Chapter 2
Soundscape: A Construct of Human Perception

André Fiebig

Abstract A soundscape is a perceptual construct of an acoustic environment and, therefore, must be distinguished from the actual physical environment. Because the definition of soundscape is based on the perception or experience by a person or people in context, the study of human perception has become a major objective of soundscape research. The soundscape approach has roots in environmental psychology and goes beyond the simplistic notion of conventional environmental noise assessment. A listener is not only a passive receiver of environmental noise; instead, a listener becomes part of a dynamic system of information exchange and is involved in its creation. The listener responds not only to sound in terms of wasteful annoyance, but within the soundscape paradigm, environmental sound can be interpreted as a resource composition that can elicit diverse affective reactions. These affective reactions are believed to reflect evolutionarily shaped responses that prepare humans for action and are accompanied by physiological responses and behavioral changes. This perspective has stimulated multiple investigations regarding the main affective descriptors and the underlying indicators of soundscape appraisal, with some affective factors increasingly being acknowledged as the driving factors of emotional apprehension. Soundscape research surpasses the simplistic realm of environmental noise assessment solely in terms of sound pressure level indicators and annoyance and promotes the idea that multidimensional responses to sound cannot fully be understood without contemplating the context.

Keywords Affect · Affective quality · Emotion · Sound perception · Saliency

---

A. Fiebig (✉)
Department of Engineering Acoustics, Technische Universität Berlin, Berlin, Germany
e-mail: andre.fiebig@tu-berlin.de

B. Schulte-Fortkamp et al. (eds.), *Soundscapes: Humans and Their Acoustic Environment*, Springer Handbook of Auditory Research 76,
https://doi.org/10.1007/978-3-031-22779-0_2

2.1 Introduction: The Measurability of Sensations

The nature of human perception has been the subject of scholarly and scientific inquiry over centuries and the enthusiasm of researchers has not waned. Ancient philosophers, as early as Plato, speculated about the relationship between the conscious mind and the physical body, which is now considered as the mind–body issue and has caused intense philosophical debates (Hassett 1978).

In the late nineteenth century, the emerging discipline of psychophysics became increasingly popular and with it came the view that sensations could be measured quantitatively and mapped. Ernst Heinrich Weber postulated that the amount by which the intensity of a stimulus feature must change for a difference to be perceived is a fixed proportion of its magnitude (Weber's Law). This formed the basis for Gustav Theodor Fechner to propose that psychological magnitudes can be measured based on "just noticeable difference." Consequently, the belief grew that empirical psychology (studying the phenomena of mental life) can be an "exact science" in the fullest sense of the term (Titchener 1922), measuring psychological events with the aid of comparative scales (e.g., Lockhead 2004).

That view attracted severe criticism as it contrasted strongly with the traditionalist view that human perception is inherently qualitative and cannot be expressed in terms of magnitudes, especially about feelings, emotions, and affects. For example, James (1884), in a precursor of behaviorism, described empirical psychology as limited to cognitive and volitional aspects of the brain, thereby ignoring pleasures and pains, and its emotions.

Sellars (1907) later remarked that different individuals cannot have identical experiences in a numerical sense; they are not able to provide reliably exact numbers to compare individual experiences. Thus, in the area of sensation and perception, introspective reports were often limited to simple judgments of size, intensity, and duration of physical stimuli in the context of experimental psychology (Danziger 1980). Even today, the *quantity objection argument* claims that experiments to measure sensation only determine the estimation of physical differences instead of quantifying the sensation itself.

Another argument against empirical psychology was expressed by Cattell (1893), who asked whether we do in fact judge differences in the intensity of sensations or whether we merely judge differences in the stimuli determined by association with their known objective relations. This criticism is frequently called the *stimulus-error problem* and is a serious methodological pitfall in studying human perception (Chirimuuta 2016). According to Boring (1921), psychological reports must be based on the mental material itself to study sensation rather than on objects that judge the stimulus magnitude. Although the term "stimulus-error" is rarely in use today, the significance of this potential error has not disappeared (Chirimuuta 2016). If participants use their knowledge of the stimulus for judgements, this processing is labeled "cognitive," referring unwittingly to the stimulus-error.

Even today, sensations are regarded as difficult to measure, not because they are mental, subjective, or inaccessible but simply for want of an adequate psychophysical theory (Marks and Algom 2001). To make things worse, the absolute nature of perception is frequently questioned: perception in terms of responding to stimuli is frequently understood as merely based on relationships between the stimulus and its context rather than on the intensity of an attribute of the stimulus (Lockhead 2004). In other words, if a stimulus has a certain magnitude, the response cannot be predicted without considering its context. Consequently, Lockhead (2004) conjectured that people do not identify a stimulus and its magnitude as presented but instead search for its relation to memories of other, preceding events, thereby broadening the scope of psychophysics.

Overcoming the barriers imposed by previous beliefs, Stevens (1975) forged a fresh paradigm that was unimaginable 100 years ago and laid the groundwork for modern psychophysics. He claimed that nearly every sensory continuum can be described by means of a very basic principle: power functions with varying exponents. Nonetheless, discussions about the proper quantification of human perception are still ongoing. Researchers still struggle to draw the right conclusions regarding the relationship between stimulus strength and perceptual magnitude. They still seek clearer distinctions between body and mind and between the physiological and psychological processes inherent to humans; however, there is increasing acceptance that, in principle, genuine sensations and genuine perceptions are measurable.

2.1.1 History of Soundscape

The origin of the soundscape concept dates back to Southworth (1967), who analyzed the perceptual form of the soundscape with the purpose to study the possibilities and relevance of sonic design for cities and to establish criteria for design. By stressing the need for a holistic concept and concluding that (optimized) soundscape design may be a way of improving the aesthetics and acceptability of cities for their inhabitants, he also pioneered the notion that it is no longer sufficient to design environments which only satisfy the eyes (Southworth 1969).

Schafer (1977), a Canadian musician, popularized this idea a few years later with his book on the sonic environment and tuning of the world. At the time of Southworth's publication, Schafer had begun working in the newly established, interdisciplinary department Centre for Studies in Communication and the Arts at the Simon Fraser University in Vancouver with a simple but novel inspiration: To study all sounds, not merely those that were unpleasant or dangerous (Schafer 2012).

According to Schafer (2012), "soundscape" was not recognized in the early 1970s, or at least the definition of the term was unknown to almost everyone, allowing it to become an umbrella term for the study of diverse sounds: past and present, useful and useless, beautiful and ugly, exciting and boring. Until then, acousticians had not understood the merit of the word *soundscape*, because in their view, sound could be adequately described by phon, decibel, and other technical terms. However, the new, invented term united the practical and aesthetic aspects of sound, allowing researchers to study and describe acoustic environments on a more pragmatic level that was closer to daily experiences (Schafer 2012).

Schafer argued that up until that point, researchers engaged with the same question used different approaches while attempting to answer it: what is the relationship between humans and the sounds of the environment? Soundscape studies would aim to unify these various themes, drawing conclusions from each other (Schafer 1977). Because the concept of soundscape was originally rooted in music and acoustic ecology (Kang et al. 2016), understanding health-related issues (like well-being and restoration) required an enhanced approach to discover new relevant relationships that constitute a supportive environment (Schulte-Fortkamp 2002). Therefore, soundscape research can be seen as a countermovement to the conventional *noise control perspective*. Up until that point the preoccupation with noise as a disease that could somehow be cured had overshadowed the understanding of how healthy soundscapes function (Truax 1984).

Schafer (1977) observed that the efforts to reduce noise pollution were primarily focused on noise abatement with every additional sound source being regarded as a negative addition. Therefore, he called for a more positive study of environmental acoustics. This simple change of perspective may constitute the reason for the success of the soundscape concept. Acceptance of this paradigm shift may have been supported due to the inefficacy of the conventional sound level reduction measures, which did not lead to a noticeable improvement for quality of life in urban and rural areas (Kang et al. 2016). The soundscape approach involved not only physical measures but also actively sought the contribution of humanities and social science to account for the diversity of soundscapes across countries and cultures. In doing so, environmental sound was understood as a resource rather than as an environmental burden only. The soundscape approach emphasizes an analysis of how an environment is understood by those creating it and those living within it. The listener is no longer merely a passive receiver of sound; instead, the listener becomes part of a dynamic system of information exchange (Truax 1984).

The increasing interest in this alternative approach is illustrated by numerous publications in several special issues of peer-reviewed journals on acoustics. In addition, since the late 1990s, special sessions related to the soundscape topic have become an integral part of conferences and congresses on acoustics. Moreover, a European Cooperation in Science and Technology (COST) action *Soundscape of European Cities and Landscapes*, an intergovernmental network for cooperation in research, enabled researchers to connect with each other across Europe and beyond, with the aim of providing a scientific underpinning and practical guidance for intensified international research activities in this field (Kang et al. 2013).

