under noisy conditions and to a progressively higher degree with increasing concentration. The author summarizes the findings, stating that "the multisensory properties of the environment we consume our food within can alter our perception of the food we eat" (Yan & Dando, 2015, p. 594).
A possible explanation of this phenomenon is given in the form of direct mechanical stimulation within the brain between nerve fibres of taste and sound as they lie close to each other in the Chorda Tympani. The author furthermore reasons that noise could be a major factor as to why airline food is consistently rated lower than it would be expected (Yan & Dando, 2015).

The way sound and taste are interconnected was further investigated by Crisinel et al. (2012) and Simner, Cuskley, and Kirby (2010).
Crisinel et al. (2012) found that identical cinder toffees were rated as significantly more bitter while listening to a soundtrack connoted with bitterness than when listening to a soundtrack connoted with sweetness. These results provide empirical evidence that crossmodal congruency between auditory and gustatory senses can be used to modify the taste of foodstuff.
Simner et al. (2010) investigated cross-sensory pairings between sound and taste cues and suggests that "people make systematic associations across taste and sound in terms of shared mapping between tastants in the mouth, and the acoustic qualities of accompanying auditory stimuli." Bitter mapped to lower-frequency sounds than sour, while it was judged higher in frequency than sweet.

The results of research discussed in this chapter give reason for the hypothesis that crossmodal correspondences between sound and taste exist. The effect is likely to arise from cognitive (and emotional) connotations (liking of music → liking of food) but might also be caused physiologically (high noise level → taste level changes). As the sound perceived by guests in restaurants does contain a lot more information than noise or music only, it might be helpful in the process of this research to investigate the perception of acoustic environments. The topic is known under the term soundscape research and some findings of it will be summarized subsequently.

1.4 Soundscape research

Soundscape is a term that was originally introduced by the composer Murray Schafer in the seventies. A definition of soundscape given by Truax[1] reads

> The totality of all sounds within a location with an emphasis on the relationship between individuals or society's perception of understanding of and interaction with the sonic environment.

[1] as found in (W. J. Davies et al., 2013, p. 225)

Thus, its paradigm is to focus on the relationship between sound and listener, rather than on generalized predictions by physical values. The soundscape approach considers higher-level cognitive processes and cannot be determined by physical measures only. According to soundscape research, perception of sound is inevitably connected to the context in which it is heard, the meaning of the sound and the listener. Studies have shown that lower SPL is not necessarily connected with a more pleasant sound environment. It is argued that in that sense it is winning over established acoustical parameters (Steele, Tarlao, & Guastavino, 2019; Aletta, Kang, & Axelsson, 2016).

The application of methods from sound art, acoustic ecology, and social science as well as techniques from acoustics, psychoacoustics, physiology, neuroimaging, and sound quality makes it a highly multidisciplinary field.
The point of introducing soundscape research at this point is to learn more about how soundscapes are perceived, to better understand what are relevant characteristics of, as well as emotional and behavioural responses to soundscapes.
A topic of soundscape research is the categorization of soundscapes or, in other words, how people distinguish one soundscape from another (both as how they internally describe it as well as externally evaluate the soundscape). Axelsson, Nilsson, and Berglund (2010) found three major dimensions of soundscapes: Pleasantness, Eventfulness and Familiarity. Ensuing studies suggest that familiarity was less suitable as a category, so the two first dimensions were identified and found their way into the recently released Soundscape standard ISO-12913-2 (2018). The two-dimensional factor solution is illustrated in figure 9. Alike dimensions were

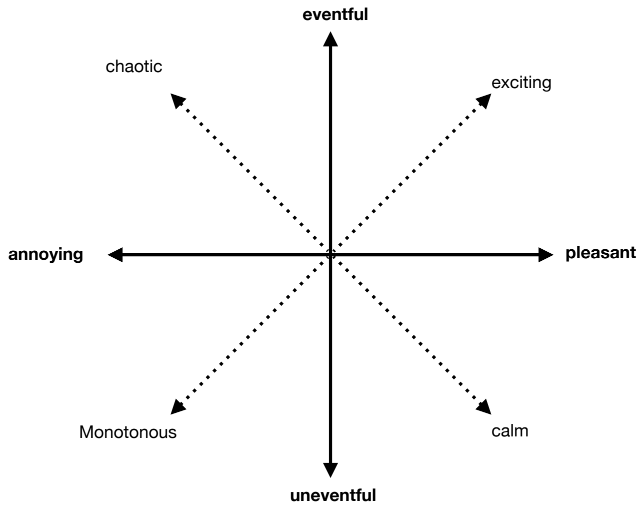

Figure 9: Graphical representation of item loadings within the 2-dimensional structure of soundscape sensation as proposed by ISO-12913-2 (2018)

found in terms of Calmness and Vibrancy by Cain, Jennings, and Poxon (2013).

In contrast, (Guski, 1997) suggests three dimensions: ‘activity’, ‘clarity’ and ‘emotional evaluation and strength’. Whilst activity could be understood as eventfulness, the subsequent terms show differences to previous findings. Further differences to the ISO dimension categorization were found by Kang and Zhang (2010) in a semantic differential analysis of soundscapes: relaxation, communication, spatiality and dynamics. This could imply that there might be more dimensions of soundscapes than it is assumed within the standard. The differences between the mentioned findings might be explained by the high sensibility of results due to the phrasing of questions and the methods being used (Raimbault, 2006).

While the categorization above describes the soundscape itself, structurally different approaches of categorization were made by Maffiolo (Event sequences and Amorphous sequences), which is rather describing the audible character of the sounds heard. Another way of categorizing soundscapes is according to the nature of its sound sources into the three categories: ‘natural’, ‘human’ and ‘mechanical’ (W. J. Davies et al., 2013).
In the given context Aletta et al. (2016, p. 68) points out:

> Several descriptors have been proposed, investigating wider or narrower aspects of soundscape. Because it is a multi-layered construct, the different components of soundscape do not necessarily emerge at the same level. It is possible to develop descriptors related to perceived sound sources (e.g., technology, humans, and nature). Descriptors may also concern the sensation of sound, such as loudness, or perceived affective quality, such as pleasantness. At an overall level one might be concerned with whether or not the soundscape is perceived as appropriate for a place, or with the meaning of sound in a given context. For this reason, it is unlikely that a single common soundscape descriptor will be established. Consequently, it is worthwhile defining a framework for supporting the systematic development of tools for characterizing soundscape, or some of its components Zhang and Kang (2007). Tools that eventually will be used for urban planning and design.

Other investigations go into the direction of examining the responses of soundscape listeners in terms of behaviour, attention, information and individual differences.
Of particular interest for the current study is the question of which sounds and soundscapes are perceived as positive, as has already been addressed in the positive soundscape project (W. Davies et al., 2007). Qualitative results have shown that soundscapes that include natural sounds, vibrant soundscapes that indicate life and the presence of humans (e.g. hubbub of human voices) and soundscapes that indicate positive emotional states, such as happiness and relaxation are evaluated as positive.
Distinguishing between wanted (e.g. background music) and unwanted sounds (e.g. shouting of a vendor from outdoors) (Kang, Meng, & Jin, 2012) found evidence that acoustic comfort could be improved or decreased independently from physical measures. Guski (1997) suggests three aspects of sound quality in general: ‘Stimulus-response compatibility’, ‘Pleasantness of sounds’ and ‘Identifiability of sounds’, which show similarity to findings from soundscape research (Appropriateness, Pleasantness, Familiarity) (Aletta, Axelsson, & Kang, 2017).
Zhang, Ba, Kang, and Meng (2018) suggest that acoustic comfort is positively correlated with relaxation when natural or anthropogenic sounds are perceived dominantly.

