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# A taxonomy of sound sources in restaurants

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ABSTRACT

Restaurants are complex environments engaging all our senses. More or less designable sound sources, such as background music, voices, and kitchen noises, influence the overall perception of the soundscape. Previous research suggested typologies of sounds in some environmental contexts, such as urban parks and offices, but there is no detailed account that is relevant to restaurants. We collected on-site data in 40 restaurants ($n$ = 393), including perceptual ratings, free-form annotations of characteristic sounds and whether they were liked or not, and free-form descriptive words for the environment as a whole. The annotations were subjected to cladistic analysis, yielding a multi-level taxonomy of perceived sound sources in restaurants (SSR) with good construct validity and external robustness. Further analysis revealed that voice-related characteristic sounds including a 'people' specifier were more liked than those without it ($d$ = 0.14 SD), possibly due to an emotional crossmodal association mechanism. Liking of characteristic sounds differed between the first and last annotations that respondents made ($d$ = 0.21 SD), which might be due to an initially positive bias being countered by exposure to a task inducing a mode of critical listening. Comparing the SSR taxonomy with previous classifications, we believe it will prove useful for field research, simulation design, and sound perception theory.
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## 1. Introduction

The acoustical richness of restaurants provides ample opportunities to study sound perception in context. Restaurants, being one kind of servicescape i.e. the "manmade, physical surroundings, as opposed to the natural or social environment", are characterised by "elaborate physical complexity" and "interpersonal services" [10, p. 58]. The complexity is evident in that ambient environmental conditions affect the senses through physical factors such as temperature, lighting, noise, music, and scent, as well as through psychological factors such as memory, appraisal, and "imagery" ([18, p. 172]; see also [48]). Restaurants are interpersonal in that actions are performed both by customers and employees in face-to-face interaction. Bitner [10, p. 66] suggested that sensorial effects are mainly holistic, and that they might only become problematic when either extreme (e.g. high ambient noise levels), persistent (e.g. faint yet annoying sounds), or in open conflict with people's expectations (e.g. 'wrong' music genre). While overall aspects are important, we believe it is necessary to identify and classify the physical and interpersonal design elements in as much detail as possible, if we want to identify how the servicescape can be improved.

The present study extends our recent work [5] and attempts to answer the call for contextual specificity in soundscape research ([25]; see also [18]). We focussed on perceived sound sources in restaurants and chose an empirically grounded approach.

Two related forms of systematic classification of phenomena are typology, concerned with universals and constructed top-down, and taxonomy, built bottom-up from empirical observations. [51,52]. Schafer [49, p. 137–148, 268–270, p. 26] classified the sonic realm by referential aspects ('natural sounds', 'human sounds', 'sounds and society' and so forth) and by significance ('keynote', 'signal', and 'soundmark'). The first typology refers to physical sources in the world and the second to their purpose as understood by humans. Schafer's work influenced numerous operational classifications of sounds in outdoor urban soundscapes (e.g. [59,39,22,9,7,8,25,12,13]). However, indoor soundscapes have received comparatively less attention. Sound sources in restaurants were discussed by Aletta and co-authors [1, p. 1549], and in Migneron and Migneron [31]. In our previous work, we have proposed a typology of acoustic design elements in restaurants [5]. Some but not all of the proposed classification schemes retained Schafer's distinction between the attributed source and

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interpreted purpose of perceived sounds (further discussed in Section 4.3).

Restaurant sonic environments are constituted by designable acoustic elements. Models of restaurant soundscapes might be validated against ecologically strong measures such as profit [32,38] and 'priciness' [5]. Through crossmodal correspondences, sound is known to affect people's perception of the taste and flavour of food [53,38]. Cognitive assessment of sound sources is conditioned on perceiving certain sounds as foreground events [11]. The strength of the emotional reaction to a foreground event depends on whether the physical source is recognisable or if the sound is abstract [2]. Indeed, source identification might be a stronger predictor of perceived quality than sound level [35]. The recent ISO definition states that soundscape is a perceptual construct originating in sound sources that are distributed in space and time in a physical environment [14]; see also e.g. [50]. Studies of the urban soundscape have shown that most people prefer natural over technological sounds [49,41]; see also [21,40,57,35,9]. Bosch and Andringa [11] combined appraisal and event annotations of sound sources in an urban soundscape and found "attractors" towards 'calm' and 'chaotic', indicating a tendency for dichotomisation. Some sounds appear to be almost universally undesirable, yet might still be wanted in particular settings [18, p. 174]. Perceptual experiments have shown that soundscape evaluation depends on the activities that the listener observes or imagines taking place [34]. Perhaps due to innate ecological listening principles, people spontaneously attribute auditory phenomena to causal actions [54]. Individual differences such as age [58], personality factors [4], and noise sensitivity [60], have also been shown to influence the perception of sound. As emphasised in the ISO definition, context matters. However, it is easier to define what is annoying than what is pleasing [18, p. 169].

Among the various designable acoustic elements in restaurants, music is the most obvious. It is something that managers have at their immediate disposal and it is an effective way in which they can communicate information about the venue. On the other hand, how restaurant customers perceive background music is less well understood. Researchers have focussed on how behaviour and appraisal are influenced by music style and sound level [56,36,37]. Manipulation of such factors have typically shown that moderately arousing music is preferred ([32,38]; see also field studies by [15,17]). The effect of other aspects of background music design, such as loudspeaker sound diffusion design and interactive personalisation, remain to be systematically investigated.

Another prominent acoustic element in restaurants is constituted by voices, commonly identified as a major source of annoyance. For example, "conversation of others" was found to be the most predominant noise source in restaurants and a factor that limited, not promoted, social interaction [17, p. 11]; see also [61]. While speech is essential for restaurants as social places, voice sounds become problematic mainly due to room acoustic factors that are largely designable [45]. Different kinds of restaurants may have different design priorities. Interior design materials, which clearly affect room acoustics, are associated with food style, design style, and priciness [5]. For a vocal communication to be intelligible it needs to be 7 dB or more above the background level [29, p. 362]. With multiple simultaneous conversations inside an enclosure, each speaker tends to raise the voice in order to be heard, thereby contributing to the background din for listeners that are outside the communication perimeter. This produces a feedback loop of increased ambient noise known as the Lombard effect (see [55]). A survey of 112 restaurants documented a median level of 70 dBA [5], significantly higher than the "optimum level... for dining pleasure", 64 dBA, suggested by Novak and collaborators [38]. In social situations, listeners tend to direct their attention towards one speaker at a time, while the voices of others perceptually fuse into the background (a.k.a. the cocktail party effect, described by Cherry [16]). As background levels soar, the soundscape becomes saturated and the cocktail party effect is overpowered; individual conversation breaks down and is replaced by crowd din. Music that is not loud enough to be listened to and understood as communication becomes part of the background noise. Contemporary practices in interior design, such as a proclivity for large, open spaces with few partitions, and hard, easily maintained surfaces, create generous reverberation that further compounds to the effect.

Beyond music and voices, other sound sources might influence the experience more subtly. Navarro and Pimentin [33] investigated vocal comfort in food courts and concluded that improving the design of incidental sources, via "fix-mounted chairs, improving dish tray handling, and avoiding game stations", might have a larger and more immediate impact on the perceived quality than controlling crowd noise with acoustic panels. There is a vast array of 'other noises' in restaurants, as diverse as coffee bean grinders, cutlery, and cash register bells. From common experience and anecdotes (e.g. the vivid account in [47]) it is clear that the perception of such sounds goes from extremely negative to extremely positive. Yet, the prevalence of all the 'other noises' in restaurants has not been systematically investigated in the reviewed literature; the influence that individual sound sources have on the overall soundscape quality is unknown. Addressing this lacuna of knowledge, the aim of the present work was to create a taxonomy of perceived sound sources in restaurants. Our hypothesis was that the appraisal of sound sources would correlate with the perceived quality of the soundscape as a whole.

## 2. Methods

### 2.1. Questionnaire

We developed a questionnaire aiming to capture restaurant customer behaviour and their perception of the environment. One part was designed to identify perceived sound sources via free-form annotations, and the other part adopted the Swedish Soundscape Quality Protocol (SSQP; version of March 2011, [8]. Three questionnaire items are relevant to the present study.

First, respondent were asked to "Describe 3 characteristic sounds of this restaurant". They answered by writing free-form text (a single word or a short phrase) on three numbered lines. At the end of each line, they were asked: "Do you like this sound? Yes/No (Please circle)". The appraisal was registered in a variable called Liking, encoded numerically with 'yes' = 1, 'no' = −1, and blank (no response) = 0. Annotation order was also coded.

Second, respondents had to "Give 5 words that you would use to describe this restaurant to a friend". They answered by writing free-form text (a single word or a short phrase) on five numbered lines.

The third item was adopted from the SSQP: "To what extent do you agree with the statements below on how you experience the present surrounding sound environment?". Responses were made on 5-point Likert scales labelled "pleasant", "chaotic", "exciting", "calm", "annoying", and "monotonous" and anchored by "Agree completely" and "Disagree completely". According to the circumplex model that the authors had developed, a score for Pleasantness can be derived from the six ratings on unidimensional scales by calculating:

$$Pleasantness = pleasant - annoying + 0.71 * (exciting - monotonous + calm - chaotic). \quad (1)$$

Note that the scales are taken pairwise, each pair representing a bipolar perceptual dimension. The first pair is aligned with the Pleasantness construct, while the latter two dimensions are offset by ±45° (i.e. $\cos(45°) \approx 0.71$).