Today, studies referring to the soundscape concept are more and more popular. As the systematic literature of To et al. (2018) has shown, the number of soundscape publications regarding non-open-access and open-access documents grew rapidly from 1985 to 2018. Due to all of these developments, the soundscape approach has received significant attention in particular since the early 2000s until today in the field of community noise and environmental acoustics by researchers, policy makers, and practitioners (Kang et al. 2016).

2.1.2 The Definition of Soundscape

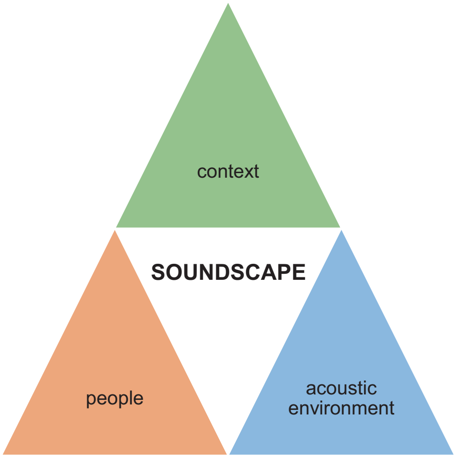
The international standard on soundscape (ISO 12913-1) defines soundscape as a perceptual construct that must be distinguished from the physical phenomenon: "*Soundscape is an acoustic environment as perceived or experienced by a person or people in context.*" (ISO 12913-1 2014, p. 1). This definition resembles the one from Truax (1984), a former colleague of Schafer, who wrote in 1984 that the term soundscape emphasizes how an environment is understood by those living within it and therefore must be distinguished from the physical sonic environment. The term soundscape is also used in other contexts, for example, as in underwater acoustics to characterize ambient sound (ISO 18405 2017) and thus differs from the definition that refers to sound perceived by humans in context (ISO 12913-1 2014).

For several decades there was no universal agreement about the meaning of the term soundscape. Even working group 54 for ISO/TC 43/SC 1 struggled with diverse views, concepts, and levels of understanding until a consensus was reached (Brown et al. 2011). According to the working group, standardization was initiated after the realization that progress in soundscape research was impeded by the lack of a clear, shared understanding of what was meant by the term (Schomer et al. 2010). Noise annoyance research with its different instructions, different annoyance scales, and unreported contextual factors had shown that a lack of standards significantly impedes meta-analyses (Brown et al. 2011).

Today, the term soundscape is acknowledged widely as a reference to the construction of an acoustic environment based on human perception. This was supported by the standardization efforts and many researchers cite the international standard (Fiebig 2018), although deviations from this established notion are still found frequently. Even with a rigorous ISO definition, the term soundscape is sometimes used as a synonym for the physical acoustic environment.

According to Kang et al. (2016), this may be admissible, if such equivocal usage of the term soundscape does not introduce confusion in communication. In general, the working group expected that by the introduction of standardized definitions and the description of soundscape investigation methods to be utilized by researchers, the outcomes from various studies dealing with relationships between perceived soundscape quality and acoustic, physical, and visual properties of areas would be more compatible, thereby ensuring comparability (Brown et al. 2011). This is true to a certain extent. There are three key components, which are understood to constitute a *soundscape*: people, acoustic environment, and context (see Fig. 2.1). According to the ISO/TS 12913-2 (2018), data from all key components must be collected for a study to be acknowledged as a full-featured soundscape study (see Schulte-Fortkamp and Jordan, Chap. 3). Some researchers deviate from this key understanding by using slightly different terms, such as Kogan et al. (2017), who called the key components of soundscape *experienced environment*, *acoustic environment*, and *extra-acoustic environment*. However, those alternative components are usually like the components proposed in the ISO 12913-1 (2014).

Fig. 2.1 Key components of soundscape studies



Due to the emphasis on perception and cognitive construction processes by the established soundscape concept, the study and understanding of human perception becomes the main objective of all research dedicated to soundscapes. Since this concept of soundscape emerged, researchers have investigated how acoustic environments affect the perceived (sonic) quality of cities and how sounds can be effectively used in urban planning and design (Aletta et al. 2016a). Soundscape research aims for an understanding of the relationship between people and their acoustic environments by examining the sounds that people value or disapprove and their reactions to them in specific contexts of place and activity (Kamp et al. 2016).

2.2 Perceptions of Environments

Environments affect humans and humans affect environments. This simple statement seems trivial, but it is not. The impact the physical environment has on human beings is classically understood to be a bottom-up process. Noise control engineering still uses this simplified concept and still strives to reduce annoyance strictly by minimizing the sound pressure level of unwanted noise. Any interactivity of this process is neglected, and any multidimensionality is discarded. In the area of environmental psychology, however, the notion that the perception of an environment involves an interaction between the individual and said environment has long been established (Fisher et al. 1984), as Fig. 2.2 illustrates. This simple diagram highlights that an individual is not simply a reacting and adapting organism trying to make sense of the fast-changing environment. An individual is not only struggling to cope successfully with the environment in order to survive, but the person is also an agent based on individuality and actively influences the environment (Barandiaran et al. 2009).

Fig. 2.2 Basic concept of interaction between individual and environment in environmental psychology

Some of the explanations for perceptual experience lie within the environment, some rest within the individual, and some are the outcome of their interaction. A simple example can illustrate the need for widening the theory of perception based on solely bottom-up mechanisms: There are numerous examples of auditory or visual illusions that demonstrate elementary sensations are not sufficient to provide an explanation for these perceptions, such as the influence of the color of a train on judgements of loudness (Fastl 2004).

Humans do not simply react to physical stimuli exciting the senses; they partially create their surrounding environment. They use heuristics and knowledge to extract and manage useful information out of a stream of continuous input. According to Brosch et al. (2010), a certain category in the mind is activated, which supports the process to give meaning to the world.

The person cognitively constructs the environment to a certain extent through knowledge-driven information processing. In contrast to the simplistic bottom-up concept, top-down controlled perception causes human perception and responses are not determined only by external physical stimuli. Thus, the knowledge-driven component within the perception process (top-down processing) should not be underestimated. Consequently, Schafer claimed that humans are anti-entropic creatures; humans are a random-to-orderly arranger and they perceive patterns in all things (Schafer 1977). Sensory perception could even be regarded as a factor that corrects and fine-tunes mental representations. Humans influence their perceptions of the surrounding world by top-down processes in which they pay attention to particular aspects of the environment. This is sometimes described as the *attended stimulus* (Goldstein 2002). Thus, any theory of perception must consider the adjustive process of the organism that contributes to adaptation to its environment (Helson 1967). Disentangling bottom-up from top-down processes is difficult, as is understanding how physical stimuli give rise to mental representations, but both processes must be addressed.

Attention guides how humans perceive their environments. Any information that becomes part of working memory (due to mechanisms of attention) is evaluated and analyzed, allowing decisions about that information to be made and plans for action to be elaborated (Knudsen 2007). Attention-related factors (i.e., sustained attention to an entire auditory scene, selective attention to particular objects or streams within a scene, attention switching, or attention limitations) can have dramatic influences on the perceptual organization of scenes and the ability to detect important events in the environment. At the same time, there is evidence that other high-level mental processes, such as intention and previous knowledge, also greatly impact auditory perception (Snyder et al. 2012). Moreover, in this context the process or act of *recognition* needs special attention because, through recognition, perceived objects are placed in a category and are given meaning (Goldstein 2002).

Human perceptions of physical environments lead to a few basic emotional dimensions, which are indicative of human feelings and are thought to be independent of each other. According to Mehrabian and Russell (1974), these dimensions are *pleasure*, *arousal*, and *dominance*. Theses emotional dimensions are still used by numerous researchers in the field of environmental psychology (Bakker et al. 2014).

Affect is understood as the semantic representation of emotion and can be distinguished from the perceptual or cognitive processing of the environment (Russell et al. 1981). In contrast to sensations, which are induced by the excitation of sensory cells, emotions can be considered as an affective response of the body to an external stimulus. Traditionally, the study of perception has been quite distinct from the study of emotion, but these basic processes of *perception*, *cognition*, and *emotion* (*affect*) seem to be highly interrelated and must be studied beyond isolation (Zadra and Clore 2011). An affective response depends upon the way in which it is first perceived and recognized (Russell et al. 1981).

Are pleasure and arousal conceived as indicators of affect? Is dominance as a feeling that the environment is dominant or fully in control more or less a cognitive product? Simplifications such as these are highly questionable. Bakker et al. (2014) assumed that pleasure is an affect, and arousal has a cognitive nature, whereas dominance underlies a conative concept, which is connected with the wish, intention, or effort to achieve something. The term dominance representing a conative dimension was not used by Mehrabian and Russell and should emphasize effects on behavior beyond affect and cognition according to Bakker et al. (2014).