In the review of Socio-acoustic surveys for soundscape studies (Engel, Fiebig, Pfaffenbach, & Fels, 2018) only 4 studies with restaurant or café sources are listed, indicating that the concept of soundscape has not yet been applied in the restaurant context.

It can be concluded, that the soundscape approach encompasses a broad range of activities, perceptual focus, sound content etc. making it difficult, yet not impossible to draw generalizable statements on the perception of soundscapes. These could be manifested in terms of soundscape dimensions such as appropriateness, pleasantness, activity, etc. or the nature of the sounds inherent in the listening environment. Considering the purpose of investigating a listening environment by the soundscape approach using a questionnaire instrument, it might be helpful to specify certain (known) characteristics of the soundscape beforehand.

1.5 Focus and hypothesises of this thesis

Summarizing the literature review above, the following aspects discussed are most important:

- The acoustic environment influences well-being
- Auditive Senses (musical and non-musical sounds) have an effect on food choice and perception
- Noise can lower the intensity of taste perception
- Music in restaurants influences time and joy spent dining
- Atmospheric sounds inherent in restaurants is seldom considered in research on the hospitality industry and might thus be underrated
- National Standards, acoustic consultants and scientists formulate ambiguous requirements for restaurant acoustics
- Enhancement of speech intelligibility and noise reduction is one of the primary goals for acoustic consultants and scientists, while other (acoustic and non-acoustic) effects of reverberation reduction might be unjustifiably neglected

It can be inferred that auditive perception seems to be important within the restaurant context, but by acousticians it has so far mostly been considered under the concept of noise which needs to be lowered. However, evidence in the studies above suggests that auditive perception is also able to enhance the hedonic experience of enjoying a meal. It would thus be necessary to analyse the perception of sound environments in restaurants more precisely, considering their positive and negative aspects, as it is done through the soundscape approach:

- Complex listening environments, including human interaction, can barely be analysed by physical measurements only
- It is important to understand the relations between sounds and humans and explore the interdependence between contexts (person, activity, place)
- Positive effects of sounds exist; lower SPL does not necessarily mean more pleasant soundscapes

The purpose of the current study is to unite the outcomes of the individual disciplines discussed above and analyse the effects of soundscapes and room acoustics compared to other, non-acoustic, moderating factors. For this purpose this study will focus on three main topics, investigating the interaction between auditive and overall perception in restaurants: “Interrelations between physical measures and soundscape perception in restaurants”, “Interrelations between auditive variables and overall quality ratings in restaurants” and finally “Interrelations between auditive and non-auditive variables in restaurants”.

These topics will individually be elaborated on in the subsequent sections individually and concluded with hypothesises that will be the starting point for the empirical investigations in the field. In this manner it is hoped to gain more insight into the specific interrelations of auditive effects on restaurant quality.
To end this chapter it seems appropriate to cite one of the founders of the soundscape research, Schäfer (1993):

> We need not accept noise surroundings as compositions by chance, but we can shape and compose them as we would like (...) also adding noises might improve the soundscape (e.g. masking of unwanted noise by water fountains or music) sounds are not seen unidimensional as something annoying, sounds can evoke certain emotions. Sounds can be exciting, inappropriate, comfortable, soothing, stimulating, disruptive, etc.

1.5.1 Interrelations between physical measures and soundscape perception in restaurants

As a starting point of investigations, it is necessary to understand and verify common theories of sound environment perception. More specifically, the question of whether physical measures of the soundscape can be used to predict the perception of soundscapes. For this purpose two of the most common physical sound measures (Sound Pressure Level and Reverberation Time) will be used as independent variables. The two factors of soundscape perception (Eventfulness and Pleasantness) will be the dependent variables (as suggested by ISO-12913-2 (2018)). Thus, the hypothesises for this investigation read as following:

Hypothesis 1A: Sound Pressure level is correlated with Soundscape pleasantness
Hypothesis 1B: Reverberation time is correlated with Soundscape pleasantness
Hypothesis 1C: Sound Pressure level is correlated with Soundscape eventfulness
Hypothesis 1D: Reverberation time is correlated with Soundscape eventfulness

1.5.2 Interrelations between auditive variables and overall quality ratings in restaurants

The second question will be dedicated to predicting overall restaurant quality ratings by auditive variables. Hence, the two common physical sound measures (Sound Pressure Level and Reverberation Time) present in the restaurant during the visit will be used as independent variables. Likewise, the subjective pleasantness of the soundscape, as rated by the guests, will be used as an independent variable to predict Overall Restaurant Quality Ratings. Thus hypothesises for this question read:

Hypothesis 2A: Sound Pressure level is correlated with Overall Restaurant Quality Rating
Hypothesis 2B: Reverberation time is correlated with Overall Restaurant Quality Rating, following an inverted u-shape
Hypothesis 2C: Soundscape Pleasantness is correlated with Overall Restaurant Quality Rating

1.5.3 Interrelations between auditive and non-auditive variables in restaurants

Evidence in the literature has shown that the auditive and gustatory senses are correlated with each other by crossmodal-effects. More specifically, noise has been shown to lower gustatory cues. It may thus be hypothesized, that an effect between Sound Pressure Level and food taste is also measurable within restaurants in the field.

Hypothesis 3: Sound Pressure level is correlated with Food quality rating

2 Method

> Everything should be made as simple as possible. But no simpler. (Albert Einstein)

The quality of an empirical study is given distinction by the theoretical model that is supposed to be tested. It is thus essential to elaborate a theoretical basis that is both comprehensive and feasible. In other words, it should consider everything that is necessary, but it needs to be simple enough to be operationalized and tested within the possibilities of statistics.

2.1 Investigation model

The primary idea was to analyse the quality of a restaurant before and after room acoustical measures. However, in order to ensure generalisability of results several restaurants of different type and price range would have had to be analysed in this manner. As resources were limited, it was necessary to find a different way to gain generalisable insights. It has thus been decided to analyse the hypothesises comparing overall quality ratings and auditive variables within several differing restaurants, using the existing differences in room acoustics and soundscapes. Since also multiple non-acoustic variables contribute to the overall quality rating, it was hoped to capture these moderating variables by an extensive questionnaire, based on findings of hospitality industry science.
The aim was to statistically extract the effect of auditive differences within restaurants while controlling for as many other quality factors as possible. It was thus necessary to create a theoretical model that predicts the overall quality rating of the customer based on non-acoustic and acoustic variables.
In order to create the model, it seemed plausible to use the method of path diagrams. The first path diagram consisted of an attempt to capture every effect found in the literature with an attempt to organise these effects according to their possible higher-order dimensions.

