MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

The perception of acoustic environments and how humans form overall noise assessments

Fiebig, André[1]
Technical University of Berlin
Sekr. TA 7
Einsteinufer 25
10587 Berlin, Germany

At the time of writing
HEAD acoustics GmbH
Ebertstr. 30a
52134 Herzogenrath, Germany

ABSTRACT

Human beings recognize patterns out of auditory sensations, which leads to sound perception. Due to the omnipresence of noise, the perception of noise has a strong impact on the well-being and life-quality of human beings. By means of cognitive processes, meaning is assigned to the world around us following rules with an inherent logic. A specific aspect concerns how humans retrospectively form overall assessments of hedonic or sensational profiles as they experience environmental noise. If humans are requested to provide an overall assessment of an environment regarding for example annoyance, pleasantness or restorativeness, they have to retrospectively assign a magnitude of perception or affective appraisal to the experienced past period. Since experiences of environments typically change over time, a deeper understanding of the cognitive processing of time-variant experiences is needed. This processing is quintessentially contextual affecting auditory sensation, the interpretation of auditory sensation, and the responses to the acoustic environment. Frequently it can be observed that people rely more on patterns and key moments of episodes instead of averaging equally the whole stream of momentary experiences like a sound level meter does.

Keywords: Perception, Noise effects, Environment
I-INCE Classification of Subject Number: 61

[1] andre.fiebig@tu-berlin.de

1. INTRODUCTION

With the emergence of psychophysics in the 19th century psychological phenomena were scientifically investigated by measurement techniques rather than by philosophic speculations about them [1]. Weber and Fechner started to constitute psychophysics by measuring sensory thresholds and Stevens later introduced and established the direct measurement of sensory attributes [2].

What is so specific about perception? First of all, we perceive rather than we just have sensations [3]. We construct our perception by means of multiple sensations. Based on a number of sensations, which are put together by mediational processes, we recognize patterns out of sensations leading to perception, i.e. humans construct the perceptions from sensations and from long-term memory of past experiences with similar sensations [4]. This “recognition” process seems to be complex and is still subject to research. New research permanently causes us to rethink what was once well established and new findings occasionally disapprove the “laws” of the past [5]. By now, it is widely recognized that the perception of a sequence is not simply the sum of the perception (or sensation) of its parts [6].

In particular, psychophysicists have first assumed that the process by which physical properties are mapped into perceptions and finally mental representations is implicitly a bottom-up process – the physical energy is transduced into neural activity giving rise to sensations and perception respectively. But, it has become apparent that top-down processes affect how information is gathered and processed [7]. Aspects, such as attention, expectations, knowledge, working memory capacity, shape our perception of the world and lie beyond the simplistic notion of bottom-up information-processing. Accordingly, Marks noticed that for example ‘loudness’ is not a relatively low-level sensory process, but is a process that fundamentally entails the properties of a cognitive act [8]. He observed that matches derived from magnitude estimates of the loudness of different sounds change dramatically with changes in the relative intensity levels (contexts) of the stimuli being judged [9]. Those effects - apparent changes in the perception - cannot be simply attributed to a response bias but rather indicate that the sensory representation itself was affected [10]. This means that human perception due to its intertwined bottom-up and top-down processes is and will remain a subject for further research. Challenges in psychophysics - researching how humans perceive their world(s) - have to be met understanding that psychophysical tasks are rich in complex psychological processes, which depends on memory, comparative behaviour, and response strategies. It is evident that there is no bias-free method in investigating human perception - “biases can perhaps be eliminated singly, one at a time, but their elimination all at once in the same experiment probably lies beyond probability” [2]. Thus, the researcher must always be aware of the methodological implications of the applied methods and tools.

2. PERCEPTION OF ACOUSTIC ENVIRONMENTS

We are permanently surrounded by sound and we cannot avoid that; our ears remain always in the mode of listening. We listen and process even during sleep. We process consciously or subconsciously the noise surrounding us in order to retrieve relevant information, which sometimes leads to large effects.

2.1 How sound shapes humans life

Acoustic environments have several effects on humans, regardless of the fact that we are aware of the effects or not. For example, even when in experiments the participants are instructed to ignore the noise, background noise severely impairs the human verbal short-term memory. The irrelevant noise deteriorates the serial recall of items. Of course, the level of impaired short-term memory depends on several aspects such as the properties of sound. For example, Schlittmeier discovered that instrumental music with prominent staccato-passages significantly reduced auditory serial recall performance, whereas legato-music had no effect [11]. It is evident that the so called irrelevant sound effect impairing the human short-term memory has a significant importance, because it exerts influence on work performance, efficiency or decision-making capabilities, which greatly suffer under suboptimal acoustic conditions.

Comparably, exposure to environmental noise and poor acoustic conditions in classrooms have detrimental effects upon children's learning and performance. For example noise greatly affects reading abilities significantly reducing the learning success [12], but also other aspects such as memory, motivation or attention. In particular, school children with special educational needs were found to be more susceptible to noise effects [13].