Positiveness or negativeness of affect are assumed to refer to satisfaction and well-being. Thus, affective responses play a major role in the perception and appraisal of environments. There seems to be an almost unlimited array of affective descriptors, but environmental psychologists focused their attention on only a few (such as degree of comfort, annoyance, pleasantness, or psychological stress). In the context of the perception of acoustic environments, a relatively simple conceptualization that encompasses diverse affective concepts has been increasingly preferred (Aletta and Kang 2018) due to the observation that several researchers repeatedly explored the same dimensions in the context of soundscape (see Fiebig et al. 2020). On the other hand, human sensations, responses, and outcomes cannot easily be reduced to singular values of physical units because responses to sounds can depend on the listener's mental, social, and geographical relationships with the sound source (ISO/TS 12913-2 2018).

2.3 Perceptions of Acoustic Environments

2.3.1 How Sound Shapes Human Life

As early as 1914, Hollister (1914) observed the effect of attitude in dealing with controllable and unavoidable noises in the context of nursing. She concluded that the more passive our stance towards said noise, the better we can cope with it, such as for sleeping. If we can go as far as to convince ourselves that we like the noise, the noise may even prove to be a source of help. Although this statement is partly questionable from the viewpoint of noise effect research, it underlines the fact that human perception of sound is based on an interaction between the perceiving individual and the acoustic environment. Through this interaction, human behavior is enriched by aspects of social characteristics and the environment. Thus, acoustic environments can affect human perception, and human perceptions can in turn influence environments and other humans in both indoor and outdoor spaces (Meng et al. 2018).

It is beyond question that the appraisal of sound is more complex than loudness of the sound. The assessment of a sound's desirability has no obvious relationship to this simple unit (van den Bosch et al. 2018). If, for example, noise annoyance is considered, only one-third of variance in annoyance data can be explained by acoustical properties of the sound, usually determined in terms of overall, time-averaged, sound pressure levels (Guski 1999). The amount of variance in data on unpleasantness that could be explained by loudness-related metrics (e.g., level, psychoacoustic loudness) was also evaluated by repeated soundwalks, which are on-site evaluations at different points by local experts, where a similar amount of variance was explained (Fiebig 2018).

Understanding the relationship between people and their soundscapes in an urban context of diverse sensory stimulations is a difficult endeavor (Bild et al. 2018); thus, research on noise annoyance has slowly broadened to include an increasing number of physiological and psychological aspects (e.g., Taghipour and Pelizzari 2019). In the context of soundscape, auditory attention, which allows humans to focus mental resources on a particular auditory stream of interest while ignoring other acoustic elements, is of particular interest (de Coensel and Botteldooren 2010). Due to the crucial role for the perception of acoustic environments, several researchers have investigated the *saliency* of sounds (Botteldooren and de Coensel 2009; Filipan et al. 2019).

Sound events that are salient and stand out in the sonic environment capture our attention and contribute highly to the perception and the appraisal of the soundscape (Filipan et al. 2019). In general, auditory saliency can be distinguished into two non-exclusive dimensions: *sensory saliency*, referring to specific sound features meeting the enhanced sensitivity of human hearing; and *semantic saliency*, which is based on recognition of the sound and its potential incongruency within the environment (Filipan et al. 2019). In this context, the mechanisms between *signal-driven attention*, which is due to the prominent acoustic features of the sound (Genuit and Fiebig 2006; Oldoni et al. 2013), and *meaning-related attention*, which is responsible for drawing or losing interest in auditory events, are still not fully understood (Botteldooren et al. 2012). Clearly, attention and the cognitive load of listeners affect noise ratings for complex sound scenarios (Steffens et al. 2019).

Moreover, the perception and assessment of environmental noise depends on the social and cultural background of the individual, indicating another limitation of simplified bottom-up concepts (Schulte-Fortkamp and Fiebig 2006). Bruce and Davies observed that assessment of a soundscape is affected by expectations in several different ways, including the aspects of *behavior* and *control*, which are partly based on an acquired set of social rules or norms (Bruce and Davies 2014). Sun et al. (2019) noticed that soundscape perception also depended on potential interference with other possible activities at the respective site.

There are numerous studies revealing the crucial role of environmental noise on human life in all facets:

- Noise affects behavior. Individuals were less affiliative and less helpful with increasing noise (Moser and Uzzell 2003).
- Noise affects environmental awareness. Attentiveness dropped with increasing noise (Korte and Grant 1980).
- Noise affected the length of stay at public places (Aletta et al. 2016b).
- Noise (music and speech) affected human serial recall performance (Schlittmeier et al. 2008).
- Environmental and classroom noise had a detrimental effect on learning and performance by children (Shield and Dockrell 2008). Relationships with their peers and teachers and their motivation for achievement were also negatively affected (Klatte et al. 2010).
- Listening to bird songs decreases walking speed compared to walking with city noise conditions (Franek et al. 2019).
- Moderate levels of ambient noise positively affected creative cognition in contrast to low or high ambient noise levels (Mehta et al. 2012).
- Sound can mitigate antisocial behavior, can lead to pro-social effects and increase the feeling of safety (Lavia et al. 2016) or vice versa.
- Sound can reduce agitated behavior in older adults with dementia (Lin et al. 2018).

Worth noting is that these soundscape influences on humans and their behavior in response to the soundscape often take place without being noticed. In many cases, humans are unaware of this special role of sound and they underestimate its impact on behavior and well-being. Thus, a soundscape has the potential to evoke responses in the individual and to induce certain outcomes within a particular context (Brown et al. 2016).

2.3.2 Affective Qualities and Emotions Attributed to Acoustic Environments

A core doctrine of the soundscape concept is that acoustic environments can elicit different affective responses and emotions. This differentiates soundscapes from classical environmental noise assessment, which only deals with levels of annoyance. There is a long-running debate about human emotions, their causes and effects, which must be addressed if psychology is ever to explain them (Hasset 1978). Unfortunately, the definition of the construct *emotion* is in a state of conceptual and definitional chaos and remains a heavily freighted term full of imprecision (e.g., Gross 2010).

According to the Merriam-Webster dictionary (2022), emotion is defined as "*a conscious mental reaction (such as anger or fear) subjectively experienced as strong feeling usually directed toward a specific object and typically accompanied by physiological and behavioral changes in the body*." This definition illustrates the building blocks of emotion: a triggering stimulus (object), physiological and psychological responses, and behavioral changes.

Lang and Bradley (2000) observed the close relationships between the building blocks of emotion and noticed that the affective quality of sounds that elicit physiological reactions does not correlate with the intensity of those sounds. Accordingly, van den Bosch (2015) argued that the understanding of the acoustical properties of a certain place is far less important than understanding how that place influences a person emotionally. The question remains: Does an environment elicit a pattern of bodily changes leading to emotions or do humans actively develop emotions to prepare the organism to deal successfully with an environment? How are cognitive processes and emotional regulation involved in this bottom-up related notion of emotion?

Emotions are short-lived affective processes (in contrast to attitude and mood which are understood to be more stable, less affected by the moment, and long-lasting). Emotions are responses to situations that are perceived as relevant to an individual's current goals and consist of appraisals that give rise to changes in feelings, behavior, and physiological processes (Gross 2010). Most researchers dealing with emotion theories agree that emotional stimuli and emotional responses represent a special type of stimulus–response as they possess high relevance for survival and well-being, potentially preparing the individual for action (Brosch et al. 2010). It is assumed that by means of elicited emotions, humans rapidly recognize and quickly adapt with the necessary behavioral output.

This complexity shows that it is necessary to study not only the objective environment but also the internal representation of that environment: the meaning people attribute to it (Russell et al. 1981) and the psychophysiological concomitant effects. A milestone of research in the context of affective qualities attributed to physical environments is the work of Mehrabian and Russell (1974). The authors proposed a conceptual framework that bears some resemblance to the conceptual framework proposed in the ISO 12913-1 (see Fig. 2.3 and Sect. 2.3.3). Fiebig et al.