### 2.2. Statistical techniques

Statistical analyses were carried out in R [43], including standard tools such as correlation, ANOVA, and Tukey's test for honest significant differences (see e.g. [24, p. 391]). Shapiro–Wilk's test was used to check the normality of distributions [46]. For distributions that could not be assumed normal (e.g. Liking values, Section 3.4) confidence intervals around the mean where formed using a bootstrap method by Efron and Tibshirani [20] as described in Kabacoff [28, p. 303]. Correlations between non-normal distributions were calculated with Kendall's tau as a non-parametric statistic. It was chosen over e.g. Spearman's rho since the error distribution is known and thus the level of significance for each comparison could be determined. Non-parametric tests on the differences between distribution medians employed Wilcoxon's signed rank test (or the two-sample version known as the Mann-Whitney test), following recommendations in Howell [24, p. 304 and 673–686] and Kabacoff [28, p. 166–170]. Pearson's Chi-square test was used to test the independence of variables in contingency tables (in Section 2.4; see Howell [24, p. 148] for a discussion of alternative tests). As a measure of the agreement among judges evaluating a set of ratings (e.g. Conveyed Pleasantness, Section 3.5), standard coefficient alpha was used ([19]; see also [44, p. 217]). In analyses where multiple comparisons were made on the same data, the family wise error rate was controlled by applying Bonferroni correction with Dunn-Sidak's method (see e.g. [24, p. 378]). Effect sizes of distribution differences were expressed as Cohen's d (e.g. [24, p. 200]).

### 2.3. Acoustic measurements

$L_{eq}$, or equivalent continuous sound level, is a basic descriptor of fluctuating sounds. It takes into account the total sound energy over a given time period and expresses the level as a single value in dB that corresponds to what a steady-state sound with the equivalent amount of total energy would have. Similarly to other sound pressure level (SPL) measures, $L_{eq}$ is specified by the time interval and the filtering curve that has been applied. For example, $LA_{eq,3m}$ indicates that the time period was three minutes and that the A-weighting curve was used. The A-weighting curve is similar to the response of the human ear at lower levels, while the C-weighting curve is similar to its response at higher levels (for details see e.g. [29, ch. 12]).

In the present work, SPL was measured on-site using a calibrated meter (Checkmate) with Fast (125 ms) and Max (i.e. peak) settings. Since this device does not offer level equivalent measurement, estimates of $LA_{eq,3min}$ and $LC_{eq,3min}$ were made in the following way. Ten peak level readings were captured over a period of approximately 3 min (one reading every ~20 s) on the A-weighted scale, followed by similarly capturing peaks using the C-weighted scale. The values for each scale were then dB-averaged to produce the estimates. A pilot laboratory study comparing $L_{eq}$ estimates obtained by this method against $L_{eq}$ measured by a professional SPL meter (Extech 407790) suggested that the former are accurate for steady-state sounds but that they tend to overshoot in the case of time-varying sounds, such as various soundscapes, by up to 2 dB depending on their character (cf. discussion in [31] about ambient and peak levels).

### 2.4. Data collection and sample characteristics

Suitable restaurants were identified by considering food style, price level, and design. To assure variety of price levels yet consistency in terms of food style, restaurants were selected in pairs: one with relatively high prices and the other with relatively low prices, yet both serving food of the same style and cuisine (cf. [5]). Furthermore, the restaurants had to be indoor environments with no large open windows or doors. After selecting a restaurant, the collector approached customers one by one, introduced the purpose of the survey, and asked if the customer was willing to participate. Respondents below 18 years old were only included if a parent or other adult in their company gave permission. After consenting, the respondent was asked to fill out the two protocols without communicating with table neighbours. Meanwhile, the collector made acoustic measurements as described in Section 2.3, made a 3-min stereo recording using a handheld device (Edirol R-09), and wrote down observations about the architecture, location, interior design, food and design styles, and other general characteristics of the restaurant.

#### 2.4.1. Restaurants

Data were collected at 40 restaurants. The representativeness of this sample was determined by analysis of SPL measurements, price levels, and general characteristics. The mean sound pressure level was 72.2 dBA (78.1 dBC), in a range between 57.9 and 82.8 dBA (67.7 and 92.2 dBC). This corresponds well with previous findings [5] considering that the method employed in the present study had been found to slightly overestimate $L_{eq}$. The distributions of LA, and LC among the 40 restaurants were both normal (Shapiro–Wilk's $W > 0.96$, $p > 0.17$ n.s.; for statistical techniques, see Section 2.2). Annotations of menu price were incomplete, so the analyst retrieved information for the restaurants from a web service (http://www.HungryGoWhere.com) that lets people share e.g. how much they have spent. There were on average 32 user reports per restaurant, allowing robust estimates of typical spending. Across the sample of 40 restaurants, mean spending was 19.6 SGD per customer, in a range between 5.0 and 46.0 SGD. The distribution of mean spending was normal (Shapiro–Wilk's $W > 0.96$, $p = 0.26$ n.s.). The web service was also used to categorise each restaurant by style in line with previous work [5]. In terms of Food Style, the restaurants were: 'Western' (21 places), 'Other Asian' (13), 'Chinese (5), and 'MixFusion' (1); and in terms of Design Style, they were 'Dining' (21), 'Café' (9), 'FastFood' (7), 'Bar & Buffet' (2), and 'Hawker' (1). Analysis showed that Food Style and Design Style were independently distributed (Pearson's $\chi^2 = 13.4$, simulated $p = 0.27$ n.s.). Lastly, observations of general characteristics and architecture confirmed that the sample consisted of typical restaurants and that none stood out as unusual. Thus, the representativeness of the sample of restaurants was supported by the normality of distributions of SPL and price, and in regards to design.

#### 2.4.2. Respondents

In total, 393 individual customers consented to participating. Responses were gathered from 10 people at 35 restaurants, 11 at three, and 5 at two. Mean age was 27 years, in a range between 12 and 61 years. 35 respondents (8.9%) below 18 years old had been given permission to participate by their guardian. Gender was balanced, with 193 female, 197 male, and 3 blank responses. Gender and age were independently distributed in the sample (Pearson's $\chi^2 = 76.6$, simulated $p = 0.45$ n.s.). These statistics support the assumption that the sample of respondents is representative of the general population.

### 2.5. Classification

The objective of the on-site data collection was to provide empirical material for the development of a taxonomic classification of characteristic sounds. Our approach was based on cladistics; some terminology will be needed to explain how the classification was made. Hyponyms are units at one level (or taxon) that are grouped and associated with one and the same unit at a

higher level. The taxonomic process of identifying and judging hyponyms is driven by observable and systematic characteristics attributed to the phenomena. This process can be automatic, if computational classifiers are available, or manual, when they are not or when the taxonomy is relatively small. In the latter case, hyponyms can be identified by careful semantic interpretation constrained by contextual factors. Homoplasy refers to a situation where a certain characteristic is shared by different lower-level units that do not connect to a common higher-level unit; this may or may not be acceptable in a given context; in the present study, we have avoided it. Levels and units connected without homoplasy form a clade (or minimally connected tree). For general introductions to cladistics, see Scott-Ram [51] or Smith [52]. For linguistic classification, see Jurafsky and Martin [26].

## 3. Results

### 3.1. Characteristic sounds

In all 375 respondents provided at least one annotation of a characteristic sound. The remaining 18 respondents (4.6%) were excluded from further analysis. There were a total of 1018 original annotations (on average 2.7 per respondent). Of these, 492 were indicated as "liked" (48.3%; encoded with Liking = 1) and 460 as "not liked" (45.2%; Liking = −1). In 66 cases neither alternative was indicated (6.5%). Such skips might be due to negligence, that the respondent found the sound ambivalent, or that she was neutral towards it. Regardless of which, these cases were encoded with Liking = 0.

Most of the original annotations consisted of one or two words, and none had more than eight. The lion's share of the annotations consisted of a straightforward description that indicated either a sound in itself (e.g. 'talking', 'crying', 'music'), or a physical source (e.g. 'people', 'cutlery', 'chairs'), or both sound and source together (e.g. 'soft music', 'people talking', 'plate clattering'). There was a significant minority of annotations of more general character, sometimes similar to psychoacoustic descriptors (e.g. 'loud', 'quiet') or terms encountered in affective appraisal (e.g. 'peaceful', 'busy'). We have assumed that respondents faithfully identified sounds present in their environment at that moment in time, and that listeners chose those sounds that appeared to be characteristic. We cannot rule out that some actual sounds (acoustically present) went unnoticed, that some were misidentified, or even that some sounds that the respondent 'heard' might have been imaginary. Notwithstanding, we believe that uncertainty of this kind will not cloud the overall validity of our approach. Therefore, the responses were taken at face value to describe sounds that were perceptually relevant to the respondents at the restaurants. In cases where a source was not literally annotated it could often be inferred from a word describing a sound, and vice versa. When neither source nor sound was explicit, a reasonable classification could still be made through contextual interpretation (see Section 2.5).