Studies have confirmed the relevance of environmental noise in the context of social behaviour as well. Environmental conditions like noise and crowding have specific effects on behaviour, such as paying less attention to others, and being less affiliative and less helpful [14]. Korte and Grant observed that the environmental awareness of pedestrians was significantly reduced as the level of traffic noise rose and concluded that the sight and sound of dense traffic preclude pedestrians' to notice peripheral elements of the environments they pass through [15]. The consequences of such reduced level of environmental awareness might be manifold and severe. In contrast to these noise effects, sound can be beneficial for humans as well. Non-participatory observational studies capturing and assessing human behaviour observed changed behaviour due to designed changes to acoustic environments. Those methods are sometimes understood as superior to participatory methods, because they do not interfere with peoples' perceptual and behavioural processes and thus are not prone to known bias effects of self-report methods [16]. Moreover, in the West Street Tunnel experiment in Brighton it turned out that by using background music antisocial behaviour was considerably mitigated, which improved public safety [17]. Positive effects were observed with respect to loitering, walking speed, individuals queuing behavior and even the willingness to donate to collectors [16].

Aletta et al. showed that music influenced the mean duration of stay in a public space by adding musical sound, which caused a longer duration of stay than the one measured in the control (no music) condition [18]. Steele et al. confirmed that by means of an installed interactive sound system in a busy public park, the pleasantness, eventfulness, and vibrancy of the soundscape for users and non-users was improved compared to the pre-installation condition [19].

These examples underline on the one hand the potential of sound to affect humans and on the other hand the complexity of such effects indicating the relevance of studying the perception of acoustic environments in detail.

2.2 The concept 'soundscape'

The term *soundscape* was established by the Canadian composer Murry Schafer in the late sixties and early seventies. He understood a soundscape as a musical composition, which can be studied just as a given landscape – but according to Schafer a microphone does not operate the way like a photograph of a landscape does. It only samples details [20]. Soundscape as a perceptual construct of an acoustic environment does not simply correspond to the measured microphone signal; soundscape contains all the information humans retrieve out of their environment. The acoustic environment of a place or space is the sound from all the sources that could be heard by someone in that place [21]. Thus, the acoustic environment depends on the sources present and their spatial distribution, the location of the receiver and the propagation conditions along the paths. If we consider the perception of the acoustic environment, we do not think anymore about the physical entity of the environment, but about the perceptual construct of it. Often the term 'soundscape' is used to differentiate between physical and perceptual world. The international standard ISO 12913-1 published in 2014 defines 'soundscape' as follows: soundscape is the acoustic environment as perceived or experienced and/or understood by a person or people, in context [22]. Figure 1 shows the elements of soundscape according to the ISO 12913-1.

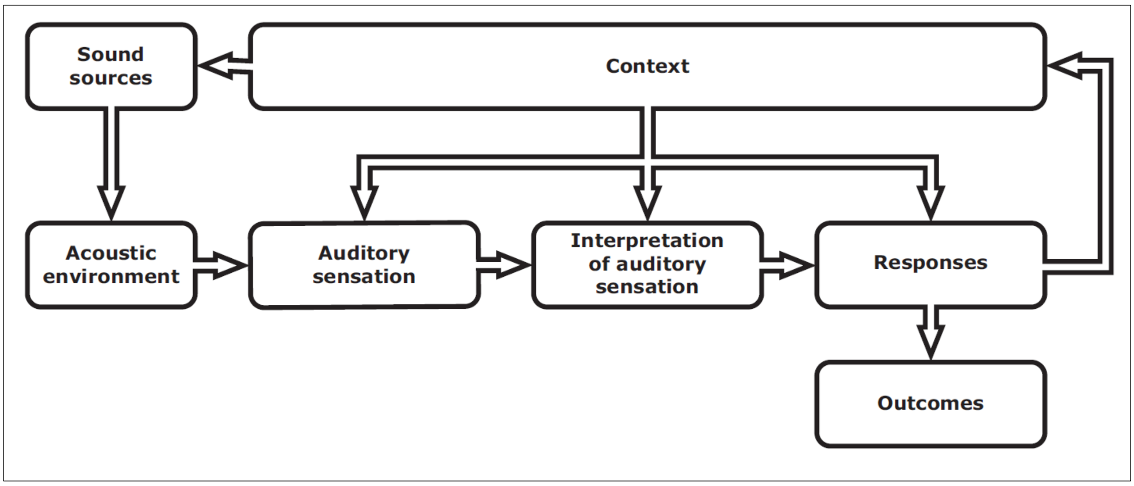

Fig. 1 – Elements in the perceptual construct of soundscape according to ISO 12913-1 [22]

Although soundscape started to be a research field in the late sixties, it received significant attention by researchers in the last fifteen years in the field of community noise and environmental acoustics, and recently by policy makers and practitioners due to its multidisciplinary approach focussing on how people actually experience their acoustic environments [23]. Consequently, Genuit concluded that soundscape can provide the missing part to grasp all phenomena related to noise perception exploiting psycho-acoustics, psychology, and sound quality [24].