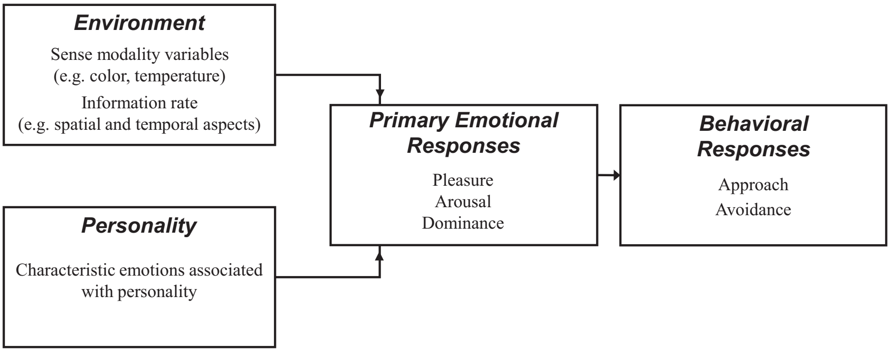


Fig. 2.3 Outline of the conceptual framework of environmental psychology. (Adapted from Mehrabian and Russell 1974)

(2020) combined the insights of emotion research with the conceptual framework proposed in ISO 12913-1 in order to highlight the important role of emotion in the concept of soundscape. They explained that soundscapes frequently elicit unconsciously emotions, which exert influence on individuals' behavior, well-being, and health.

Mehrabian and Russell (1974) believed in a common core of responses that are the immediate result to stimulation of all types, regardless of the modality excited. They concluded that there is a limited set of emotional (connotative, affective, feeling) responses to all stimulus situations: responses of evaluation and activity correspond to emotional responses of *pleasure* and *arousal* and the response of potency corresponds to *dominance* (vs. submissiveness) (Mehrabian and Russell 1974). Although meaning attributed to environments contains both affective and perceptual-cognitive components, with the two highly interrelated, the basic dimensions described by Mehrabian and Russell (1974) focus specifically on emotions (Russell and Pratt 1980).

Russell (1980) believed that affective states elicited by environments are best represented as a circle in a two-dimensional bipolar space based on the dimensions of *pleasure–displeasu*re and *degree of arousal*. This representation leads to a circumplex model of affect: pleasure, excitement, arousal, distress, displeasure, depression, sleepiness, and relaxation. Usually, these dimensions are obtained by the results of factor analyses based on a set of data consisting of a heterogenous sample of adjectives and a set of rated stimuli. The deduced factors denote some of the most fundamental affective or perceptual components.

For example, Russell et al. (1981) used a list of 105 adjectives, analyzed the ratings of 323 environments by means of a common factor analysis, and detected three factors (*pleasure*, *arousal*, *potency*) accounting for 47% of the total variance in the data set. These fundamental affective dimensions attributed to environments could be ecologically interpreted in their combinations: "[…] *exciting places are both pleasant and arousing. Peaceful and comfortable places are also pleasant but unarousing. Frightening and harsh places are unpleasant and high in arousal* *quality. Depressing places are unpleasant and unarousing.*" (Russell et al. 1981, p. 280).

The affective concepts attributed to environments have been subject to intensive research in the context of soundscape. For example, Axelsson et al. (2010) proposed a few basic dimensions of affective qualities that resemble the widespread circumplex model of Russell et al. (1981) as shown in Fig. 2.4. Interestingly, the underlying dimensions of affective appraisal for acoustic stimuli are like those determined for image processing (Bradley and Lang 2000; Axelsson 2011).

In the context of soundscape, Axelsson et al. (2010) found three basic dimensions: *pleasantness*, *eventfulness*, and *familiarity*. Because of the low variance explained by *familiarity*, this component is often disregarded. Botteldooren et al. (2016) noted that one could argue that these dimensions are related to the individual person rather than to the sonic environment, but with soundscape interpreted as an object in the mind, this does not pose any problem.

According to van den Bosch et al. (2018), the two frequently observed independent dimensions *pleasantness* and *eventfulness* reflect characteristics with evolutionary significance that would promote survival by causing a preference for certain environments and avoidance of others. The descriptors of *emotional* responses to the environment (valence, arousal) substantially differ from those used to express its *affective* quality (pleasantness, eventfulness). However, they can be related to the appetitive and defensive motivational systems that underlie affective judgments: valence indicates which system is active; arousal indicates the intensity of activations of these systems (Bradley and Lang 2000; van den Bosch et al. 2018).

Tarlao et al. (2019) used slightly different terms for the two basic dimensions, naming them *appreciation* and *dynamism*. Despite apparent similarities, they could not fully confirm Axelsson's circumplex model because they found that *monotony* was an independent factor. Davies et al. (2013; also Cain et al. 2013) observed two principal dimensions of emotional responses to soundscapes: *calmness* and *vibrancy*

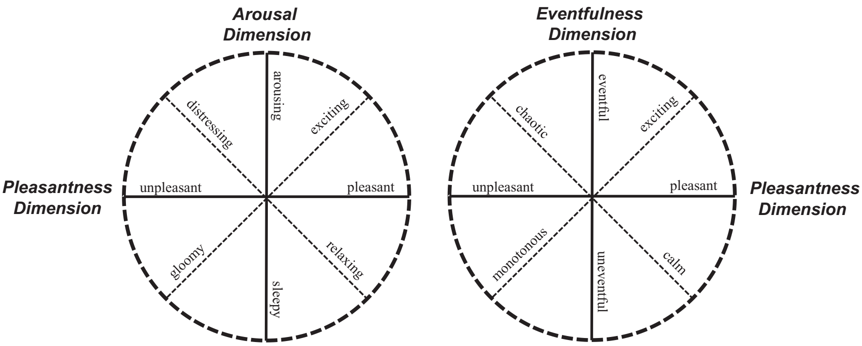


Fig. 2.4 Two-dimensional representation of the affective quality attributed to physical environments in general. (left, adapted from Russell et al. 1981) and to acoustic environments in particular. (right, adapted from Axelsson et al. 2010) (cf. Fiebig et al. 2020)

which are close to the pleasantness–eventfulness model, if one were to rotate the axes in the components analysis result of the circumplex model by 45° as shown in Fig. 2.4.

Andringa and van den Bosch (2013) referred to the main dimensions of *pleasure* and *activation*, which according to the authors belong to the *core affect*. The core affect characterizes a relationship to the world as a whole and not to something specific within that world (van den Bosch et al. 2018). Welch et al. (2019) observed five affective dimensions for soundscapes (*calming*, *protecting*, *hectic*, *belonging*, and *stability*) by applying a factor analysis on questionnaire data.

Yu et al. (2016) extracted five major perceptual factors of soundscape perception in urban shopping streets, using these factors: *preference*, *loudness*, *communication*, *playfulness*, and *richness*. In very specific locations, further affective dimensions are conceivable. For example, Sudarsono et al. (2019) identified the dimensions *privacy*, *disturbance*, *dynamic*, *fear*, and *satisfaction* in crowded third-class hospital wards.

According to Aletta et al. (2016a), the *appropriateness* of a soundscape could be a potential third dimension. Since an encountered situation is usually matched against existing cognitive schemes, appropriateness viewed as the level of congruency between a scheme and a real-world situation will influence positive affective responses. Inappropriate matches consequently lead to negative affective responses (van den Bosch et al. 2018).

Referring to Jeon et al. (2018), the components *pleasantness* and *eventfulness* have been commonly identified in several studies across different countries, demonstrating their robustness across languages, cultures, and environments (see Table 2.1). Because of their universality, these two components have gained recognition by several researchers and have recently been included in a questionnaire defined in the ISO/TS 12913-2 that consists of response scales related to eight affective attributes: pleasant, chaotic, vibrant, uneventful, calm, annoying, eventful, monotonous. Although the developed dimensions of affective qualities have been

Table 2.1 Soundscape descriptors as emotion dimensions. Dimensions proposed by selected publications are related to the Mehrabian and Russell's pleasantness and arousal dimensions

Publication	Main dimensions related to circumplex model from Mehrabian and Russell (1974)		Further dimensions
Mehrabian and Russell (1974)	Pleasantness	Arousal	
Truax (1984)		Variety	Coherence
Axelsson et al. (2010)	Pleasantness	Eventfulness	Familiarity
Cain et al. (2013)	Calmness	Vibrancy	
Andringa and van den Bosch (2013)	Pleasure	Activation	
ISO/TS 12913-3 (2019)	Pleasantness	Eventfulness	
Tarlao et al. (2019)	Appreciation	Dynamism	Monotony

applied by numerous researchers, a debate about the interpretation of the dimensions and their underlying mechanisms continues (Bakker et al. 2014).

Van den Bosch et al. (2018) assumed that the affective quality dimensions that are typically observed reflect motives with evolutionary significance, such as survival (*coping mode*) and flourishing (*co-creation mode*). The authors relate all affective qualities to the indicators of *affordance* and *complexity*, allowing for the establishment of *audible safety* to various degrees. *Affordance* can be understood as cues from the environment that immediately allow us to detect a function. These cues furnish behavior (Gibson 1979). According to van den Bosch et al. (2018), the evolutionary perspective of *audible safety* is an important component of auditory environments, warning humans of potential danger. In an acoustic environment lacking a high level of audible safety, people become vigilant and are alerted more easily, which results in stress and appraised unpleasantness. Simply said, people appraise their soundscapes based on the level of safety they attribute to them (van den Bosch 2015). This means that next to an emotional appraisal, a semantic one (e.g., in terms of the attribution of audible safety to an environment) is also involved.