### 3.2. Annotation and Sound Source levels

The 1018 original annotations were corrected for misspellings and brought to lower case, yielding 402 unique words or short fragments. These constituted units in a level labelled Annotation; Table 1 contains several examples. The most common literal annotations were: 'music' (94), 'talking' (69), 'people talking' (43), 'cutlery' (26), 'utensils' (23), 'background music' (21), 'chatting' (21),

**Table 1**
Classification of original annotations into Annotation and Sound Source. Annotation (examples) = the most common annotations in each unit of Sound Source, with their count given in parenthesis if higher than one. Sound Source = basic level with 34 units. Liking = mean across Liking values associated with the original annotations classified in a unit. In Sound Source unit labels, a (/) indicates that related but different units within either of the intermediary taxa were merged, and a dot (.) indicates that a sound taxon and a source taxon were combined.

| Annotation examples | Sound Source | Liking |
|---|---|---|
| Fountain (3), wind (3), leaves (1), water, water fountain | Geophony (9) | 1 |
| Quiet (13), calm (9), peaceful (9), soothing, peace | Positive (65) | 0.877 |
| People talking and laughing (6), people talking/laughing (3), people talking/walking/laughing (1) | Laughter.people (10) | 0.8 |
| Background music (21), soft music (3), ambient music (1), background music from radio, background music is nice | Background.music (32) | 0.719 |
| Birds (3), birds chirping (1), chicken call, duck call, pigeons | Biophony (7) | 0.714 |
| Music (94), classical music (4), catchy (1), classical, contemporary music | Music (117) | 0.701 |
| Sizzling (6), frying (2), sizzling sound (2), bbq, food cooking on the teppan | Sizzle.cooking (16) | 0.688 |
| Laughter (12), laughing (4), loud laughter (1) | Laughter (17) | 0.647 |
| Waitress greeting (10), ordering (2), ordering food (2), orders, waiters greeting | Greeting/ordering (32) | 0.562 |
| Cash register (5), cashier (1), cashier till, coins | Machine.service (8) | 0.25 |
| Children (4), kids (4), babies (2), children playing, children running | Children (12) | 0.167 |
| Bottles clinking (2), clinking (2), glass (2), glasses, glasses clinking | Clinking./glassware (18) | 0.167 |
| People chatting (5), people chattering (3), human chatter (2), customers chattering, group of girls chatting | Chatter.people (14) | 0.143 |
| Conversation (7), conversations (5), gossip (4), speech, conversations from different tables can be heard | Conversation (22) | 0.136 |
| Cooking (10), food cooking (3), food preparation (2), beef, cook | Sound.cooking (28) | 0.036 |
| Chatting (21), chatter (14), chattering (8), murmuring, chat | Chatter (51) | 0.02 |
| Staff talking (3), waiter talking (3), waiters doing their work (2), waiters talking, customers and waiters | Talking./waiter (22) | 0 |
| People talking (43), customer talking (2), customers talking (2), chinese speaking people, crowd noise | Talking.people (61) | −0.082 |
| People (11), crowd (3), human (2), study, human beings | People (24) | −0.125 |
| Cutlery (26), utensils (23), plates (17), cups, utensil | Tableware (93) | −0.204 |
| Airconditioner (4), fan (3), air con (2), air ventilator, aircondition | Aircon (24) | −0.208 |
| Talking (69), voices (6), voice (3), talk, chinese accent | Talking (84) | −0.214 |
| Kitchen sounds (5), kitchen (4), washing (4), kitchen sound, conveyor belt | Kitchen/washing (44) | −0.432 |
| Plates clattering (3), wrappers unwrapping (3), clattering (2), cutlery clattering, cutlery clinking | Clatter/sound.tableware (47) | −0.447 |
| Eating (5), eating noises (3), people eating (3), drink slurping, drinks being slurped | Eating/slurping (20) | −0.45 |
| Coffee machine (4), blender (3), chiller (1), cupboards, oven | Machine.cooking (11) | −0.455 |
| Machinery (3), mrt sound (2), road noise (2), aeroplane, drill sounds | Machine/traffic (15) | −0.533 |
| Announcement (1), beep, beeping, ding-dong sound, kitchen bell | Signal (6) | −0.667 |
| Footsteps (4), walking (3), footstep (2), heels on wood floor, knocking of feet to wooden floor | Steps/walking (13) | −0.692 |
| Busy (2), monotonous (2), ants biting (1), disruptive, hollow | Negative (11) | −0.727 |
| Shouting (3), people talking loudly (2), children running and screaming (1), children shouting, cry | Crying/shouting/ringtone (17) | −0.824 |
| Loud (9), noise (7), noisy (7), no music at all, noisy environment | Noise (25) | −0.84 |
| Chairs (7), chair (4), chairs being dragged (3), chair sounds, chairs dragging | Screech/sound./chair (29) | −0.862 |
| People walking by (6), people passing by (3), people walking about (2), people footsteps, people walking around | Steps/walking.people (14) | −0.929 |

and 'plates' (17). To reduce complexity in the data, morphological variations (cf. [26]) were brought together into a single unit. For example 'chatter', 'chatting', and 'chit-chat' were joined under 'chatter'. Likewise, close synonyms were classified together. For example, 'children', 'kids', and 'babies' were brought into a unit labelled 'children'.

The units in Annotation were inspected one by one to identify the explicit presence of a word expressing a sound (i.e. a sonic essence) or a source (a physical essence). This semi-automatic process yielded 38 units in a Sound taxon, among which the most numerous were: 'music' (150), 'talking' (143), 'chatter' (64), 'sound' (36), 'laughter' (27), 'conversation' (22), 'greeting' (22), 'clattering' (18), and 'noise' (18); and 49 units in a Source taxon, among which the most common were: 'people' (115), 'cutlery' (51), 'waiter' (50), 'plate' (44), 'cooking' (35), 'utensil' (30), 'chair' (29), 'background' (26), 'aircon' (24), 'kitchen' (21), and 'children' (16).

Note that 'music' and 'talking' were by far the most common sounds, and that 'people' was the most common source. This is in line with previous empirical research (e.g. [1,31,17]) as discussed in the Introduction. Further investigation of these observations is discussed in Section 4.1.

As illustrated in Fig. 1, the Sound and Source taxa were treated as intermediary levels. Their units formed 140 unique combinations, where not all included both a sonic and physical essence. Through contextual interpretation and step by step judgement, the number of combinations was reduced. Of primary importance was to retain high parsimony and compatibility with the original annotations. Homoplasy (see Section 2.5) was avoided by interpreting the units in Annotation within the context of restaurants and by comparing different possibilities. In an iterative process, 34 units were created to constitute a basic level, labelled Sound Source. Its units are listed in Table 1 together with examples of the most common Annotation units that they contain.

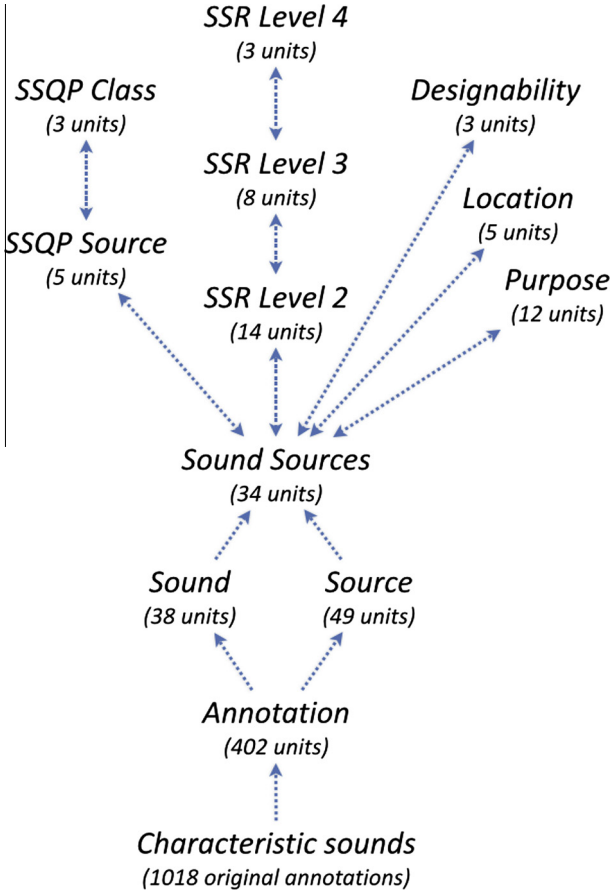



**Fig. 1.** Overview of units and levels developed in the taxonomy.

### 3.3. Higher levels

The iterative process of classification was continued upwards in the taxonomy to create several higher levels based on the Sound Source level while also considering the two intermediary taxa, the Annotation level, and the original literal descriptions of characteristic sounds. Each higher level would contain a smaller number of units than the one below. Again, homoplasy was avoided by defining units unambiguously (e.g. units in Annotation that were grouped into one and the same unit in Sound Source could not be interpreted as belonging to separate units higher up). Three ways to develop cladistic structures (see Section 2.5) were followed through in parallel. They were based on (1) categories inherent in the SSQP; (2) the 'SSR approach'; and (3) three alternative classification constructs of special interest for servicescapes.

#### 3.3.1. SSQP clade

The Sound Source units were interpreted according to the Swedish Soundscape Quality Protocol (see Section 2.1) in terms of SSQP Source with five units and SSQP Class with three units. Classification was straightforward in both cases. It was evident that some categories such as 'human' and 'othernoise' were dominant in terms of the number of original annotations attached to them, and that they therefore might not be ideally suited to reflect the variation in the observed data. The two SSQP levels together with Annotation and Sound Source formed a clade. Details are given in Table 2.

#### 3.3.2. SSR clade

The most important principle of the 'SSR approach' was to build successive levels from the bottom up. Since each higher level contained approximately half the number of units as the level below, each unit had to be approximately twice as broad in scope in order to maintain the overall balance between units in relation to the original annotations of characteristic sounds. The 34 units in Sound Source (i.e. Level 1) each contained on average 30 original annotations. They were processed to form SSR Level 2 with 14 units, each containing on average 73 original annotations. These were further reduced into SSR Level 3 with eight units, each with 127 original annotations on average. Finally, they formed SSR Level 4 (i.e. the "top level") with three units. To sum up, SSR Level 4, Level 3, and Level 2 connect with Sound Source (Level 1) and Annotation (Level 0) to constitute a clade. See Table 3 and Fig. 6.