2.2 Questionnaire design

In the next step, it was necessary to substitute the effects in the diagram with empirically grounded measurement instruments (questionnaires). One of the requirements for the latter were their brevity, as it was necessary to keep the questionnaire within a reasonable duration for an in-situ study. Challenges were finding an appropriate empirical instrument for (non-acoustical) restaurant evaluation factors. The existing instruments (DINEX, TANGSERV, DINESERV, SERVQUAL, DINESCAPE) (Antun et al., 2010; Raajpoot, 2002) differ significantly in focus area, detail and completeness. DinEX was considered as the most suitable instrument because of its creation and validation methods as well as the fact that is has been used in studies among 1000 participants (Blose et al., 2017). However due to two reasons it has not been selected. First, two of the five dimensions have been shown to have very small effects (Blose et al., 2017) Second, the atmosphere dimension does include two auditive items ('noise was too loud' and 'music was pleasing'), making it hard to separate acoustic and non-acoustic dimensions. It has thus been decided to go with the instrument suggested by (Ponnam & Balaji, 2014), which - in comparison to DinEX - also includes items considering the value for price, which seemed missing in the DinEX scale. The items have been translated into the German language by the authors. The drawback of this instrument however is that it has not yet been tested for validity and reliability, leading to uncertainty of results. However, it was hoped to test the reliability of the constructs by factor analyses conducted below.
In order to make the participation of the study more attractive to restaurant managers, an

Importance-Performance analysis of non-acoustic restaurant attributes has been added (according to Bufquin, Partlow, and DiPietro (2015)).
Since Lindborg and Friberg (2016) suggests that personality traits bias the perceived quality of sonic environments, it seemed necessary to include a short personality test. A suitable instrument with three items per personality dimension (according to the Big-Five theory) was found in the BFI-S by Gerlitz & Schupp on a 7-step Likert scale (Gerlitz & Schupp, 2005). Here it has been expected that only the dimensions of neuroticism and extraversion would significantly affect quality perception, thus only the six according items were chosen for the questionnaire.
Another potential moderating factor for perception of sonic environments is the sound sensitivity of individuals (Novak, La Lopa, & Novak, 2010). Since no inventory for testing of noise sensitivity fulfilling the requirement of shortness could be found, the authors were obliged to create the items themselves.
Visitation motive items have been added, since (Ponnam & Balaji, 2014) suggest that such motives influence restaurant attribute importance.
According to (Ryu & Han, 2011), perception of the physical environment can be distinct between new or repeated customers, making it necessary to add an item for past visits in the restaurant.
Soundscape parameters were assessed by means of the recommended items suggested in the ISO standard (2018) and translated into German by the authors. Here, a two-dimensional 5-step Likert scale was used, labelled with the symbols [–] [-] [0] [+] [++]. Ultimately, 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 related items
- 16 soundscape items
- 6 personality traits items (Extraversion and neuroticism)

All rating-items, except personal data and the BFI-S items, were assessed using 5-step Likert scales and can be found in the appendix.

2.3 Data collection

2.3.1 Acoustical measurements

$L_{Aeq15'}$ 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. 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.
Room acoustical measurements were conducted according to the short measurement defined in (e. V. DIN, 2008) 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. Where possible, cooling aggregates and other noise sources were switched off. To obtain values of T_{leer}, octave band measurements from 125 to 4000 Hz have been arithmetically averaged. The reverberation time in occupied state T_{occ} was calculated for the occupation state at the moment of the questionnaire's completion according to (DIN, 2016) 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 3.

ID	**Area**	**Volume**	**Capacity**	T_{leer}	T_{occ}	$L_{A,eq,15'}$	T_{DIN}	T_{RIN}
	$[m^2]$	$[m^3]$	persons	[s]	[s]	[dB(A)]	[s]	[s]
1	54.3	152.04	47	0.70	0.48	n.A.	0.75	0.20
2	118.70	391.71	72	0.53	0.44	64.3	1.672	0.34
3	44.3	141.76	36	0.80	0.56	75.0	0.80	0.25
4	110.6	353.92	75	1.01	0.69	73.3	0.76	0.29
5	97.4	301.94	70	0.64	0.49	69.6	1.10	0.27
6	n.A.	n.A.	n.A.	n.A.	n.A.	70.9	n.A.	n.A.
7	61.2	201.96	44	0.54	0.43	58.9	1.39	0.29
8	80.40	337.68	23	1.02	0.90	74.1	2.33	0.92
9	118.57	429.82	72	0.70	0.56	76.7	1.39	0.37
10	62.8	194.21	58	0.74	0.50	73.5	0.73	0.21
11	55.8	184.14	33	0.68	0.54	75.6	1.33	0.35
12	240.3	792.99	195	0.97	0.64	71.2	0.68	0.25
13	n.A.	n.A.	n.A.	n.A.	n.A.	72.8	n.A.	n.A.
14	n.A.	n.A.	n.A.	n.A.	n.A.	64.3	n.A.	n.A.

Table 3: Measurements and requirements for the restaurant sample

For the L_{Aeq15} measurements, a NTI XL2 acoustic analyser with M2210 microphone was used. The acoustical scenes were recorded in first order ambisonics format using a Sennheiser Ambeo VR Mic to allow for prospective 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.

L_{Aeq15} measurements failed in one restaurant (ID 1) due to technical problems, in three other restaurants room acoustical measurements were not possible (ID 6, 13 and 14). 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.
Measurements of reverberation time in empty condition are shown in figure 10 and compared

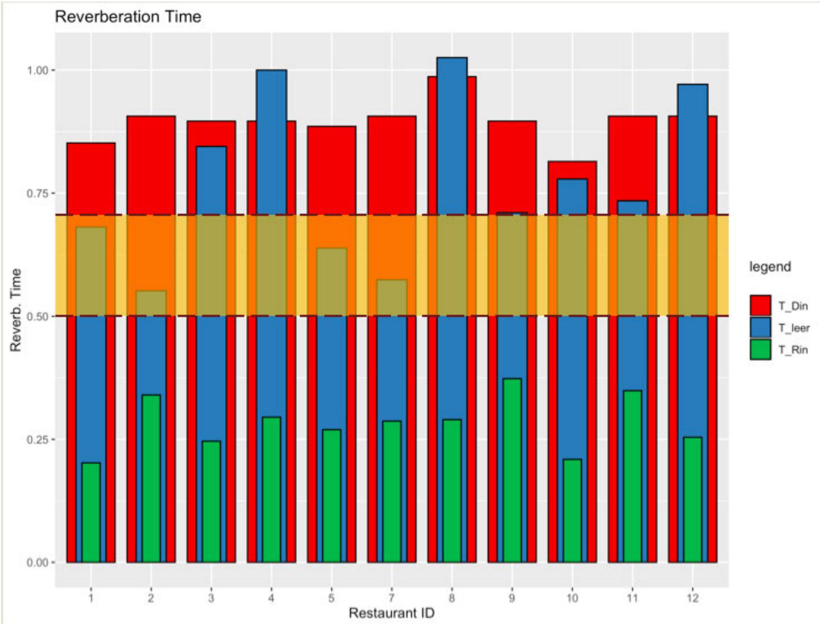

Figure 10: Measurements of Reverberation Time in empty condition (T_{leer}) of the participating restaurants compared to requirements by national standards (T_{DIN}), suggestions by Rindel (2018) (T_{Rin}) and Battaglia (2015) (yellow marked area)

to the requirements for room acoustic quality by the German standard (DIN, 2016) and the suggestions by Rindel (2018) and Battaglia (2015).

2.3.2 Assessment of questionnaire data

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 author or the restaurant's staff. Participants filled out the questionnaire on a tablet PC provided by the author or on their own smartphone using the browser-based platform LimeSurvey.

2.4 Data analysis

2.4.1 Variable reduction

The theoretical model includes 9 non-acoustic restaurant attributes. As interdependencies within these attributes seemed likely, a principal component analysis (PCA) was conducted to explore potential dimensions. Beforehand, the Kaiser–Meyer–Olkin measure verified the sampling adequacy for the analysis KMO $= .74$, and all KMO values for individual items were $> .67$, which is well above the acceptable limit of .5. Bartlett's test of sphericity, $\chi^2(36) = 449.75, p < .001$, indicated that correlations between items were sufficiently large for PCA.