Like the complexity indicator postulated by Van den Bosch et al. (2018), Axelsson (2011) referred to the amount of *information load* that drives affective responses to stimuli. The components of *pleasantness* and *activation* are then a direct result of information load. Bakker et al. (2014) explained pleasure and arousal as related to the degree of *order* and *variation*.

Truax (1984) proposed *variety* and *coherence* as soundscape-related indicators that are important to consider in acoustic design; in contrast, Llorca (2018) refers to *congruence* in the context of multisensory attention, which is closely related to soundscape appraisal. According to Llorca, congruence moderates the level of valence of a soundscape.

There is a lot of evidence that multisensory interactions can play a dominant role with respect to annoyance, pleasantness, or perceived quality of sound in daily environments (e.g., Fastl and Florentine 2011). Therefore, the dimension of congruence or coherence related to the multisensory experience might be relevant in the context of soundscape as well. Eventfulness would then be interpreted as a semantic dimension of (auditory) *order* and *variation*. Doubtless, future research must also further explore the fundamental affective dimensions involved in soundscape dealing with different mechanisms of affect such as *incidental affect* (affect unrelated to a judgment or decision such as a mood) versus *integral affect* (affect as part of the individual's internal representation) (see Västfjall et al. 2016). In particular, the generalizability of the latent dimensions observed and the association of those dimensions with (physical) indicators seems of utmost importance (Aletta and Kang 2018). Research on emotion and its source is of vital interest because as Brosch et al. (2010) concluded: "*Emotional stimuli are prioritized in perception, are detected more rapidly and gain access to conscious awareness more easily than non-emotional stimuli.*" (Brosch et al. 2010, p. 385).

Having a broader view of soundscape appears necessary. The dimensionality involved may gradually have to be increased or different dimensionalities may have to be applied to a soundscape. Currently, it is still challenging to disentangle all the intertwined emotion-related approaches, theories, and concepts, where contrary opinions of cause and effect can be found. Researchers will be kept busy with the further elaboration of emotion theory in the context of soundscape. However, the consideration of different emotion-related dimensions—in contrast to the simplistic, annoyance-focused community noise approach—is undoubtedly one of the core principles in soundscape research. The general aim of understanding perception requires us to examine its building blocks (emotion, affect, behavior, physiological responses) in more detail. By currently accepting *pleasantness* and *eventfulness* as main affective descriptors of soundscape appraisal, the hunt for the underlying indicators has begun (van den Bosch et al. 2018).

2.3.3 Human Perception of Acoustic Environments: ISO 12913-1

As described in Sect. 2.1.1, a soundscape is defined as an acoustic environment that is perceived or experienced and/or understood by a person or people in a context. ISO 12913 applies this definition as a perceptual construct (ISO 12913-1 2014). Figure 2.5 shows this perceptual process and highlights the important elements involved. An acoustic environment triggers auditory *sensations*. The interpretation of these sensations creates useful information (called auditory *perception*) that results in responses and an outcome. A *response* is considered to be related to short-term reactions, emotions, and behaviors that may change the context. An *outcome*, on the other hand, is understood as an overall, long-term consequence of attitudes, beliefs, judgments, or habits that are facilitated or enabled by the acoustic environment.

The *context* refers to the interrelationships between person, activity, and place in space and time, according to the ISO 12913-1 standard. Context simply influences perception at all perceptual and cognitive stages. Clearly, the term *context* covers a

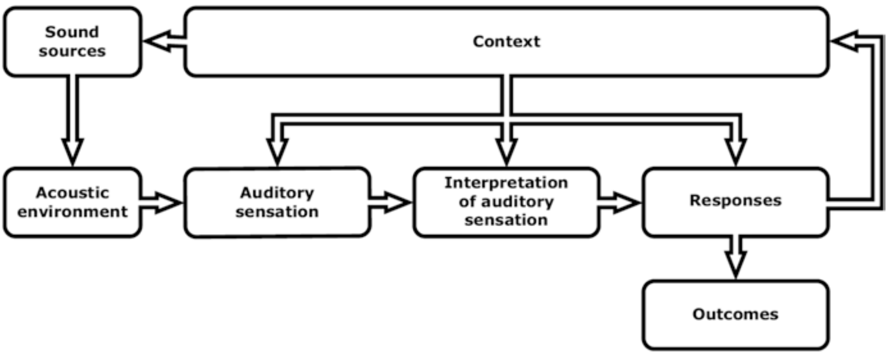


Fig. 2.5 Elements in the perceptual construct of soundscape according to ISO 12913-1 (2014), p. 2

wide range of factors that potentially affect soundscape perception (Bruce and Davies 2014).

A soundscape is formed within a context (Botteldooren et al. 2016) and soundscape preferences critically depend on context (Brown et al. 2011). Consequently, the perception of an acoustic environment also depends on the context in which the perception process is embedded (ISO 12913-1 2014). The apparent difficulty of this consideration quickly becomes obvious: in a sense, a full and viable theory of context could be a theory of nearly everything (Marks and Algom 1998). Context affects processes occurring at every stage, from early sensory transduction, perceptual encoding to cognitive recoding, and decision-making (Marks and Algom 1998). Although a comprehensive theory of context is lacking, at least the ISO 12913-1 standard provides a starting point to address the context factor sufficiently.

No fixed relationship exists between the physical stimulus and the human reaction. An act of interpretation takes place, which depends on the way people accept certain sound sources and trust the authorities who are responsible to protect them against harmful noise (Schulte-Fortkamp and Fiebig 2006). A person's response to an environment cannot be completely understood within a strict stimulus–response framework because responses depend on moods or intentions often formed in whole or in part before encountering a specific stimulus and environment (Snodgras et al. 1995). Humans construct their perceptions by interpreting sensations and apparently rely on normative principles and on heuristic principles (Fiebig 2019). They usually do this by considering components of acoustic environments as carriers of meaning (Fiebig 2015). High-level cognitive effects using heuristic principles are at least as significant as low-level percepts or physical attributes of the signal; humans extract meaning from a soundscape through information conveyed by the soundscape and in terms of human behavior (Davies et al. 2013). In fact, any acoustic environment can be viewed as a kind of composition where sounds play an informative role (Schulte-Fortkamp and Fiebig 2016).

2.4 Appraisal of Soundscapes: Processing Streams of Experiences

A particular aspect of human perception concerns the construction of overall assessments of complex, prolonged experiences. Frequently, the perception of acoustic environments is considered in terms of the instantaneous response to acoustic stimuli; but in everyday life it is a viable need to cope with complex environments that continuously excites human receptor cells. Indeed, a soundscape is considered to be a dynamic system that is characterized by the time-dependent occurrence of particular sound events embedded in specific environments (Schulte-Fortkamp and Fiebig 2016).

With regard to data collection, ISO/TS 12913-2 recommends that participants listen to a given sound in silence for a defined period of time (e.g., 3 min) and that they then assess their experiences on different rating scales. This task involves a recollection of the past period with perceived intensities that probably varied over time. Retrospective summarized evaluations seem very natural because they form the basis on which decisions are made to repeat or avoid past experiences that have direct hedonic consequences (Ariely and Carmon 2000).

Most investigations in the context of perception and assessment of environmental noise request ratings, evaluations, or descriptions of how a certain acoustic environment was perceived over a certain period of time in total, whether in the context of noise annoyance or a soundscape. The requested *summary assessment* of a past episode requires a significant reduction of complex streams of varying momentary sensations into a simple category (like a judgment on a rating scale). This reduction of complexity is needed to avoid cognitive overload. Humans would experience stress if they had to recount every moment of a longer episode to conclude whether they want to repeat or avoid it in future (Fiebig 2019).

Sensations endure and inform cognition well beyond the physical presence of the triggering stimulus (Algom 2001). In cognitive processes, memories and experiences are coupled with past and present judgments to help with recognition and organization of the layout of an environment (Bell et al. 2001). Moreover, there was a strong connection between what people felt and how they appraised the acoustic environment surrounding them (van den Bosch 2015).

On the other hand, a dissociation of retrospective evaluations from immediate experience is frequently observed in different sensory domains (Kahneman et al. 1993). Indeed, there is substantial evidence that people tend to use selected moments of extended experiences to form overall assessments, which is described by Kahnemann (2000) as *judgment by prototype*. This could be explained by an underlying economy principle for processing complex perceptual data; however, some questions remain. What are the possible determinants of retrospective evaluations of time-variant (noise) sequences? How are complex feelings transformed into overall appraisals? Is the construction of an overall soundscape appraisal based on normative or heuristic principles? The construction of soundscape appraisals does not occur only when overall assessments are requested. Appraisals are the product of an ongoing, unconscious process that is based on the omnipresent need of humans to constantly reevaluate past experiences.