#### 3.3.3. Alternative taxa

Three separate levels were created to explore the potential of other principles of classification. First, the Sound Source units were interpreted according to Purpose, in a taxon with 12 units, shown in Table 4. By 'purpose' we mean how the Sound Source units (and the original annotation) might implicitly answer the question "to whom or what is this sound directed?" (cf. Schafer [49]; also [54] about causal listening).

Second, we classified units by Location, interpreting them in regards to spatial and temporal aspects based on the concepts of "ubiquity" and "metabole" [3,23] as well as the taxonomy of acoustic design elements proposed in our previous work [5]. We combined three dichotomies: (1) location in acoustic space, whether 'omnipresent' or 'directional'; (2) location in time, whether 'persistent' or 'occasional'; and (3) location in physical space, whether a sound source could be understood as existing inside the restaurant or if its sound was leaking in from outside, defining five units. See Table 5.

**Table 2**
Clade based on SSQP categories, with mean Liking estimates. 34 Sound Source units classified into SSQP Source and further in SSQP Class. See also Table 1.

| Sound Source | SSQP Source | Liking | SSQP Class | Liking |
|---|---|---|---|---|
| Biophony, geophony | Nature (16) | 0.875 | Natural (16) | 0.875 |
| Background.music, clatter/sound.tableware, clinking./glassware, kitchen/washing, machine.cooking, machine.service, music, negative, noise, positive, screech/sound./chair, signal, sizzle.cooking, sound.cooking, tableware | Othernoise (550) | 0.104 | Technological (589) | 0.075 |
| Aircon | Fan (24) | −0.208 | | |
| Machine/traffic | Traffic (15) | −0.533 | | |
| Chatter, chatter.people, children, conversation, crying/shouting/ringtone, eating/slurping, greeting/ordering, laughter, laughter.people, people, steps/walking, steps/walking.people, talking, talking./waiter, talking.people | Human (413) | −0.063 | Human (413) | -0.063 |

**Table 3**
Clade of SSR with mean Liking for units in Levels 2, 3, and 4. See also Table 1 and Fig. 6.

| Sound Sources (Level 1) | Level 2 | Liking | Level 3 | Liking | Level 4 | Liking |
|---|---|---|---|---|---|---|
| Geophony, positive, biophony | Nature.calm (81) | 0.877 | Nature (81) | 0.877 | Sound design | 0.61 |
| Background.music, music | Music (149) | 0.705 | Music (149) | 0.705 | (269) | |
| Aircon, machine/traffic | Aircon.machine.traffic (39) | −0.333 | Other noise (39) | −0.333 | | |
| Sizzle.cooking, sound.cooking | Cooking.sound (44) | 0.273 | Cooking (44) | 0.273 | Cuisine (116) | −0.12 |
| Machine.service, signal | Service.signal (14) | −0.143 | Kitchen (69) | −0.377 | | |
| Kitchen/washing, machine.cooking | Kitchen.noise (55) | −0.436 | | | | |
| Laughter.people, laughter | Laughter (27) | 0.705 | Conversation | 0.178 | Customers (633) | −0.185 |
| Greeting/ordering, chatter.people, conversation, chatter | Clear.individual.conversation (119) | 0.202 | (163) | | | |
| Crying/shouting/ringtone | Shouting (17) | −0.824 | | | | |
| Clinking./glassware | Glassware.clinking (18) | 0.167 | Eating (178) | −0.258 | | |
| Tableware, clatter/sound.tableware | Tableware.clatter (140) | −0.286 | | | | |
| Eating/slurping | Eating.slurping (20) | −0.45 | | | | |
| Children, talking./waiter, talking.people, people, talking, negative, noise | Blurred.crowd.talking (239) | −0.222 | Crowd (295) | −0.339 | | |
| Steps/walking, screech/sound./chair, steps/walking.people | Footsteps.chairs (56) | −0.839 | | | | |

**Table 4**
Classification of Sound Source units according to Purpose.

| Sound Source | Purpose | Liking |
|---|---|---|
| Background.music, music | Entertainment (149) | 0.705 |
| Negative, noise, positive | Affective (101) | 0.277 |
| Aircon, biophony, geophony | Physical (40) | 0.225 |
| Machine.cooking, sizzle.cooking, sound.cooking | Cooking (55) | 0.127 |
| Crying/shouting/ringtone, laughter, laughter.people | Affectburst (44) | 0.114 |
| Greeting/ordering, kitchen/washing, machine.service, talking./waiter | Service (106) | 0.009 |
| Children, people | Crowd (36) | −0.028 |
| Chatter, chatter.people, conversation, talking, talking.people | Social (232) | −0.073 |
| Clatter/sound.tableware, clinking./glassware, eating/slurping, tableware | Feeding (178) | −0.258 |
| Machine/traffic | Traffic (15) | −0.533 |
| Signal | Alarm (6) | −0.667 |
| Screech/sound./chair, steps/walking, steps/walking.people | Movement (56) | −0.839 |

**Table 5**
Classification of Sound Source units according to Location.

| Sound Source | Location | Liking |
|---|---|---|
| Biophony, geophony, machine/traffic | Outside (31) | 0.194 |
| Aircon, background.music, chatter, chatter.people, clatter/sound.tableware, clinking./glassware, conversation, music, negative, noise, people, positive, tableware, talking, talking.people | Omnipresent & persistent (688) | 0.103 |
| Crying/shouting/ringtone, greeting/ordering, laughter, laughter.people, machine.cooking, machine.service, screech/sound./chair, signal, talking./waiter | Directional & occasional (152) | −0.059 |
| Children, eating/slurping | Omnipresent & occasional (32) | −0.219 |
| Kitchen/washing, sizzle.cooking, sound.cooking, steps/walking, steps/walking.people | Directional & persistent (115) | −0.252 |

Third and last, units were interpreted according to Designability, a concept that we defined operationally as the degree of difficulty (or alternatively, cost) for an acoustic designer (or restaurant manager) to control a sound source and to make it more pleasant. See Table 6.

### 3.4. Comparing taxa via Liking and Pleasantness

At this point, we had arrived at creating eight higher-level taxa on top of the two basic levels, Annotation and Sound Source. To compare them and establish a parsimonious model, we evaluated them via the Liking value the participants had associated with each characteristic sound (see Section 2.1). In line with our main hypothesis, this was a direct comparison between the perception of individual sound events and the perception of the sonic environment as a whole. Liking in taxonomic units and Liking for respondents were calculated as follows.

#### 3.4.1. Liking in units

First, taking each level and unit in turn, the originally annotated characteristic sounds classified under the unit were identified, along with the value corresponding to the original Liking that the respondents had indicated in the questionnaire. The numerical values were then averaged across several respondents. The Liking value for a unit in a given level thus expresses the degree to which the corresponding category of sound was perceived as likeable. For example, Fig. 2 graphically illustrates Liking for the 34 units in

**Table 6**
Classification of Sound Source units according to Designability.

| Sound Source | Designability | Liking |
|---|---|---|
| Aircon, background.music, greeting/ordering, kitchen/washing, machine.cooking, machine.service, music, screech/sound./chair, signal, sizzle.cooking, sound.cooking, steps/walking, steps/walking.people, talking./waiter | Designable (396) | 0.144 |
| Children, clatter/sound.tableware, clinking./glassware, geophony, machine/traffic, negative, noise, people, positive, tableware | Semi-designable (319) | −0.028 |
| Biophony, chatter, chatter.people, conversation, crying/shouting/ringtone, eating/slurping, laughter, laughter.people, talking, talking.people | Non-designable (303) | −0.053 |

Sound Source (SSR Level 1), with confidence intervals around the means. See also Tables 1–6.

### 3.4.2. Liking for respondents

Second, taking each level and respondent in turn, the different units associated with the three originally annotated characteristic sounds were identified, along with the units' Liking estimates as calculated above. The values were then averaged for each respondent. For example, if a customer had annotated "music", "people laughing", and "plates clattering" and we wanted to calculate her average as expressed through SSR Level 3, we would retrieve the corresponding units and Liking estimates from the taxonomy (see Table 3), i.e. 'music' (0.705), 'conversation' (0.178), and 'eating' (−0.258). The average (in this case 0.258) was the Liking of sound sources (categorised at the given level) for the respondent.

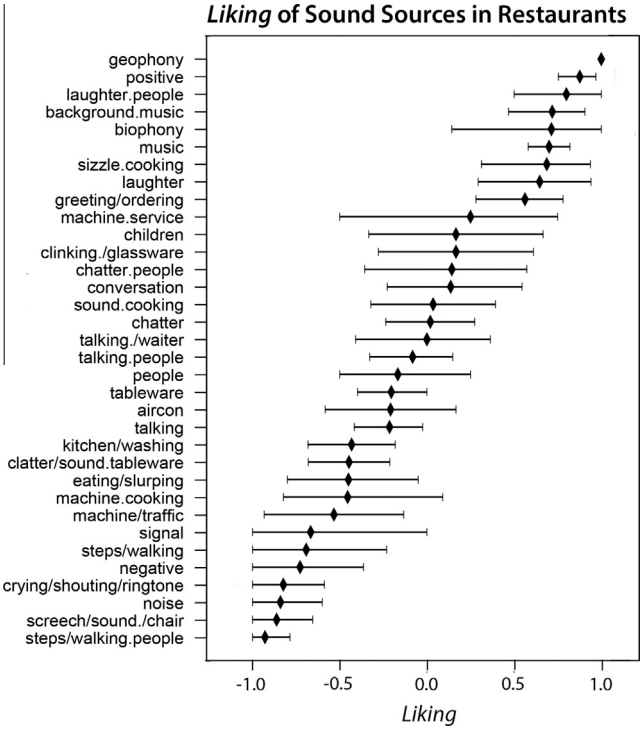



**Fig. 2.** Liking of 34 sound sources (units in the Sound Source taxon) based on 1018 annotations of characteristic sounds by 375 respondents in 40 restaurants. Means with 95% confidence intervals formed using a bootstrap method (see Section 2.2).