The screeplot depicted in figure 11 suggests 2 underlying dimensions. However, a PCA with 3 underlying dimensions yielded a theoretically better fitting structure, as the items' contents were corresponding with each other. Furthermore, a 2-dimensional PCA only accounts for

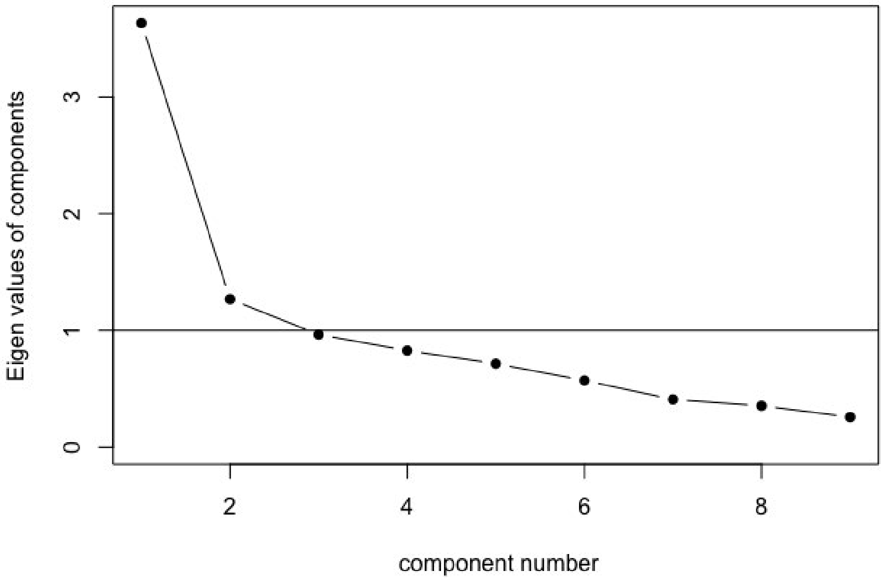

Figure 11: Screeplot of restaurant attributes

47% of total variance, whereas adding a third dimension sums up to explaining 65% of variance. Thus a PCA with three underlying dimensions and orthogonal rotation (varimax) was calculated. Results are shown in table 4.

	Varmiax rotated factor loadings		
Item	Product	Atmosphere	Service
Culinary Quality	**0.82**	0.13	0.19
Choice	**0.71**	0.20	0.25
Price for value	**0.69**	0.01	0.15
Plating	**0.63**	0.31	0.08
Interior Design	0.02	**0.86**	0.16
Ambience	0.17	**0.75**	0.00
Image	0.36	**0.60**	0.20
Friendliness	0.28	0.04	**0.87**
Availability	0.19	0.21	**0.85**

Table 4: Summary of Principal Component Analysis results for the restaurant attribute quality items with 3 underlying dimensions

This 3-dimensional structure was used subsequently to conduct a confirmatory factor analysis (CFA). In addition the three hypothesized restaurant quality items (overall quality, revisit, recommendation) were added. The CFA was used to compute individual factor scores for each observation (i.e. restaurant guests). In this manner it is possible to create a reduced model including three non-acoustic restaurant variables. Factor scores were computed with Bartlett's method and z-transformed.
CFA for restaurant attributes yielded a well-fitting $\chi^2(36) = 65.795, p < .01$ Fit indices indicated that the structure was fitting well with the data. Root Mean Square Error of Approximation was well under the recommended cut-off value of .08 (RMSEA = 0.072), just as Standardized Root Mean Square Residual (SRMR = 0.048) (Recommended <.08). Comparative Fit Index (CFI = 0.955) was well above the recommended cut-off (CFI > .90)

As it has been hypothesized that atmosphere includes acoustic as well as non-acoustic features, a partial correlation has been computed in order to decorrelate the two variables of soundscape pleasantness and atmosphere.

2.4.2 Analysis of soundscape data

Robust values for soundscape pleasantness P and eventfulness E were calculated from the eight soundscape items using the following formulas according to ISO-12913-2 (2018):

$$P = (p - a) + \cos 45 \cdot (ca - ch) + \cos 45 \cdot (v - m) \tag{5}$$

$$E = (e - u) + \cos 45 \cdot (ch - ca) + \cos 45 \cdot (v - m) \tag{6}$$

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

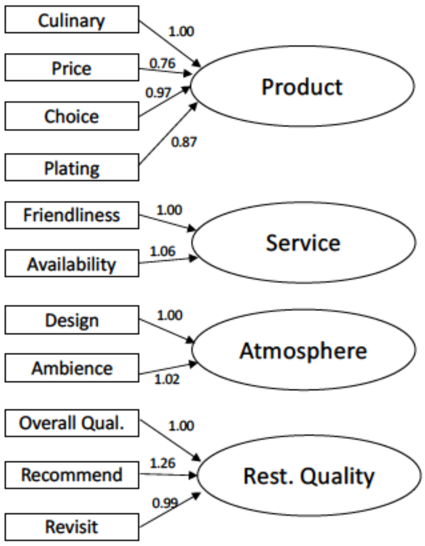

Figure 12: Structure and factor loadings of the computed confirmatory factor analysis

by ISO-12913-2 (2018)
The item loadings on the 2-dimensional factor solution are illustrated in figure 9.

2.4.3 Final models for hypothesis testing

The used method can be regarded as multiple repeated measures (guests) per subject (in this case: restaurants), meaning the gathered data was hierarchically structured. The basic issue with the data structure at hand is that the key predictors are measured at the restaurant level but the outcome variable is measured at the person level. The key fact is that random variation and structured effects may exist at both levels (Bryk & Raudenbush, 1992). Aggregation bias can occur, if a variable "takes on different meanings and therefore may have different effects on different levels" (Bryk & Raudenbush, 1992). For example, the average menu price may have an effect on restaurant quality above and beyond an individual guest's price rating. At the guest level, menu price provides a measure of the willingness to pay for a meal. At the restaurant level, it is a proxy measure of the restaurant's price category and therefore the available resources for products, service, design etc.
In order to decompose these effect levels, hierarchical linear modeling was used. Several linear mixed-effects models (LMM) were computed to test the hypotheses, estimating both fixed and random effects. More concretely, several random intercept models including a random intercept for each restaurant were computed.

A limiting factor for a model's complexity (or variable capacity) lies within its identification. As long as a model is over identified or equally identified, estimates of variable effects can be computed. However, if a model is under identified, this is no longer possible. Unfortunately, it turned out that potential moderating factors, like personality traits, visitation motifs, mealtime etc. could not be accounted for within the assumed model, as it would lead to identification problems. Therefore a part of the gathered data had to be discarded in the statistical analysis.
The final models were computed with z-standardized variables as follows:
To test hypothesis **H1A & H1B** (the effects of physical values on perceived soundscape pleasantness), a linear mixed model was computed:

$$P = L_{A,eq,15'} + T_{occ} \tag{7}$$

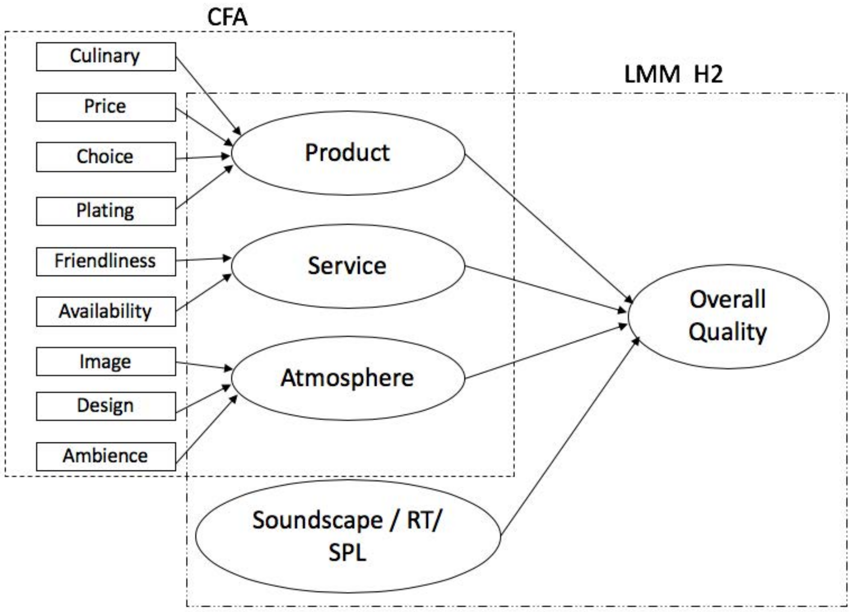

Figure 13: Graphical representation of tested effects between acoustical and non-acoustical factors on overall quality of restaurants

where P is the Soundscape Pleasantness, $L_{A,eq,15'}$ is the in-situ mean sound pressure level during 15 minutes before the time stamp of questionnaire delivery and T_{occ} is the in-situ reverberation time.
To test hypothesis **H1C & H1D** (the effects of physical values on perceived soundscape eventfulness), a linear mixed model was computed:

$$E = L_{A,eq,15'} + T_{occ} \tag{8}$$

where E is the Soundscape Eventfulness.
To test hypothesis **H2A** (the effects of sound pressure level on restaurant quality), a linear mixed model accounting for the non-acoustic restaurant attributes was computed:

$$RQ = L_{A,eq,15'} + Prod + Atmo + Serv \tag{9}$$

where RQ is the total restaurant quality factor score, $Prod$ is the product quality factor score, $Atmo$ is the (decorrelated) atmosphere quality factor score and $Serv$ is the service quality factor score as computed by confirmatory factor analysis.
To test hypothesis **H2B** (the effects of reverberation time on restaurant quality), a linear mixed model accounting for the non-acoustic restaurant attributes was computed. To account for the hypothesized inverted u-shape, the variable T_{occ} was squared and z-transformed:

$$RQ = T_{occ} + T_{occ}^2 + Prod + Atmo + Serv \tag{10}$$

To test hypothesis **H2C** (the effects of perceived soundscape pleasantness on restaurant quality), a linear mixed model accounting for the non-acoustic restaurant attributes was computed:

$$RQ = P + Prod + Atmo + Serv \tag{11}$$

Statistical analyses were carried out using R (R Core Team, 2019) and R Studio Version 1.2.5019 (RStudio Team, 2020). Including the packages lavaan (Rosseel, 2012), nlme (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2020), lme4 (Bates, Mächler, Bolker, & Walker, 2015), semPlot (Epskamp, 2019), psych (Revelle, 2019) and ggplot (Wickham, 2016)

3 Results

3.1 Results of interrelations between physical measures and soundscape perception

The first Linear mixed model revealed that both $L_{A,eq,15'}$ and T_{occ} were significant predictors for Soundscape Pleasantness, as can be drawn from table 5.

Calculating the $R^2_{marginal} = 0.216$, revealed that SPL and Reverberation time explained

$L_{A,eq}$	F(1,97) = 22.96	$\beta = -.028$	$p < .01$
$T_{20,occ}$	F(1, 97) = 3.97	$\beta = -.027$	$p < .05$

Table 5: Results of Linear Mixed Models to test H1A & H1B (effects of SPL and reverberation time on soundscape pleasantness)

21.6% of total variance in soundscape pleasantness ratings. Hence,

Hypothesis 1A: Sound Pressure level is correlated with Soundscape pleasantness

Hypothesis 1B: Reverberation time is correlated with Soundscape pleasantness

could both be confirmed.
Results are depicted in figure 14 & 15.

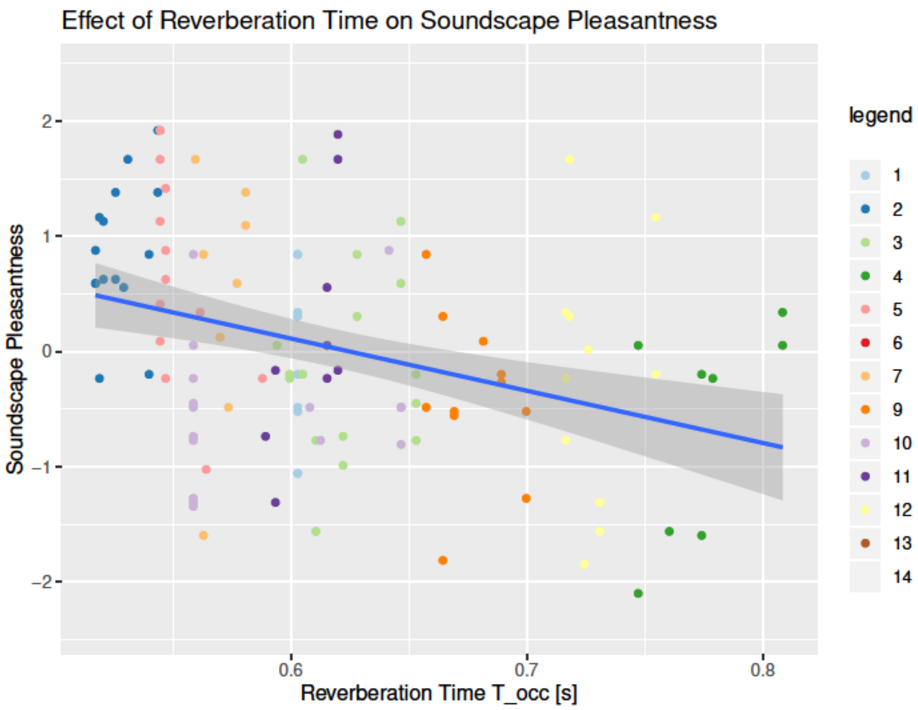

Figure 14: Effects of Reverberation Time on Soundscape Pleasantness, colours grouped by restaurant ID

The second Linear mixed model revealed that sound pressure level ($L_{A,eq,15'}$) is a significant predictor for soundscape eventfulness, whereas reverberation time had no measurable effect on soundscape eventfulness.