Despite their naturalness, retrospective reports harbor serious methodological problems. These problems include possible distortions of memory and the evidence that human memory can be full of gaps (Danziger 1980). For example, with respect to noise annoyance surveys, self-reported long-term noise annoyance judgments were significantly affected by the very moment of questioning (Brink et al. 2016). Studies have shown that the season where a noise annoyance survey is performed has an impact on the annoyance ratings, although the respondents are always requested to consider the last 12 months (Brink et al. 2016). For example, the environmental noise of the last 12 months at home is rated in average as less annoying and disturbing in spring than in autumn, which illustrates a bias in retrospective reports.

Although a satisfying solution to this problem has yet to be found, there is strong evidence that the construction of an overall assessment goes beyond pure "cognitive averaging" when evaluating a soundscape as a whole (Steffens and Guastavino 2015). Humans must rapidly make sense of their environment to successfully move in the world and respond to its challenges, which might be achieved by creating an efficient mental representation of sensory stimuli by grouping certain objects as equivalent and reducing the complexity of information in the external world. Information about a particular stimulus is then inferred due to its association with a category (Brosch et al. 2010).

In laboratory experiments, participants often rely on normative principles and avoid ignoring larger parts of experienced episodes and their respective intensities (Fiebig and Sottek 2015). However, it is very likely that in everyday situations, humans tend to use selected moments of extended experiences to form overall assessments (Kahneman et al. 1993). People compare each stimulus event with known possibilities and judge it in comparison to perceived relationships and remembered alternatives (Lockhead 2001). Although it is conceivable that humans reduce complex episodes to a few properties, preserving only the information needed to navigate the real world and to form a stable global percept (Ariely 2001), the idea of mental representation with statistical properties as a kind of hedonic calculator has its limits. It appears likely that experienced episodes and their components are summarized into a global percept.

According to Schulte-Fortkamp (2014), the assigned meaning to sounds significantly affects the evaluation of sounds. Clearly, this notion must push the body of empirical work beyond the study of only one type of affect into studies of experiences characterized by multiple or mixed affective states, including cognitive processes and meaning attribution (Fredrickson 2000). At the same time, gaining a comprehensive understanding of human cognitive processing streams that are involved in the perception of acoustic environments might be a difficult endeavor, especially if we accept that humans possess a variety of cognitive schemes, each of which can be evoked or suppressed by subtle contextual features (Frederick and Loewenstein 2008). Without doubt, in the context of soundscape, studying the way humans summarize long-term experiences of acoustic environments in ecological settings is essential because that is the way humans report on their experienced acoustic environments. Unfortunately, there still seems to be a significant gap in understanding of which elements of perception contribute to retrospective assessments of time-variant experiences of acoustic environments.

2.5 Summary

The soundscape approach moves beyond current noise control engineering and retrofitting of the acoustic environment (Aletta et al. 2016a). Schafer laid the basis for this approach by interpreting environmental noise as a musical composition that could sound pleasant or terrible. Schafer wanted to establish a novel way of thinking, and he believed that it is up to the composers to tune the world (Schafer 1977).

This creative paradigm shift when dealing with acoustic environments lead to a focus on perception instead of treating the physical aspects of unwanted noise sources as linked to noise annoyance. It became evident that a listener within a soundscape is not simply engaged in a passive type of energy reception, but rather is part of a dynamic system of information exchange (Truax 1984). Accordingly, soundscape research embraced environmental psychology's understanding that (environmental) perception is constituted by the individual, the environment, and the interaction between the two.

Indeed, humans and soundscapes have a dynamic bidirectional relationship: humans affect soundscapes with their behavior and humans are in turn influenced by their soundscapes (Erfanian et al. 2019). These interactions between individuals and acoustic environments are broadly acknowledged and incorporated in the available soundscape standards and technical specifications (e.g., ISO 12913-1).

As humans presumably like places that allow them to carry out their plans and dislike places that violate their expectations (Snodgras et al. 1995), the concept of soundscape must deal with the function of sound in context and must include examination of the expectations and attitudes of the individuals experiencing acoustic environments. Therefore, it seems advisable to focus more strongly on the individual with his or her inherent traits, beliefs, moods, and desires instead of only considering the average person (Botteldooren et al. 2016). In this context, emotions elicited by the (acoustic) environment play a major role in well-being. Instead of debating the nature of "true" emotions and whether they do or do not require cognition, research must be focused on the details of cognition–emotion interaction and the function of these human processes in everyday life (Gross 2010).

In the past, adverse health effects of environmental noise on people and communities have been thoroughly investigated, primarily addressing unwanted sound. In contrast, the aspects of environmental noise that could induce potentially positive moods have been disregarded entirely (Aletta et al. 2018). As a matter of fact, preventative health research involving positive health outcomes from exposure to urban sounds is still limited (Payne and Bruce 2019). In particular, soundscape research requires more scientific evidence on the potential to use cognitive restoration to promote healthy urban environments (Kang et al. 2016). Some studies suggest that recovery from psychological stress and physiological recovery from sympathetic activation is faster during exposure to pleasant than to unpleasant sounds (Alvarsson et al. 2010).

The identification and preservation of "quiet areas" is enforced by Directive 2002/49/EC of the European Parliament and of the Council relating to the assessment and management of environmental noise (END 2002), and local authorities are required to seriously address this issue. Quiet areas in urban context are assumed to be beneficial and to have a health-promoting function by acting as buffers against the adverse health effects of traffic-noise exposure (Gidlof-Gunnarsson and Ohrstrom 2007). However, it remains astonishingly unclear how restoration and health benefits are supported by (acoustic) elements of a quiet area. Natural sounds, for example, have the ability to evoke pleasant feelings (Gidlof-Gunnarsson and Ohrstrom 2007), but classical indicators related to sound-pressure-level threshold values cannot accurately explain this induced feeling. Only limited correlations have been found between sound pressure levels and feelings of restoration in urban parks (Brambilla et al. 2013).

In this context, it is likely that the soundscape approach, with its implicit orientation to positive aspects of sounds, will gain in significance to support investigations of quiet areas and explorations of the (acoustical and perceptual) elements that are fundamental for restoration and health. Accordingly, Aletta et al. (2018) concluded in their literature review that positive perceptions of acoustic environments (soundscapes) can be associated with positive health effects. Thus, it is the long-term objective of soundscape research to design acoustic environments that specifically evoke emotional responses composed of positive affective qualities and to reduce adverse noise effects. However, the current understanding of the entanglement between psychology and soundscape is mostly limited to the link between acoustic characteristics and overt appraisal of soundscapes. This view lacks clarification of the corresponding responses in the physiological domain, which is probably relevant for genuine restoration and recovery (Erfanian et al. 2019). The literature on beneficial effects of sound is still scarce (Kamp et al. 2016). Most soundscape research has provided little insight into the promotion of physical and mental health, but mostly dealt with adverse effects (see Lercher and Dzhambov, Chap. 9).

The major challenge of soundscape research will continue to lie in determining ways to measure perception, especially outside of laboratories, which is the basic tenet of soundscape. There is still a significant lack of clarity and consensus regarding the use of terms such as *sensation*, *perception* (including *emotion*), and *cognition*, which impedes scientific progress. In addition, future research efforts must focus on improving the ecological validity of the experimental settings (Steffens and Guastavino 2015). Narrowly conceived studies that are based on empiricism and that ignore relevant conceptual and philosophical issues are not informative (Michell 1997). Because experimental design and data interpretation are fundamentally shaped by the theoretical commitments of the researchers (e.g., Chirimuuta 2016), further work is needed to develop sophisticated theoretical concepts that will allow researchers and practitioners to test the applicability of different methods to measure perception of a soundscape and to evaluate the validity of experimental outcomes.

Compliance with Ethics Requirements André Fiebig declares that he has no conflict of interest.