### 3.4.3. Correlations

Third, we evaluated how well Liking matched with ratings of Pleasantness as measured by the SSQP (see Eq. (1)). Recall that Liking measures the appraisal of sound sources, and Pleasantness measures the appraisal of the environment as a whole. If the correlation is high, the taxonomic description of sound sources would be useful. Among the 375 customers who provided one or more annotations of characteristic sounds, the 14 (3.7%) who had not completed the SSQP adjectival ratings were excluded from this analysis; there were thus 361 complete cases. Table 7 gives correlation results and Fig. 3 shows scatterplots of Pleasantness and Liking as expressed through each of the ten taxa.

The results revealed that Pleasantness was strongly correlated with Liking calculated for the basic levels (Annotation and Sound Source), as expected. The correlation was also strong for the three higher levels defining SSR, remaining high with tau in range {0.216. . .0.246} throughout the clade, i.e. Levels 1, 2, 3, and 4. This indicated that there was only a small loss of descriptive capacity in the higher levels, and that no significant amount of information was lost at any step in the process even as the classification structure was gradually simplified with each higher level of the SSR clade. In neither of the two levels in the SSQP clade did Liking correlate with SSQP Pleasantness. Among the three alternative taxa, the Purpose taxon emerged as significant, but neither the Location nor the Designability taxon. Note that for some levels, such as SSQP Source or Designability, the units became conceptually very broad and contained original annotations with both negative and positive Liking. Therefore the mean tended to go towards zero and the variance to be large, leading to the overall correlation being non-significant. This reflects the fact that the principle by which the taxon had been defined was not successful in the given context.

In summary, the evaluation of the ten taxa showed that the clade defined by SSR Levels 1, 2, 3, and 4 yielded consistent and significant correlations between Liking and Pleasantness. To test if it might constitute a robust model to describe the relation between perceived sound sources and pleasantness in restaurants, we performed two validation analyses.

## 3.5. Internal validation

The evaluations performed so far indicated a strong association between SSQP Pleasantness and Liking as defined in the SSR clase. To test if Liking is a reliable measure when comparing the perception of sound sources with the perception of the quality of the

**Table 7**
Correlations between Pleasantness score and Liking in ten taxonomic levels, in responses obtained on-site at 40 restaurants. Units = number of units in the taxonomic layer. tau = Kendall's non-parametric correlation statistic. p = probability of obtaining a test statistic result at least as extreme as the one that was actually observed, under the assumption that the null hypothesis (no effect) is true. Asterisk codes for degree of significance: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$. Signif. re FWE = significance when corrected for familywise error rate $\alpha_{FWE} = 0.05$, so that each correlation was evaluated at $\alpha = 0.0051$ (Dunn–Sidak's correction for 10 comparisons; see Section 2.2).

| Taxon | Units | Correlation with Pleasantness (361 cases) | | |
|---|---|---|---|---|
| | | tau | p | Signif. re FWE |
| Annotation | 402 | 0.246 | <0.0001*** | Yes |
| Sound Source | 34 | 0.246 | <0.0001*** | Yes |
| SSR Level 2 | 14 | 0.216 | <0.0001*** | Yes |
| SSR Level 3 | 8 | 0.227 | <0.0001*** | Yes |
| SSR Level 4 | 3 | 0.217 | <0.0001*** | Yes |
| SSQP Source | 5 | 0.016 | 0.67 | No |
| SSQP Class | 3 | 0.038 | 0.34 | No |
| Purpose | 12 | 0.179 | <0.0001*** | Yes |
| Location | 5 | 0.070 | 0.067 | No |
| Designability | 3 | −0.002 | 0.95 | No |

sonic environment as a whole, we derived and evaluated an alternative measure of environmental pleasantness. This was simultaneously a test on the construct validity of SSQP Pleasantness. The pleasantness construct developed by Axelsson et al. [9] measures the affect people have towards a sonic environment. In their protocol, the key word is "to experience" and the scale labels have been carefully selected. Since soundscape perception depends on which sounds are heard [14], the assessment of pleasantness depends on the appraisal of several, individual sound sources. Our questionnaire had been developed (see Section 2.1) with a view towards producing an alternative construct of holistic pleasantness. The idea was that a measure of the respondent's experience could be extracted from the free-form Restaurant Descriptions. To evaluate the level of pleasantness expressed in these descriptions, we performed a separate rating test, as follows. Each respondent had written five words to "describe" the environment "to a friend" (the key words in the questionnaire). Seven judges individually rated the descriptive words, in randomised order, according to the instruction: "Imagine that a friend used these words to describe a restaurant. How would you imagine the environment?" They entered evaluation on a 7-point Likert scale anchored by "extremely pleasant" and "extremely annoying". Analysis showed that the level of agreement among raters was excellent (coefficient $\alpha = 0.89$; see Section 2.2). We proceeded by defining a score, labelled Conveyed Pleasantness, as the mean of evaluations across judges. The correlation between this variable and SSQP Pleasantness was strong (tau = 0.291, $p < 0.0001^{***}$), supporting the validity of the construct.

Finally, we performed a series of correlations in the same way as before, though now between Conveyed Pleasantness and Liking as expressed through the various taxa under evaluation. As Table 8 shows, results for Conveyed Pleasantness were almost identical to those for SSQP Pleasantness. The correlations with Liking for the SSR clade were at a similar level, with tau in range {0.181...0.226}. Neither SSQP taxon emerged as significant. Among the three alternative taxa, the Purpose and Location taxa were significant, but not the Designability taxon. The similarity between these results and the preceding results with SSQP Pleasantness (cf. Table 7) supports the assumption that the Liking construct captures something real about the soundscape via its constituent sound sources.

**Table 8**
Internal validation. Correlations between Conveyed Pleasantness, derived from separate ratings of Restaurant Descriptions, and Liking in ten taxonomic levels. Data obtained on-site at 40 restaurants. For explanations, see Table 7.

| Taxon | Units | Correlation with conveyed Pleasantness (375 cases) | | |
|---|---|---|---|---|
| | | tau | *p* | Signif. re FWE |
| Annotation | 402 | 0.221 | <0.0001*** | Yes |
| Sound Source | 34 | 0.226 | <0.0001*** | Yes |
| SSR Level 2 | 14 | 0.187 | <0.0001*** | Yes |
| SSR Level 3 | 8 | 0.181 | <0.0001*** | Yes |
| SSR Level 4 | 3 | 0.218 | <0.0001*** | Yes |
| SSQP Source | 5 | 0.086 | 0.025* | No |
| SSQP Class | 3 | 0.053 | 0.17 | No |
| Purpose | 13 | 0.215 | <0.0001*** | Yes |
| Location | 5 | 0.115 | 0.0027** | Yes |
| Designability | 3 | 0.085 | 0.022* | No |

### 3.6. External validation

To test if the taxonomy could reliably describe relationships between liking of individual sound sources and pleasantness of the whole soundscape also in a context outside of the present data, we treated the taxonomy as a model and applied it on a set of external data. A separate perceptual experiment was designed and conducted as follows.

#### 3.6.1. Experiment

A listening experiment with a new set of soundscape stimuli was designed. We selected 15 restaurants (no overlap with the first sample of 40), made recordings using Ambisonic techniques (Coresound TetraMic), and measured SPL on site with a calibrated meter (Extech 407790). The restaurants had different Design Style, e.g. 'Dining' (7 places), 'Café' (4), 'FastFood' (2), and 'Bar & Buffet' (2), and served 'Western' (8) or 'Asian' (7) styles of food. These characteristics corresponded well with the first sample. Their mean sound level, 69.5 dBA, was slightly lower than that of the larger set, which might partly be due to the fact that a more exact meter was employed (cf. Section 2.3). We believe that the new set was overall comparable to the first and suitable for a validation study. The recordings were processed for binaural reproduction, which yields