Thus,

Hypothesis 1C: Sound Pressure level is correlated with Soundscape eventfulness

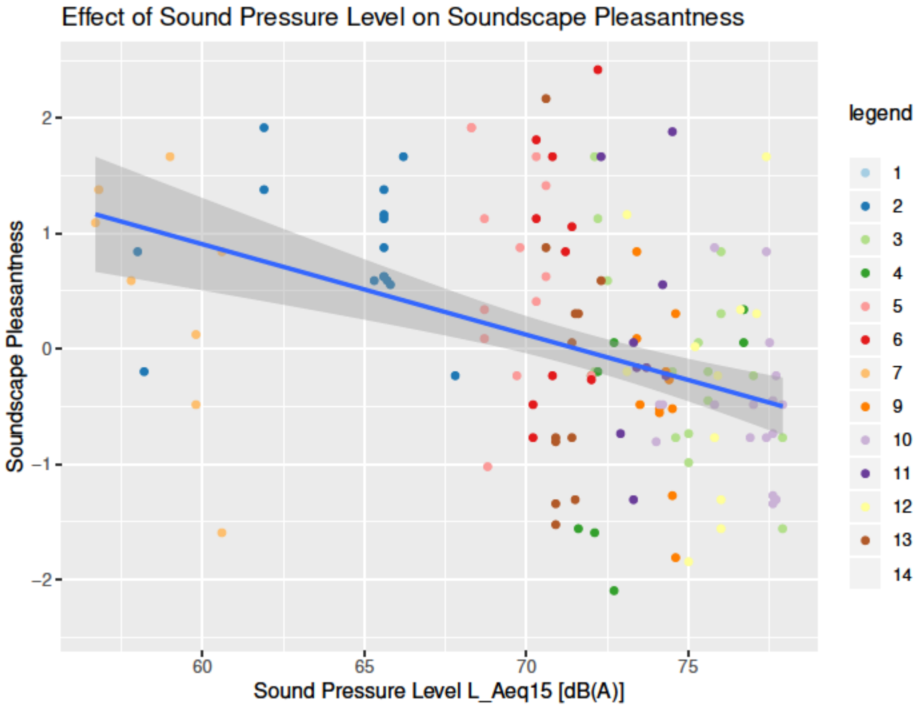

Figure 15: Effects of Sound Pressure Level on Soundscape Pleasantness, colours grouped by restaurant ID

$L_{A,eq}$	F(1, 96) = 41.07	$\beta = .55$	$p < .001$
$T_{20,occ}$	F(1, 96) = 2.25	$\beta = .60$	$p = .79$
$T^2_{20,occ}$	F(1, 96) = .14	$\beta = -.88$	$p = .71$

Table 6: Results of Linear Mixed Models to test H1A & H1B (effects of SPL and reverberation time on soundscape eventfulness)

could be confirmed, while

Hypothesis 1D: Reverberation time is correlated with Soundscape eventfulness, following an inverted u-shape

has been rejected.
The significant correlation between SPL and Soundscape Eventfulness is depicted in figure 16

The model's value of $R^2_{marginal} = 0.336$, thus Sound Pressure level explained 33.6% of variance in soundscape eventfulness ratings.

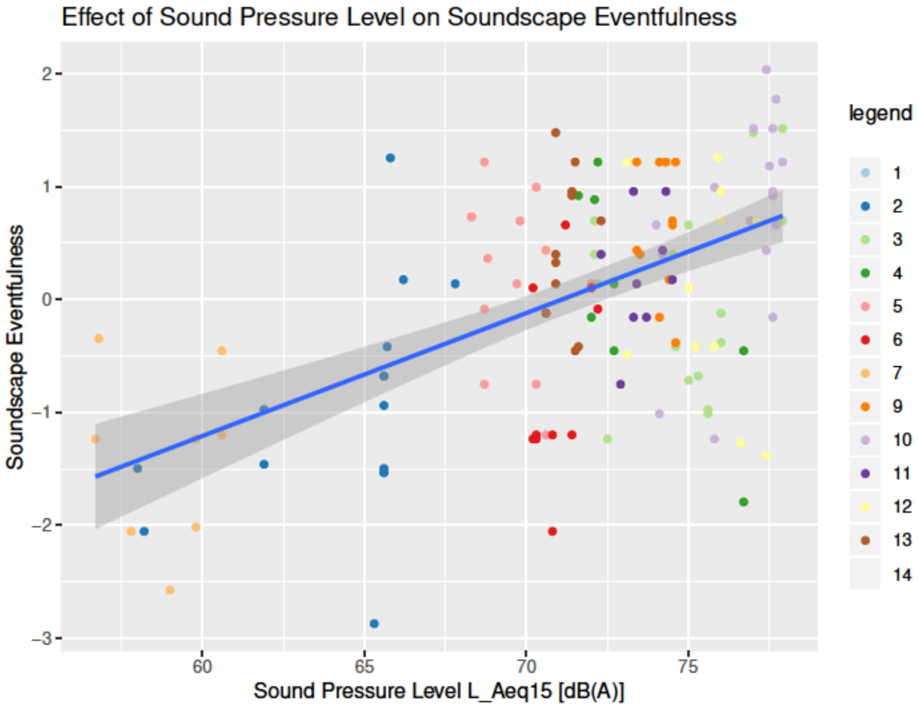

Figure 16: Effects of Sound Pressure Level on Soundscape Eventfulness, colours grouped by restaurant ID

3.2 Results of interrelation between auditive variables and overall quality ratings

The LMM concerning H2A revealed, that SPL is a significant predictor for overall restaurant quality. Results are shown in table 7. Calculating the model's $R^2_{marginal} = 0.679$, revealed that SPL the three non-acoustical factors explained 67.9% of total variance in overall restaurant quality ratings. For the purpose of comparison, another LMM without SPL as independent variable has been calculated. The model's fit indices (AIC = 299.2; BIC = 317.7; loglik = -143.6, $R^2_{marginal} = 0.644$) indicated that adding SPL as independent variable improves the model, but the additional variance explained through SPL is not large.

$L_{A,eq}$	F(1,131)=32.96	β = -0.13	$p < .05$
Prod.	F(1,131)=214.43	$\beta = 0.60$	$p < .01$
Atmo.	F(1,131)=15.21	$\beta = 0.19$	$p < .01$
Serv.	F(1,131)=12.18	$\beta = 0.20$	$p < .01$
Fit Indices	AIC = 273.3	BIC = 294.3	loglik = -129.7

Table 7: Results of Linear Mixed Models testing hypothesis 2A: Effects of Sound Pressure Level ($L_{A,eq}$) on overall restaurant quality ratings)

Consequently,

Hypothesis 2A: Sound Pressure level is correlated with Overall Restaurant Quality Rating could be confirmed.

Another LMM concerning H2B revealed, that reverberation time is not a significant predictor for overall restaurant quality when controlling for non-acoustic variables. Note that this result is only valid within the range of measured reverberation times.

$T_{20,leer}$	F(1,8) = 6.28	$\beta = -0.06$	$p = .47$
Prod.	F(1,109)= 151.98	$\beta = 0.57$	$p < .01$
Atmo.	F(1,109) = 10.03	$\beta = 0.19$	$p < .01$
Serv.	F(1,109) = 11.35	$\beta = 0.22$	$p < .01$
Fit Indices	AIC = 237.5	BIC = 257.1	loglik = -111.7

Table 8: Results of Linear Mixed Models testing hypothesis 2B: Effects of Reverberation Time in empty condition ($T_{20,leer}$) on overall restaurant quality ratings

Thus,

Hypothesis 2B: Reverberation time is correlated with Overall Restaurant Quality Rating, following an inverted u-shape

was rejected.

Finally, calculating another LMM concerning H2C revealed that Soundscape Pleasantness ratings could significantly predict overall restaurant quality ratings. Significance was only reached when the two variables Atmosphere and Soundscape Pleasantness were statistically decorrelated as described above in the methods section. In table 9 the results of the linear mixed model are depicted. Computing the $R^2_{marginal} = 0.645$ revealed, that the model accounted for 64.5% of total variance in the data.

P	F(1,144) = 46.40	$\beta = .11$	$p < .05$
Prod.	F(1,144) = 184.60	$\beta = .54$	$p < .01$
Atmo. (decorrelated)	F(1,144) = 17.07	$\beta = .21$	$p < .01$
Serv.	F(1,144) = 14.19	$\beta = .21$	$p < .01$
Fit Indices	AIC = 300.9	BIC = 322.5	loglik = -143.4

Table 9: Results of Linear Mixed Models testing hypothesis 2C: Effects of Soundscape Pleasantness (P) on overall restaurant quality ratings

As a consequence,

Hypothesis 2C: Soundscape Pleasantness is correlated with Overall Restaurant Quality Rating

could be confirmed.