References

Aletta F, Kang J (2018) Towards an urban vibrancy model: a soundscape approach. Int J Environ Res Public Health 15:1712

Aletta F, Kang J, Axelsson Ö (2016a) Soundscape descriptors and a conceptual framework for developing predictive soundscape models. Landsc Urban Plan 149:65–74

Aletta F, Lepore F, Kostara-Konstantinou E, Kang J et al (2016b) An experimental study on the influence of soundscapes on people's behavior in an open public space. Appl Sci 6:276
Aletta F, Oberman T, Kang J (2018) Associations between positive health-related effects and soundscapes perceptual constructs: a systematic review. Int J Environ Res Public Health 15:2392
Algom D (2001) Memory psychophysics. In: International Encyclopaedia for the social and the behavioral sciences, Elsevier, London, UK, pp 9610–9613
Alvarsson JJ, Wiens S, Nilsson ME (2010) Stress recovery during exposure to nature sound and environmental noise. Int J Environ Res Public Health 7:1036–1046
Andringa TC, van den Bosch KAM (2013) Core affect and soundscape assessment: Fore- and background soundscape design for quality of life. In: Proceedings of InterNoise 2013, Innsbruck, Austria
Ariely D (2001) Seeing sets: representation by statistical properties. Psychol Sci 12(2):157–162
Ariely D, Carmon Z (2000) Gestalt characteristics of experiences: the defining features of summarized events. J Behav Decis Making 13:191–201
Axelsson Ö (2011) Aesthetic appreciation explicated. Doctoral thesis, Stockholm, Sweden
Axelsson Ö, Nilsson ME, Berglund B (2010) A principal components model of soundscape perception. J Acoust Soc Am 128(5):2836–2846
Bakker I, van der Voordt T, Vink P, de Boon J (2014) Pleasure, arousal, dominance: Mehrabian and Russell revisited. Curr Psychol 33:405
Barandiaran X, Di Paolo EA, Rohde M (2009) Defining agency: individuality, normativity, asymmetry, and spatio-temporality in action. Adapt Behav 17:367–386
Bell PA, Greene TC, Fisher JD, Baum AS (2001) Environmental psychology. Harcourt College Publishers, New York
Bild E, Pfeffer K, Coler M, Rubin O et al (2018) Public space users' soundscape evaluations in relation to their activities. An Amsterdam-based study. Front Psychol 9:1593. https://doi.org/10.3389/fpsyg.2018.01593
Boring EG (1921) The stimulus-error. Am J Psychol 32(4):449–471
Botteldooren D, de Coensel B (2009) The role of saliency, attention and source identification in soundscape research. In: Proceedings of the InterNoise 2009, Ottawa, Canada
Botteldooren D, Boes M, Oldoni D, de Coensel B (2012) The role of paying attention to sounds in soundscape perception. In: Proceedings of the acoustics 2012, Hong Kong, China
Botteldooren D, Andringa T, Aspuru I, Brown AL et al (2016) From sonic environment to soundscape. In: Kang J, Schulte-Fortkamp B (eds) Soundscape and the built environment. CRC Press/Taylor & Francis Group
Bradley MM, Lang PJ (2000) Affective reactions to acoustic stimuli. Psychophysiology 37:204–215
Brambilla G, Gallo V, Asdrubali F, D'Alessandro F (2013) The perceived quality of soundscape in three urban parks in Rome. J Acoust Soc Am 134(1):832–839
Brink M, Schreckenberg D, Vienneau D, Cajochen D et al (2016) Effects of scale, question location, order of response alternatives, and season on self-reported noise annoyance using ICBEN scales: a field experiment. Int J Environ Res Public Health 13:1163
Brosch T, Pourtois G, Sander D (2010) The perception and categorisation of emotional stimuli: a review. Cognit Emot 24(3):377–400
Brown AL, Kang J, Gjestland T (2011) Towards standardization in soundscape preference assessment. Appl Acoust 72:387–392
Brown AL, Gjestland T, Dubois D (2016) Acoustic environments and soundscapes. In: Kang J, Schulte-Fortkamp B (eds) Soundscape and the built environment. CRC Press/Taylor & Francis Group
Bruce NS, Davies WJ (2014) The effects of expectation on the perception of soundscapes. Appl Acoust 85:1–11
Cain R, Jenning P, Poxon J (2013) The development and application of the emotional dimensions of a soundscape. Appl Acoust 74(2):232–239
Cattell JM (1893) On errors of observation. Am J Psychol 5:285–293
Chirimuuta M (2016) Why the "stimulus-error" did not go away. Stud Hist Philos Sci 56:33–42

Danziger K (1980) The history of introspection reconsidered. J Hist Behav Sci 16:241–262

Davies WJ, Adams MD, Bruce NS, Cain R et al (2013) Perception of soundscapes: an interdisciplinary approach. Appl Acoust 74:224–231

De Coensel B, Botteldooren D (2010) A model of saliency-based auditory attention to environmental sound. In: Proceedings of the ICA 2010, Sydney, Australia

END (2002) European Directive 2002/49/EC 2002 of the European Parliament and of the Council of 25 June 2002 (2002) relating to the assessment and management of environmental noise. Official Journal of the European Communities L 189/12, Brussels

Erfanian M, Mitchell AJ, Kang J, Aletta F (2019) The psychophysiological implications of soundscape: a systematic review of empirical literature and a research agenda. Int J Environ Res Public Health 16:3533

Fastl H (2004) Audio-visual interactions in loudness evaluation. In: Proceedings of the ICA 2004, Kyoto, Japan

Fastl H, Florentine M (2011) Loudness in daily environments. In: Florentine M, Popper AN, Fay RR (eds) Springer handbook of auditory research book series: loudness, vol 37. Springer, New York, pp 199–222

Fiebig A (2015) Cognitive stimulus integration in the context of auditory sensations and sound perceptions. epubli, Berlin

Fiebig A (2018) Recent developments in the standardization of soundscape. In: Proceedings of InterNoise 2018, Chicago, USA

Fiebig A (2019) The perception of acoustic environments and how humans form overall noise assessments. In: Proceedings of InterNoise 2019, Madrid, Spain

Fiebig A, Sottek R (2015) Contribution of peak events to overall loudness. Acta Acust united Ac 101(6):1116–1129

Fiebig A, Jordan P, Moshona CC (2020) Assessments of acoustic environments by emotions - the application of emotion theory in soundscape. Front Psychol 11:573041. https://doi.org/10.3389/fpsyg.2020.573041

Filipan K, De Coensel B, Aumond P, Arnaud C et al (2019) Auditory sensory saliency as a better predictor of change than sound amplitude in pleasantness assessment of reproduced urban soundscapes. Build Environ 148:730–741

Fisher JD, Bell PA, Baum A (1984) Environmental psychology. CBS College Publishing, New York

Franek M, Rezny L, Sefara D, Cabal J (2019) Effect of birdsongs and traffic noise on pedestrian walking speed during different seasons. Peer J 7:e7711. https://doi.org/10.7717/peerj.7711

Frederick S, Loewenstein G (2008) Conflicting motives in evaluations of sequences. J Risk Uncertain 37:221. https://doi.org/10.10070/s11166-008-9051-z

Fredrickson BL (2000) Extracting meaning from past experiences: the importance of peaks, ends, and specific emotions. Cognit Emot 14(4):577–606

Genuit K, Fiebig A (2006) Psychoacoustics and its benefit for the soundscape approach. Acta Acust united Ac 92(6):952–958

Gibson JJ (1979) The ecological approach to visual perception. Houghton Mifflin, Boston

Gidlof-Gunnarsson A, Ohrstrom E (2007) Noise and well-being in urban residential environments: the potential role of perceived availability to nearby green spaces. Landsc Urban Plan 83:115–126

Goldstein EB (2002) Sensation and perception, 6th edn. Wadsworth, Pacific Grove

Gross JJ (2010) The future's so bright, I gotta wear shades. Emot Rev 2(3):212–216

Guski R (1999) Personal and social variables as co-determinants of noise annoyance. Noise Health 3:45–56

Hasset J (1978) A primer of psychophysiology. W.H. Freeman and company, San Francisco

Helson H (1967) Perception. In: Helson H, Bevan W (eds) Contemporary approaches to psychology. van Nostrand, Princeton/New Jersey/Toronto/London

Hollister CM (1914) Toleration of noises. Am J Nurs 14:519–521

ISO 12913-1 (2014) Acoustics-soundscape-part 1: definition and conceptual framework. Geneva, Switzerland