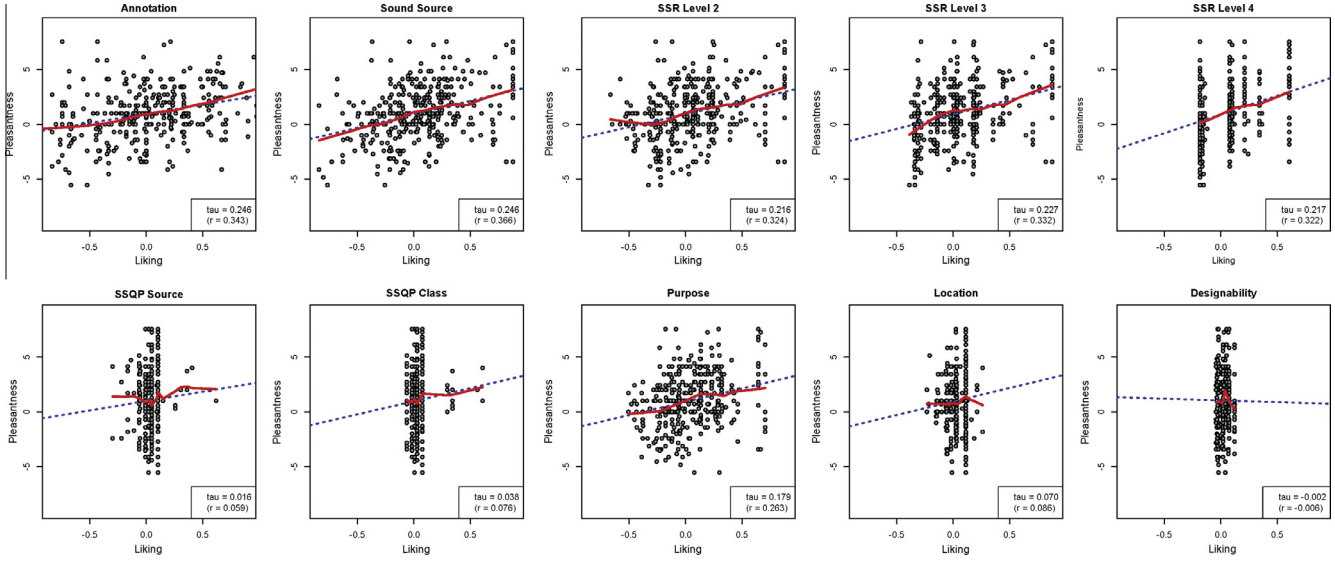



**Fig. 3.** Scatterplots of Pleasantness by Liking in ten taxonomic levels. To facilitate visual comparison, the horizontal and vertical ranges are the same in all plots. Dotted (blue) line: linear regression. Full (red) line: lowess line (smoothing = 0.5). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

a more faithful rendering of surround sound than other types of 2-channel stereo (cf. [42, ch. 12]). Playback level and equalisation were adjusted to be identical to the original sound, with a tolerance of ±1 dB on A- and C-weighted level-equivalent scales.

An open call was answered by 48 volunteers who consented to participating in the experiment. They received a movie voucher as a token of appreciation. Most were university students or faculty from a range of disciplines. The average age of respondents was 26 years, in a range between 19 and 46 years; 27 were female. Age and gender were independently distributed in the sample ($\chi^2 = 27.8$, $p = 0.99$ n.s.).

The participants individually rated the recordings, in random order, wearing identical studio-quality headphones while seated in a typical lab and entering responses via a computer interface. For each recording, they evaluated the quality of the soundscape as a whole according to the SSQP model for Pleasantness using the same scales as we had used in the preceding on-site data collection (i.e. the six Likert scales labelled 'pleasant', 'exciting', 'chaotic', 'annoying', 'monotonous', and 'calm'). They were also prompted to "Describe two characteristic sounds that you are hearing at this restaurant" by typing free-form words into text fields.

### 3.6.2. Classification

Incomplete responses were excluded (10.0%), yielding 647 complete cases for analysis. They contained 1269 original annotations of characteristic sounds (1.96 per person and recording). After spelling corrections and transcription to lower case, 735 were unique (though many were morphologically close). They were automatically matched with the original annotations from the previous corpus (the Annotation taxon), with a perfect match in 489 cases (38.5%). The remaining annotations were manually classified under one of the 34 units in Sound Source. This process was straightforward except in 17 cases (1.3%) that eluded meaningful classification: the most common annotation was 'neutral' (7). After consideration, we decided that these cases were too few to justify creating a new unit in the taxonomy, and they were placed in a rest category. Overall, the ease by which the previously developed groupings of original annotations into Sound Source could be applied on the new data lends support for the cladistic approach we had adopted.

### 3.6.3. Results

As before, we correlated SSQP Pleasantness scores (calculated from perceptual ratings on six semantic scales following Eq. (1)) with the mean Liking values expressed through each of the ten taxa that had been previously generated. Results, shown in Table 9, revealed that Pleasantness correlated strongly with Liking in the SSR taxonomic levels, and also in Purpose and Location, two of the alternative classifications. Neither of the SSQP taxa generated Liking estimates correlating with Pleasantness, and the correlation for the Designability taxon was negative and therefore not useful.

The strength of correlations was similar throughout the SSR clade (Sound Source and Levels 2, 3, and, 4), with tau in range {0.272…0.355}. It was considerably higher than that seen in the preceding analysis of data collected on-site. Note that Payne [41] reported good accordance between the quality assessments of park soundscapes that were made on-site and in laboratory, via recordings. The discrepancy in the present study might be explained in two ways. Firstly, it might be attributable to the smaller number of raters ($n = 48$) in the laboratory setting, all of whom rated multiple stimuli. The repeated-measures design allowed raters to make comparisons between various environments, something which would have made them emphasise even a small perceived difference, resulting in more discriminating use of the rating scales. Recall the tendency for dichotomisation in the study by Bosch and Andringa [11]. Secondly, it might be attributable to the absence of visual stimulation in the laboratory experiment. When people are asked to evaluate soundscape quality in a real multimodal environment, their judgement is inevitably affected by visual impressions. In the on-site situation, this would to some degree have distracted respondents' attention away from the auditory task, leading them not to notice the full variability of sound sources and to make ratings using a limited portion of the scales. We investigated these ad hoc hypotheses by comparing the variance in Pleasantness scores between the two data sets. Ratings made in the laboratory had a variance of 0.59, considerably higher than those made on-site, 0.39. The clear difference supports the hypotheses but does not say which one is more important. Direct comparison is not possible since we did not control for effects of different stimuli or respondents. Future research might investigate mechanisms of crossmodal bias in soundscape quality evaluation.

**Table 9**
External validation. Correlations between Pleasantness and Liking in ten taxonomic levels. Ratings obtained in a laboratory listening experiment with 15 restaurant soundscape recordings ($n = 48$). For explanations, see Table 7.

| Taxon | Units | Correlation with Pleasantness (647 cases) | | |
|---|---|---|---|---|
| | | tau | $p$ | Signif. re FWE |
| Annotation | 402 | 0.344 | <0.0001*** | Yes |
| Sound Source | 34 | 0.355 | <0.0001*** | Yes |
| SSR Level 2 | 14 | 0.298 | <0.0001*** | Yes |
| SSR Level 3 | 8 | 0.338 | <0.0001*** | Yes |
| SSR Level 4 | 3 | 0.272 | <0.0001*** | Yes |
| SSQP Source | 5 | 0.050 | 0.091 | No |
| SSQP Class | 3 | 0.013 | 0.67 | No |
| Purpose | 13 | 0.104 | 0.0001*** | Yes |
| Location | 5 | 0.271 | <0.0001*** | Yes |
| Designability | 3 | −0.104 | 0.0003*** | (Negative) |

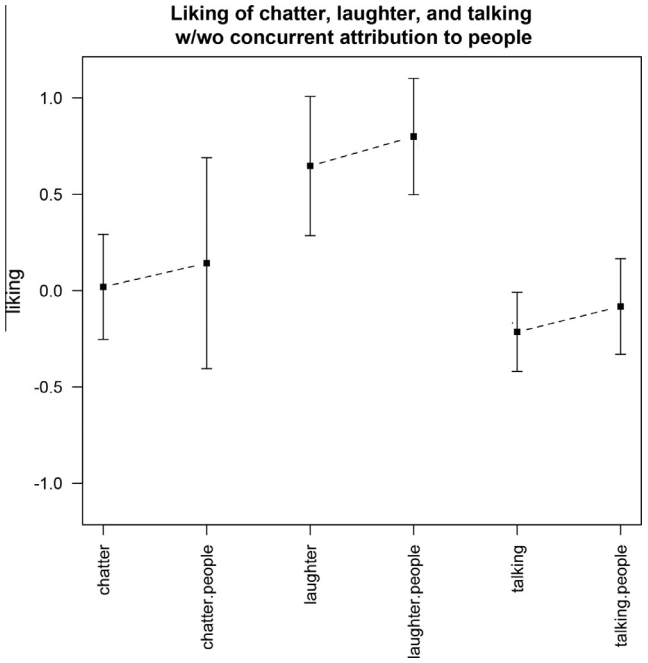



**Fig. 4.** Effect of the 'people' source qualifier on Liking of voice-related sounds. Comparison between six units in the Sound Source taxon, i.e. a subset of the original annotations. Means with 95% confidence intervals.

## 4. Discussion

As mentioned in Section 3.2, we had noted two particularities in the original annotations while developing the levels of the taxonomy. The first regarded voice sounds and words for 'people', and

the second concerned the order of liked and disliked characteristic sounds. They were investigated in the following way.

### 4.1. Liking of voices

The review of previous work highlighted that voice is a complex sound source that might be perceived more or less favourably depending on context. Relatively fine variations in voice-related annotations became apparent early in the analysis process and we retained some of these distinctions while developing the taxonomy. It is reflected in the units in the Sound Source level, where 8 out of 34 are voice-related (see Table 1) and carried into higher levels (see Table 3). There was considerable variation in Liking between these units. For example, Liking for 'clear.individual.conversation' was 0.202, much higher than for 'blurred.crowd.talking', −0.222. Looking back at the original annotations and the intermediary Sound and Source taxa, Liking appeared to be higher when 'people' (or a synonym) appeared as a qualifier to a voice-related word (see Table 1). To evaluate this observation, six units in Sound Source were selected, as in Fig. 4. They were defined by three different voice sounds, namely 'chatter', 'laughter', and 'talking', each in two version, namely voice-only (e.g. 'chatter') and voice-with-people (e.g. 'chatter.people'). We performed four post hoc tests, with the significance level for each set at $\alpha' = 0.0125$ so that $\alpha_{FWE} = 0.05$ (Bonferroni correction, see Section 2.2).