3.3 Results of interrelations between auditive and non-auditive variables

Testing H3A, the last LMM yielded an effect of SPL on culinary taste close to significance, as can be withdrawn from table 10

$L_{A,eq}$	F(1,134)=3.88	β = -0.03	p = .051

Table 10: Results of Linear Mixed Models testing hypothesis 3A (effects of SPL on food quality)

4 Discussion

In the following part present results will be interpreted and discussed in comparison to results of other studies in the field. Furthermore, this section will be dealing with the implications and limitations of this study. Finally light will be shed on future investigations on the subject.

4.1 Interpretation of results

This study aimed to investigate whether pleasantness and eventfulness of soundscapes could be predicted by physical measures. The results indicate that SPL and RT are good predictors for perceived pleasantness and eventfulness of soundscapes in restaurants. However, as suggested in Soundscape research a lot of other factors seem to have an influence on soundscape perception, as 67% of variance in pleasantness ratings remained unexplained. A lot of preference could for example be dependent on the meaning of the sounds and personal preference.

The second research question was whether, physical measures of the sound environment could predict the overall quality rating of restaurants. It has been shown that noise level (SPL) is a direct predictor for restaurant quality, which is in line with previous findings by Battaglia (2015). Conversely, reverberation time was not a direct predictor for restaurant quality, which seems to be at odds with suggestions by Battaglia (2015) and Rindel (2018). However, it should be added that dealing with noise in eating establishments has to a large extent be done over lowering reverberation time. Thus reverberation time could still be an indirect predictor when the amount of guests is kept as constant.
A possible reason as to why the noise in restaurants is not as annoying as physical measurements suggest is that the human hearing system can actively or in-actively “hear away” from unintended sounds and let them “disappear” from the conscious sphere. This is known as the cocktail party effect, as mentioned beforehand. However, it is not possible to do so for people with hearing impairments, making loud restaurants a comfortable place for well-hearing people only.
Finally, it has been tested whether interrelations between auditive variables and non-auditive variables exist. Considering that the restaurant sample did not contain very high sound pressure levels, it is surprising that there was a measurable effect of SPL on culinary taste, which only slightly missed significance. It is thus likely that significance would be reached with a larger sample containing louder restaurants. Although crossmodal effects between auditory and gustatory cues have already been empirically proven in the literature, it is exceptional to be able to observe this effect in the field considering the many other influencing factors of food taste evaluation. Soundscape Pleasantness has not shown to be a better predictor than SPL. This could be due to the items of soundscape pleasantness being too generalized for the situation in restaurants. Words such as ‘exciting’ and ‘monotonous’ might be not specific enough to describe the demands of a high quality restaurant soundscape. On the other hand, statistical tests with other items concerning acoustic quality did not do a better job predicting overall quality. Again, this could be due to the small range of RTs in the sample, not covering critical RTs over 1 s.
To close the loop, the suggestions and requirements in the literature, the standards suggested by Rindel (2018) seem to be out of scope regarding the high costs and relatively small impact. The question of necessity for the extremely low values of RT suggested to achieve speech intelligibility could not be confirmed.

4.2 Implications

It has been shown that noise level is a direct predictor for restaurant quality ratings. Restaurants dealing with high SPL should thus consider room acoustical treatment. The lack of

significance between reverberation time and restaurant quality ratings could be caused by the small range of reverberation times contained in our restaurant sample, which did not exceed critical RTs over 1 s. Some of the restaurant owners asked to participate in the study declined because they didn't want to draw their guests' attention to the acoustics. Their restaurants were strongly reverberant and thus high in noise level. Still these restaurants seemed to be running a business successfully. Hence, poor acoustics might not be a criterion for exclusion of success but a quality characteristic for restaurants.
The question of whether the acoustic atmosphere is an essential attribute mainly depends on the placement of the restaurant. Does it deliver services or experiences? If selling service is prioritized, it may be more goal-oriented to invest resources in high quality of food and service. This approach may be adequate in fast-food services, bistros or take-aways. If, however, the guest is meant to undergo a memorable experience during their visit, attention needs to be drawn to atmospherics, covering all the senses. Thus, the acoustic atmosphere needs to be designed adequately for the desired restaurant experience.

The quality of acoustic atmosphere in terms of relaxing, enjoying, and perceiving the food in company with other people can unambiguously be attained by low noise level and low reverberation. However, if we take the perspective from a marketing point of view, for guests without a determined culture of eating out, any experience could possibly be transformed into a lifestyle experience. Thus a noisy restaurant could easily be "sold" (and accepted) as an immersive, bubbly lifestyle restaurant, where some people would define it as an annoying and unnecessary place to stay. Interestingly, one of the participating restaurants' managers was in the course of establishing a franchise of lifestyle restaurants and nutrition products. He claimed that the loud music combined with the high reverberation (that could unfortunately not be measured due to a lack of time available by the staff) was part of the concept for the vibrating atmosphere.
Reviewing the measured restaurants and requirements by national standards, it becomes clear that restaurant managers are hardly ever concerned by a very high quality of acoustics. While a negative effect of high reverberation time could be shown, it only displays this effect within the range of common restaurant acoustic standards. Effects could potentially be way stronger in the range of what would be called "sound studio acoustics" (values in the range suggested requirements by Rindel (2018)).

As this would be a unique concept, it is likely that guests would perceive the visit as an exceptional memory. This concept is thus in line with the theory of the "experience economy" the market is currently moving towards, according to Pine et al. (1998). For the purpose of testing the effects on overall restaurant quality, an experimental mock-up would need to be built. It could be combined with electrical reverberation to investigate the effect of reverberation time isolated from other variables. But combined with the soundscape approach, the room could also be filled with positively connoted ambience sounds to achieve an immersive sound experience while eating. If future investigations should reveal that acoustics is indeed a factor to set quality apart from other competitors, this would be an exclusive selling point with large potential for upscale restaurants.

4.3 Limitations

As this is a field study, with highly complex surroundings, effects are mixed with interdependent other possible effects. The effect of reverberation time on restaurant quality has to be investigated experimentally. General Limitations of Empirical studies apply. For example the fact that a parametric (frequency-based) significance test is used implies that the sample is picked randomly out of the population. However, since questionnaires are only filled out by those people who want to participate in a study, the sample is "filtered" through a not-randomly self-selection process (Non-response-error) (Bortz & Döring, 2016) (p.300).

While this effect is valid for the whole sample of the study, a similar effect is expected to occur in samples in-between restaurants. The participants can only be picked from a group of people who actually chose to have a meal at the given restaurant. It is expected that there are differences of preference and demand between the guests of various restaurant types. This results in a different evaluation of restaurant quality and soundscape quality in-between restaurants. For example, a person disliking loud restaurants would not choose to visit a busy restaurant with high SPL at all and therefore their evaluation can systematically not appear in the statistics. It is thus generally questionable if the chosen method can indicate the perception of soundscape- and restaurant-quality of the population in general. What it however may deliver is a probation of the substantial hypothesizes discussed earlier. By means of the binaural recordings however, further studies can be conducted with evaluation of various soundscapes per participant.
Music was not accounted for in the questionnaire because the effect of music on people is a socially and psychologically complex subject that deserves separate examinations. Directing the attention towards the act of listening itself might have caused a more critical disposition and possibly produced a negative bias on disturbing sound sources such as mechanical sounds.
Soundscape Items were not anchored and incorrectly scaled as two-dimensional (bipolar), whereas they should have been scaled as one-dimensional (unipolar).