ISO 18405 (2017) Underwater acoustics — Terminology. Geneva, Switzerland
ISO/TS 12913-2 (2018) Acoustics-soundscape-part 2: data collection and reporting requirements. Geneva, Switzerland
ISO/TS 12913-3 (2019) Acoustics-soundscape part 3: data analysis. Geneva. https://www.iso.org/standard/69864.html
James W (1884) What is an emotion? Mind 9:188–205
Jeon JY, Hong JY, Lavandier C, Lafon J et al (2018) A cross-national comparison in assessment of urban park soundscapes in France, Korea, and Sweden through laboratory experiments. Appl Acoust 133:107–117
Kahneman D (2000) Evaluation by moments: Past and future. In: Kahneman D, Tversky A (eds) Choices, values and frames. Cambridge University Press, New York
Kahneman D, Fredrickson BL, Schreiber CA et al (1993) When more pain is preferred to less: adding a better end. Psychol Sci 4(6):401–405
Kang J, Chourmouziadou K, Sakantamis K, Wang B, et al. (eds) (2013, March 22) COST TUD Action TD 0804. Soundscape of European cities and landscapes. Oxford
Kang J, Aletta F, Gjestland TT, Brown LA et al (2016) Ten questions on the soundscapes of the built environment. Build Environ 108:284–294
Klatte M, Hellbrück J, Seidel J, Leistner P (2010) Effects of classroom acoustics on performance and well-being in elementary school children: a field study. Environ Behav 42(5):659–692
Knudsen EI (2007) Fundamental components of attention. Annu Rev Neurosci 30:57–78
Kogan P, Turra B, Arenas JP, Hinalaf M (2017) A comprehensive methodology for the multidimensional and synchronic data collecting in soundscape. Sci Total Environ 580:1068–1077
Korte C, Grant R (1980) Traffic noise, environmental awareness and pedestrian behavior. Environ Behav 12(3):408–420
Lavia L, Dixon M, Witchel HJ, Goldsmith M (2016) Applied soundscape practices. In: Kang J, Schulte-Fortkamp B (eds) Soundscape and the built environment. CRC Press/Taylor & Francis Group
Lin LW, Weng SC, Wu HS, Tsai LJ, Lin YL, Yeh SH (2018) The effects of white noise on agitated behaviors, mental status, and activities of daily living in older adults with dementia. J Nurs Res 26(1):2–9. https://doi.org/10.1097/JNR.0000000000000211
Llorca J (2018) Virtual reality for urban sound design: a tool for architects and urban planners. In: Aceves-Fernandez MA (ed) Artificial intelligence: emerging trends and applications. IntechOpen, London, UK
Lockhead GR (2001) Context and judgment. In: Sommerfeld E, Kompass R, Lachmann T (eds) Fechner Day 2001. Pabst, Lengerich
Lockhead GR (2004) Absolute judgments are relative: a reinterpretation of some psychological scales. Rev Gen Psychol 8(4):265–272
Marks LE, Algom D (1998) Psychophysical scaling. In: Birnbaum MH (ed) Measurement, judgment and decision making. Academic Press, San Diego
Mehrabian A, Russell JA (1974) An approach to environmental psychology. MIT Press, Cambridge, Massachusetts and London
Mehta R, Zhu R, Cheema A (2012) Is noise always bad? Exploring the effects of ambient noise on creative cognition. J Consum Res 39(4):784–799
Meng Q, Zhao T, Kang J (2018) Influence of music on the behaviors of crowd in urban open public spaces. Front Psychol 9:596
Merriam-Webster (2022) Emotion. Merriam-Webster.com, Dictionary, https://www.merriam-webster.com/dictionary/emotion. Accessed 8 May 2022
Michell J (1997) Quantitative science and the definition of measurement in psychology. Br J Psychol 88:355–383
Moser G, Uzzell D (2003) Environmental psychology. In: Millon T, Lerner MJ (eds) Handbook of psychology, Personality and social psychology, vol 5. John Wiley & Sons, pp 419–445
Oldoni D, De Coensel B, Boes M, Rademaker M et al (2013) A computational model of auditory attention for use in soundscape research. J Acoust Soc Am 134:852–861

Payne SR, Bruce N (2019) Exploring the relationship between urban quiet areas and perceived restorative benefits. Int J Environ Res Public Health 16:1611
Russell JA (1980) A circumplex model of affect. J Pers Soc Psychol 39(6):1161–1178
Russell JA, Pratt G (1980) A description of the affective quality attributed to environments. J Pers Soc Psychol 38(2):311–322
Russell JA, Ward LM, Pratt G (1981) Affective quality attributed to environments: a factor analytic study. Environ Behav 13:259–288
Schafer RM (1977) The soundscape: our sonic environment and the tuning of the world. Destiny Books, USA, Rochester
Schafer RM (2012) Soundscape studies: the early days and the future. Soundscape: J Acoust Ecol 12(1):6–8
Schlittmeier SJ, Hellbrück J, Klatte M (2008) Does irrelevant music cause an irrelevant sound effect for auditory items? Eur J Cogn Psychol 20(2):252–271
Schomer P, Brown A L, de Coensel B, Genuit K, et al. (2010) On efforts to standardize a graphical description of the soundscape concept. In: Proceedings of InterNoise 2010, Lisbon, Portugal
Schulte-Fortkamp B (2002) The meaning of annoyance in relation to the quality of built environments. Noise Health 4:13–28
Schulte-Fortkamp B (2014) Improving sound quality measures through the multifaceted soundscape approach. In: Proceedings of InterNoise 2014, Melbourne, Australia
Schulte-Fortkamp B, Fiebig A (2006) Soundscape analysis in a residential area: an evaluation of noise and people's mind. Acta Acust united Ac 92(6):875–880
Schulte-Fortkamp B, Fiebig A (2016) Impact of soundscape in terms of perception. In: Kang J, Schulte-Fortkamp B (eds) Soundscape and the built environment. CRC Press/Taylor & Francis Group, Boca Raton, pp 69–88
Sellars RW (1907) The nature of experience. J Philos Psychol Sci Methods 4(1):14–18
Shield B, Dockrell J (2008) The effects of classroom and environmental noise on children's academic performance. In: Proceedings of international congress on noise as a public health problem, Foxwoods, USA
Snodgras J, Russell JA, Ward LM (1995) Planning, mood, and place-liking. In: Gärling T, Canter D (eds) Readings in environmental psychology: urban cognition. Academic Press, San Diego, pp 187–200
Snyder JS, Gregg MK, Weintraub DM, Alain C (2012) Attention, awareness, and the perception of auditory scenes. Front Psychol 3:15
Southworth MF (1967) The sonic environment of cities. MIT, thesis
Southworth MF (1969) The sonic environment of cities. Environ Behav 1(1):49–70
Steffens J, Guastavino C (2015) Trend effects in momentary and retrospective soundscape judgments. Acta Acustica united Ac 101(4):713–722. https://doi.org/10.3813/AAA.918867
Steffens J, Müller F, Schulz M, Gibson S (2019) Cognitive load influences the evaluation of complex acoustical scenarios. In: Proceedings of ICA 2019, Aachen, Germany
Stevens SS (1975) Psychophysics. Introduction to its perceptual, neural, and social prospects, Wiley, New York, USA
Sudarsono AS, Sarwono SJ, Shabrina A, Tamrin LN (2019) The soundscape dimensions of third-class hospital ward in Indonesia. In: Proceedings of ICA 2019, Aachen, Germany
Sun K, De Coensel B, Filipan K, Aletta F et al (2019) Classification of soundscapes of urban public open spaces. Landsc Urban Plan 189:139–155
Taghipour A, Pelizzari E (2019) Effects of background sounds on annoyance reaction to foreground sounds in psychoacoustic experiments in the laboratory: limits and consequences. Appl Sci 9:1872
Tarlao C, Steele D, Guastavino C (2019) Investigating factors influencing soundscape evaluations. In: Proceedings of InterNoise 2019, Madrid, Spain
Titchener EB (1922) Mach's lectures on psychophysics. Am J Psychol 33(2):213–222
To WM, Chung A, Vong I, Ip A (2018) Opportunities for soundscape appraisal in Asia. In: Proceedings of the euronoise 2018, Crete, Greece

Truax B (1984) Acoustic communication. Ablex Publishing Corporation, Norwood

van den Bosch KAM (2015) Safe and sound. Soundscape research in special needs care. Doctoral thesis, Groningen, Netherlands

van den Bosch KAM, Welch D, Andringa TC (2018) The evolution of soundscape appraisal through enactive cognition. Front Psychol 9:1129. https://doi.org/10.3389/fpsyg.2018.01129

Van Kamp I, Klaboe R, Brown AL, Lercher P (2016) Soundscapes, human restoration and quality of life. In: Kang J, Schulte-Fortkamp B (eds) Soundscape and the built environment. CRC Press/Taylor & Francis Group, Boca Raton

Västfjäll D, Slovic P, Burns WJ, Erlandsson A et al (2016) The arithmetic of emotion: integration of incidental and integral affect in judgments and decisions. Front Psychol 7:325. https://doi.org/10.3389/fpsyg.2016.00325

Welch D, Shepherd D, Dirks K, Tan MY et al (2019) Use of creative writing to develop a semantic differential tool for assessing soundscapes. Front Psychol 9:2698. https://doi.org/10.3389/fpsyg.2018.02698

Yu B, Kang J, Ma H (2016) Development of indicators for the soundscape in urban shopping streets. Acta Acustica united Ac 102(3):462–473. https://doi.org/10.3813/AAA.918965

Zadra JR, Clore GL (2011) Emotion and perception: the role of affective information. Wiley Interdiscip Rev Cogn Sci 2(6):676–685