First, we compared the three differences in Liking between 'chatter', 'laughter', and 'talking' across voice-only and voice-with-people versions. The Mann-Whitney non-parametric test was employed to establish if the difference between medians in two samples was significant. Results revealed that 'laughter' was significantly more liked than both 'chatter' ($W = 1192$, $p = 0.0024^{**}$) and 'talking' ($W = 2872$, $p < 0.0001^{***}$), while there was no difference in Liking between 'chatter' and 'talking' ($W = 5237$, $p = 0.15$ n.s.) Then, we tested differences in Liking between voice-only and voice-with-people versions across the labels for voice sounds. Since 'laughter', 'chatter' and 'talking' were at different levels of Liking, we calculated difference scores between versions with and without the 'people' qualifier. That is, we calculated mean Liking for each voice-only unit and treated it as a baseline, subtracting this value from the Liking of the corresponding voice-with-people version. The three difference scores were then joined to form a single sample, and Wilcoxon's signed rank test was performed to evaluate if the sample median was different from zero. The test result was significant ($V = 2344$, $p = 0.011^{*}$), also when controlling for the previously set familywise error rate. The median difference was 0.21 on the Liking scale (range: −1...1), with a small effect size (Cohen's $d = 0.24$ SD).

What might be the cause of this effect? There must be a reason why respondents had penned down a certain kind of annotation in the first place: for example, deciding between giving only a single word essentially indicative of a sound, such as 'talking', or only a single word essentially indicative of a source, such as 'people', or a combination of the two, such as 'people talking'. Could this choice hint at subtle differences in how the voice was perceived? Imagine a person who is aware of other people's presence at the restaurant and whose attention is drawn to a vocal sound of some sort. When asked to associate a liking with this sound, she might think of it as evidence of a physical source, subconsciously substitute the sound for the source, and then evaluate her liking of the source instead (cf. [54, p. 139]). If the person's emotional disposition towards people in general is positive, she might think of the sound as "it's people who are talking", write down a voice-and-people annotation and circle the "yes" to indicate high liking. If on the other hand her feeling towards people in the restaurant is negative (for whatever reason), she might think of the perceived sound as "it's just talk", write down a voice-only annotation and circle the "no" to indicate low liking. Thus the use of a 'people' specifier could reflect a more forgiving disposition towards certain noises. The observed effect might be caused by an emotional crossmodal mechanism whereby the affective evaluation of a sound is influenced by the perceiver's social relation to the source.

### 4.2. Annotation order effect

The respondents had written down the characteristic sounds on three lines in the questionnaire, one after the other. We observed that Liking seemed to be unevenly distributed. ANOVA indicated that Liking differed significantly between the three lines ($F(2, 1015) = 3.56$, $p = 0.029^{*}$). Tukey's test for honest significant differences revealed that the Liking associated with characteristic sounds on the last line was significantly lower than that for the first line ($p = 0.023*$). The size of the effect was small (Cohen's $d = 0.21$ SD), yet, as can be seen in Fig. 5, there was a clear trend of decreased Liking: from the first annotation, through the second, and to the third.

Since it can be assumed that respondents filled out the lines in the protocol in sequence, the decreasing trend indicates an order effect. What might be the cause? Recall that people tend to over-report what they think of as "good behaviour" and under-report "bad behaviour" (social desirability bias; cf. [30]. In the present context, this bias was likely to be present initially; however, we speculate that the effect over time was caused by task directed attention causing a shift in listening mode. To borrow the terminology of Tuuri and Eerola [54, p. 148], the task itself would have induced a gradual shift from an 'everyday connotative listening' mode, via 'semantic listening', towards a 'critical' mode. Typically, customers would have selected a specific restaurant expecting to gain a favourable outcome, being prepared to pay money to receive food as well as services and other enjoyment. It is likely to have produced a positive bias towards the experience as a whole. At first, the questionnaire respondent would tend to be in a positive mood and therefore choose sounds that are likeable, due to some form of emotional contagion along the lines suggested by Juslin and Västfjäll [27, p. 565]; note that the induction effect they describe goes in the other direction: from sound to listener. This would explain the observation in the data of a high Liking for the

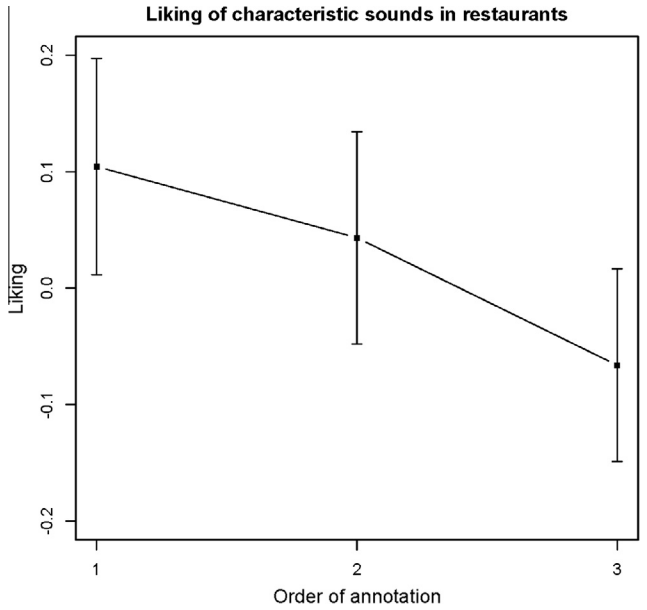



**Fig. 5.** Liking by order of annotation. Means across respondents with 95% confidence intervals.

first annotated characteristic sound. Then, the given task was to perform a listening-based evaluation, taking a couple of minutes to complete. It is an unusual thing to do for most people, and it would have placed cognitive demands on the respondent. Getting more involved in the task would necessitate an increased awareness and gradual discovery of the full range of sounds in the environment. Directing the attention towards the act of listening itself might, in the given context, have caused a more critical disposition. This would eventually have outweighed the social desirability bias and caused a restoration from the initial positive emotion towards a more negatively valenced state, leading to a preference to annotate less liked sound sources. Task-induced attention modulation could explain the observation in the data of a decrease in Liking over time, with negative annotations dominating by the time of annotating a third characteristic sound.

### 4.3. Comparison of classifications

In developing the SSR taxonomy we were inspired by the previous classification schemes mentioned in the Introduction. Comparing the details of these with the outcome of the present work is difficult due to many incongruences. Nevertheless we have identified parallels between sound source categories in SSR Level 3 and six of the previously published classification schemes. An overview facilitating comparison is shown in Table 10. Note that "small, directional, specific sources" are in the upper rows of the table, and conversely, "large, omnipresent, general sources" are below. We will briefly discuss some of the differences and similarities that can be identified in the table.

Three of the schemes (SSQP; [8,25,1]) were primarily developed for usage in outdoor soundscapes, while the SSR was developed for usage in a more narrowly delineated context, namely indoor restaurant environments. The scheme by Brown et al. [13] was a conceptual typology, large in scope and inclusive, while our strategy was to develop a taxonomy from empirical observations. The listings of typical sound sources that appeared in the two restaurant studies [31,47] were interesting though limited in usefulness, since they appeared to be created for operational purposes rather than systematic classification. Most of the seven schemes in Table 10 include well-defined categories for 'nature' and 'traffic', which are particularly important for outdoor environments. On the other hand, our classification (i.e. SSR Level 3) does not distinguish between, for example, 'traffic' and 'air conditioning'. Several schemes have confounded 'music' and 'other noise', which might be justifiable in some contexts but is impossible when it comes to servicescapes where such elements, especially music, are important for the acoustic design (compare [5], [23]). All three schemes primarily relevant to restaurant soundscapes highlight 'voice', 'music', and 'kitchen noise'. The SSR scheme is alone in explicitly discriminating between 'crowd' and 'conversation', though the distinction was implied in other restaurant soundscape studies. Furthermore, it distinguishes nuances between restaurant-specific categories such as 'eating' and 'cooking'. In summary, the comparison underlines the importance of considering context in soundscape perception research, as Joo and Jin [25] pointed out.