4.4 Future investigations

Hospitality industry and acoustic consultants could gain a lot of customer-specific knowledge in conducting a large study as to what is most important according to the preferences of individual age and character groups of their clients. Under acoustic factors it might be speech intelligibility, privacy, vibrant soundscapes, or calm soundscapes. To some customers the optical design or the hipness of a restaurant could be more crucial than acoustical factors. However, even in case of highly vibrant soundscapes being preferred, it is certainly possible to create such an atmosphere without overwhelming noise arising from many speakers in highly reverberating rooms. Well-designed room acoustics is the instrument for shifting the tipping point of vibrant soundscapes from being positively perceived human interaction to becoming incomprehensible hubbub upward, yielding a higher capacity of people in acoustically comfortable guestrooms.
In the sense of Truax, it would be interesting to design restaurant soundscapes that support the customer's dining experience by supporting sounds of food and drink preparation.
More investigations would be of interest within the spectrum of very dry and very reverberant restaurants. More specificly, it could be investigated whether restaurants start to become more unpleasant if the reverberation time gets very low (as suggested by (Rindel, 2018)). The other way around, it would be interesting to investigate whether the negative effect of poor acoustics on restaurant quality becomes more pronounced when reverberation times substantially exceed one second.
In order to outdo the usual dining experience, experiments of taste through using other statistical methods than classical structural equation modelling, like the partial least-squares method, could provide more insight within more complex models, including more variables than in the present analysis. The existing data set could thus be used for further investigations.

It could be argued that linear mixed models including random slopes would be interesting to test. For example, effects of soundscape pleasantness on restaurant quality might be individually strong for low, medium and high T_{20}. Unfortunately sample size did not allow for random slope testing.
Furthermore, it could be argued, that non-acoustic effects need to be controlled for in an

experiment under laboratory conditions, to test whether changes of room acoustics only have an effect on restaurant quality. On the other hand, we would get back to the problem that the experimental conditions might be too far from reality to allow us to make predictions within the real world. A compromise might be an experiment in the field, where several restaurants are evaluated by their guests before and after room acoustical measures.

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Appendix

Questionnaire

Group	Question	Variable Name	Scale
Demography	Ich bin ...	gender_num	single choice
	Wie alt sind Sie?	alter	open
	Welchen Bildungsabschluss haben Sie?	edu	single choice
Hearing	Sind Sie lärmempfindlich?	noise_NO001	5-point Likert-scale
	Sind Sie hörgeschädigt?	noise_IM001	
	Zu welcher Mahlzeit sind Sie hier?	mealtime	single choice
Repeat or first time customer	Wie oft sind Sie in diesem Restaurant?	visits	single choice
Motives	Warum sind Sie heute hier?		
	um einen speziellen Anlass zu feiern	motiv1_anlass	5-point Likert-scale
	um unter Leute zu kommen (z.B. entspannen, eine gute Zeit haben)	motiv2_social	
	um zu essen (z.B. Mittagessen, Abendessen)	motiv3_essen	
Restaurant Quality Items	Wie zufrieden waren Sie heute in diesem Restaurant mit den genannten Aspekten und wie wichtig ist Ihnen dieser Aspekt?		5-point Likert-scale
	Kulinarische Qualität (Gutes Essen, Qualität des Essens, köstliches Essen, Frische des Essens, Verwendung exotischer Gewürze, verwendete Zutaten)]	rq_kul_perf	
	Vielfalt des Menüs (Bandbreite der Speisekarte, gelungenes Menü, wechselnde Tagesgerichte, Motto-Menü, exquisite Küche, Küchen verschiedener Länder, Fusionsküche)	rq_var_perf	
	gehobenes Image des Restaurants (Restaurant-Name, Prestige der mit dem Namen verbunden wird, kultivierte Gäste, Standort, Spezialitäten-Restaurant, Spitzenklasse Köche)] [Skala 1] Wie zufrieden waren Sie heute in diesem Restaurant mit den genannten A	rq_img_perf	
	Bewirtung(Qualität des Service, Behaglichkeit, Gefühl, Sorgfalt, Zuvorkommenheit, Reaktion auf Anfragen, Herzlichkeit)	rq_srv1_perf	
	Preis / Leistungsverhältnis(Wertigkeit für Geld, passt ins Budget, preisgünstig)	rq_price_perf	
	Einrichtung und Design(Restaurant Design, physische Umgebung, Leitmotiv, Multifunktionaler Raum)	rq_design_perf	
	Ansprechbarkeit des Personals(Zeit für die Bestellung, Zeit zur Antwort auf Rückfragen, Aufmerksamkeit der Bedienung, Eingehen auf Sonderwünsche, vollständige Kenntnis der Speisekarte, Fähigkeit individuelle Empfehlungen zu geben)	rq_srv2_perf	
	Anrichtung der Speisen (Qualität des Geschirrs und Bestecks, Farbe des Essens, Geruch des Essens, Temperatur des Essens)	rq_plating_perf	
	Ambiente(Musik, Beleuchtung, Stimmung, ästhetische Atmosphäre, ansprechende visuelle Elemente, ästhetische innere Umgebung, angenehme Umgebung, live performance)	rq_amb_perf	
	Insgesamte Qualität des Besuchs	rq_total_perf	
Behavioral Intentions	Würden Sie dieses Restaurant einem Freund weiter emfehlen?	recomm	5-point Likert-scale
	Würden Sie dieses Restaurant wieder besuchen wollen?	repeat.	
	Welche Verbesserungsvorschläge würden Sie diesem Restaurant geben?	Open	
Soundscape ISO	Wie nehmen Sie die hier vorhandene Soundscape war?		5-point Likert-scale
	angenehm	sq_pleas	
	chaotisch	sq_chaot	
	lebhaft	sq_vibrant	
	ereignislos	sq_unevent	
	ruhig	sq_calm	
	lästig	sq_annoy	
	bewegt	sq_eventful	
	monoton	sq_monot	
Soundscape Restaurants	Wie laut empfinden Sie den Geräuschpegel in diesem Restaurant?	loudness	5-point Likert-scale
	In dieser Umgebung war eine angenehme Unterhaltung möglich	se_conv	
	Mechanische Geräusche empfand ich als störend(z.B. Küchengeräusche, Stühle schieben, Geschirrklappern, Kaffemaschine, Lüftungsgeräusche etc.)	se_mech	
	Die Unterhaltungen von anderen Gästen empfand ich als störend	se_conversat	
	Die gegenwärtige Klangumgebung ist für diesen Ort angemessen	se_appr1	
	Mein Besuchsmotiv war mit der gegenwärtigen Klangumgebung vereinbar	se_motiv	
	Eine angenehmere Klangumgebung würde die Qualität meines Aufenthalts in diesem Restaurant verbessern	se_total	
	Eine angenehmere Klangumgebung würde die Wahrnehmung der kulinarischen Qualität verbessern	se_culin	
Personality Traits	Ich bin jemand, der ...		7-point Likert-scale
	kommunikativ, gesprächig ist	pt_comm	
	sich oft Sorgen macht	pt_worry	
	aus sich heraus gehen kann, gesellig ist	pt_exrov	
	leicht nervös wird	pt_nervous	
	zurückhaltend ist	pt_reserv	
	entspannt ist, mit Stress umgehen kann	pt_relax	