**Table 10**
Comparison between SSR Level 3 and six other sound source classification schemes.

| Restaurant soundscapes | | | Outdoor soundscapes | | | All soundscapes |
|---|---|---|---|---|---|---|
| [31] | [47] | SSR Level 3 (present work) | SSQP Source [8] | [25] | [1] | [13] subset |
| Noise from the kitchen, plunges or restroom | Kitchen (kitchen appliances, staff communication) | **Kitchen** (−0.377; incl. service.signal, kitchen. noise) | – | – | – | – |
| – | | Cooking (0.273) | – | – | – | – |
| – | Customers (noise, talking) | **Eating** (−0.258; incl. glassware.clinking, tableware.clatter, eating. slurping) | – | Human sounds (footsteps, talking, and sound of leisure activities) | – | – |
| People talking too loud; Kids yelling or crying | | **Crowd** (−0.339; incl. blurred.crowd.talking, footsteps.chairs) | Sounds from human beings (e.g. conversations, laughter, children at play, footsteps) | | Crowds of people (e.g. passers, restaurants, sports event, festival) | Human movement (incl. footsteps) |
| | | **Conversation** (0.178; incl. laughter, clear. individual.conversation, shouting) | | | Sounds of individuals (e.g. conversations, laughter, children at play) | Voice & instrument (incl. voice, speech, singing, laughter, and music) |
| Music too intense or not from people's preference | Music | **Music** (0.705) | Other noise (e.g. construction noise, industry, machines, sirens, music, etc.) | Other sounds (construction noise, music and ventilation sounds) | – | Social/communal (incl. bells, clock chimes, fireworks, azan, alarms) |
| Noise emitted from HVAC equipments | Environmental systems | **Other noise** (−0.333; incl. aircon.machine.traffic) | Fan noise (e.g. ventiation) | | Other noise (e.g. sirens, construction, industry, loading of goods) | Electromechanical (incl. constructions, ventilation, agriculture, domestic, recreation, electrical installation) |
| Noise transmission from the outside, with traffic or other sources | Traffic and other businesses | | Traffic noise (e.g. cars, buses, trains, airplanes) | Traffic noise (noises from cars, trains and airplanes) | Traffic noise (e.g. cars, buses, trains, air planes) | Motorised transport (incl. roadway/rail/marine/air traffic) |
| – | | **Nature** (0.877) | Natural sounds (e.g. wind whispering in the trees, flowing water, singing birds) | Natural sounds (bird songs, water sounds, and wind sounds) | Natural sounds (e.g. singing birds, flowing water, wind in vegetation) | Nature (incl. wildlife, wind, water, thunder, earth/ice movement) |

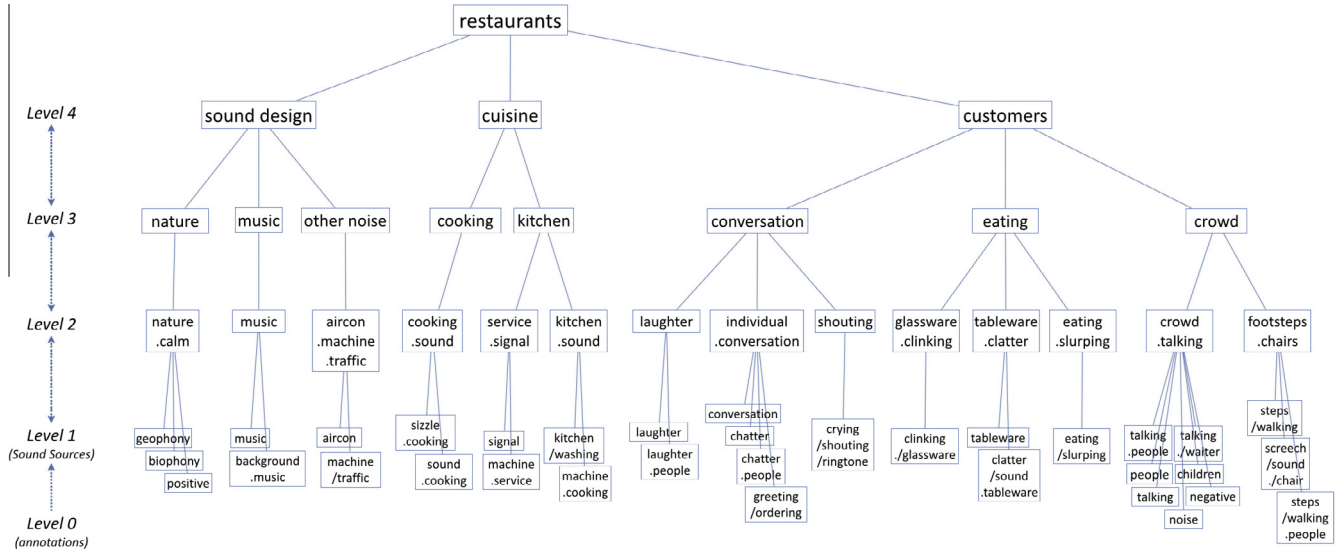



**Fig. 6.** Overview of the taxonomy of sound sources in restaurants (SSR).

## 5. Conclusion

This study has investigated how people perceive sound sources in context. Through analysis of free-form annotations obtained on-site in 40 restaurants, we developed a four-level taxonomic classification of sound sources in restaurants, SSR. We also classified annotations according to the two categorisations inherent in the Swedish Soundscape Quality Protocol, and by three alternative principles. In all, ten classification taxa were investigated side by side by comparing the appraisal of individual sound sources with the pleasantness of the soundscape as a whole. Results showed that the SSR clade consistently performed better than other taxa. This outcome was given support by internal and external validations. In the internal validation, two different pleasantness constructs were compared, yielding very similar results and supporting the reliability of the approach we have taken. In the external validation, the classification developed from the on-site data was applied as a model to analyse another set of data obtained in a laboratory experiment, again yielding similar results and supporting the robustness of the SSR taxonomy.

The four levels of the SSR clade were found to be similar in terms of their ability to capture the relationship between the liking of individual, characteristic sounds, and the overall pleasantness of the restaurant environment as a whole. Specifically, the correlations for each of the four levels between Liking and Pleasantness (or Conveyed Pleasantness) were at the same degree of strength, as measured by Kendall's tau. Naturally, more units (i.e. in the lower levels) produced slightly stronger correlations, but this gain comes at a cost in terms of practical usefulness. Going from lower to higher taxonomic levels in the SSR, the complexity of descriptions (as measured by the number of units) was reduced in a process of stepwise semantic filtering that retained the capability to describe the relationship between perception of individual sounds and soundscape as a whole. The SSR taxonomy is illustrated in Fig. 6.

We have discussed two findings in the on-site data. There was a difference in Liking between cases where respondents had annotated only a word describing a voice sound, and when they had annotated the same word accompanied with 'people' or a close synonym. We suggest that this might have been caused by an emotional crossmodal mechanism. There was also a trend for Liking annotations to start positive (high value) and then decrease into negative by the third characteristic sound. We have interpreted this as an effect of a social desirability bias being countered by a task-induced attention shift towards a critical listening mode. Finally, we discussed how SSR Level 3 compares with sound classifications in six previous studies, and the need for contextualisation.

### 5.1. Limitations

The present project has been entirely focussed on restaurant soundscapes and as a consequence, the potential for generalisations might be limited. Neither the taxonomy nor the two findings might be immediately applicable to other soundscape contexts. Our classification of sound sources has been based on a cladistic approach, though admittedly its precision is limited since every decision of association was 'manual', i.e. the judgements made by the analyst were based on close reading and contextual interpretation of written responses. As a tool of association, the inherent subjectivity in this process is open to criticism. Future research might look into strategies for making automatic decisions of taxonomic hierarchy, for example based on audio features of individual characteristic sounds that could be validated against ratings of perceived likability.

### 5.2. Applications

The SSR taxonomy might prove useful for applied soundscape research by enabling the creation of test instruments of varying size and complexity. They could be derived in a relatively straightforward fashion. For example, the 34 units in Sound Source could yield Likert scales that would already be balanced in terms of valence. A future experiment might be designed to validate Liking estimated this way against measurements of physiological responses to soundscapes (e.g. [6]. Another possibility would be to create a field protocol with a small number of items, for example, derived from SSR Level 3. The present work suggests that a 'short SSR instrument' might stand in for a long version and yield comparable results.

Another possible application of the SSR taxonomy might lie in enabling simulations of restaurant soundscapes. For example, a simulator could be built by 'reverse engineering' a taxonomic level so that a single Liking value would output a frequency distribution of sound source units. These units would then pick corresponding soundfiles for mixing and playback. Annotated sound recordings that could be used as pre-configured corpora might be gathered

from community research projects (e.g. http://www.freesound.org). Such a project would contribute to the relatively new research field of sonic information retrieval (SIR; [39].

Our results support the often stated principle that people think of sounds as sources rather than as acoustic phenomena ([54, p. 139]; see also [2]). This perceptual principle might in itself be an effect of the hard-wired nature of causal listening, ultimately dependent on the fact that auditory processing has developed for biological survival [27]. In social settings such as restaurants, people want to speak with each other. The present results suggest that voice sounds are perceived as 'conversation' when they are positively valenced and heard as individuals, and as 'talking' when they are negatively valenced and heard as a crowd. This is indicative of the strong influence that social context has on the perception of sound in complex environments.

Background music might be an efficient means both to attract people and to distract them from crowd noise (cf. Cohen et al., p. 164), but as music represents a highly elaborate kind of sound design, it seems immoral to debase it to a broadband masker. In 2000, a chef-entrepreneur said that "the second worst thing to a restaurant that is too noisy is a restaurant that is too quiet…I've opened four noisy restaurants…just got a three-star review from a critic who didn't once mention the noise" [61]. However, attitudes are changing, and the opposite of 'chaos' need not be 'boring'. Our research indicates that there is room to improve soundscapes by designing sound sources according to their associated Liking. The SSR taxonomy identifies which sound sources should be reduced or eliminated: in particular, screeching chairs (perhaps with teflon furniture sliders), clanking dishes (by relocating dish handling away from customers), and footsteps (by using carpets). It also indicates which acoustic design elements should be promoted, for example cooking sounds (perhaps by 'chef showcases') and glassware (which produces more likeable sounds than metal tableware). For optimal customer return behaviour [38], the ambient sound level needs to be lower than what is generally the case. But noisiness is only one of many aspects to characterise an environment [18, p. 172]. Designers who carefully consider acoustic details, by shaping sound sources to be perceived more positively, will succeed in creating more distinctive and attractive restaurants that are likely to be visited, and revisited. Every increase in servicescape quality is potentially a way to increase profit margins. Attention to vocal comfort, music, ambient levels, and acoustic design details, will make a restaurant memorable.

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