2.3 The effect of attention on the perception of acoustic environments

Auditory attention is believed to play an important role in the perception of acoustic environments. Attention directs to a certain extent how humans perceive and evaluate their environments. Any gained information, which due to mechanisms of attention gets access to the working memory, is evaluated in working memory, where it is analyzed, decisions about that information are made, and plans for the action are elaborated [25]. In the context of processing acoustic environments, it was observed that numerous sound sources make it difficult to identify single sources, and then acoustic sceneries are processed as a whole rather than as independent sound events [26]. Additionally, attention processes are influenced by source recognition; as soon as sound source is recognized, attention is sharpened separating source from background and influencing basic auditory sensations like perception of loudness [27].

In 1953 the relevance of attention for perception was already greatly illustrated by Cherry [28]. Due to attention there was no difficulty in listening to one speech at will while rejecting an unwanted one in case of unmixed speeches provided via headphones, one in the left ear and one in the right ear. Interestingly, although the recognition of the relevant speech was classified as easy, the participants were unable to repeat anything of what was presented on the rejected channel and they even failed to remember the spoken language afterwards [28]. This early research proved already the importance of attention processes of humans in multi-source scenarios, because it guides sensory processing and perception. Thus, auditory attention obviously allows human beings to focus their mental resources on a particular stream of interest while ignoring others indicating that bottom-up (saliency-based) and top-down (voluntary) mechanisms are applied in a competitive selection process [29].

The role of attention can be illustrated by a simple experiment [30]. 53 participants judged environmental noise sequences in a laboratory context via a semantic differential including seven category scales. The sounds were randomly presented via equalized headphones. The instruction changed during the run of the experiment. First the participants listened to the noises without any specific task. Afterwards they should focus on a certain source (and should answer some irrelevant questions regarding the nature of the source they focused on). In all cases, they were requested to provide overall assessments regarding different evaluation criteria. Figure 2 shows exemplarily the result of this experiment.

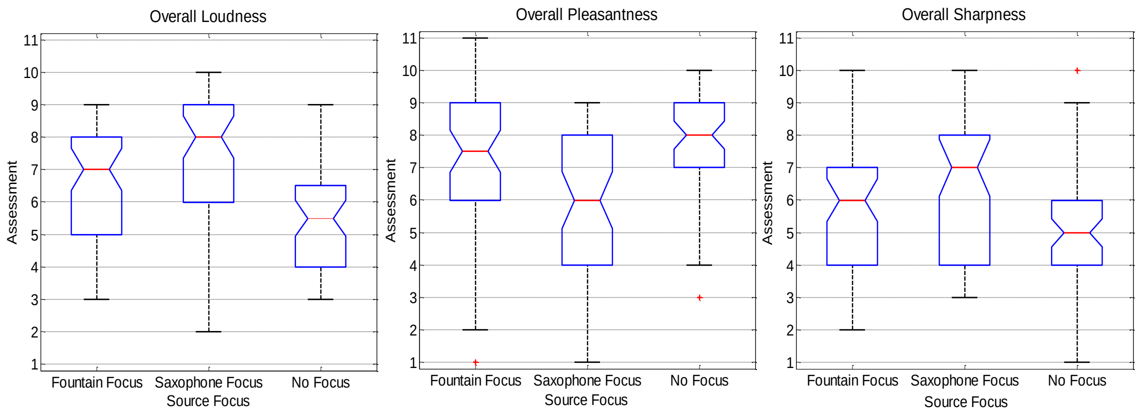

Fig. 2 – Box-whisker plot: Comparison of overall assessments of pleasantness (left), loudness (middle) and sharpness (right) with forced focus on fountain noise, forced focus on saxophone music and without any focus specified. All assessments refer to the same noise sample.

The statistical analyses showed that the assessments of the overall loudness ($F_{(2,104)}=17.9$, $p<0.01^{**}$), overall pleasantness ($F_{(2,104)}=23.7$, $p<0.01^{**}$) and overall sharpness ($F_{(2,104)}=8.4$, $p<0.01^{**}$) differ highly statistically significant due to the varying instruction with small effect sizes in terms of partial eta-squared ($\eta_p{}^2{}_{loud}=0.26$,

$\eta_p{}^2{}_{pleasant}=0.31$, $\eta_p{}^2{}_{sharp}=0.14$). In all cases, the participants were requested to provide overall assessments for the entire sample. These results illustrate that attention towards a certain sound source changes the overall noise assessment.

2.4 The role of context

It is well known that context plays always a significant role in human life. ‘Context’ includes the interrelationships between person, activity and place in space and time [22]. It seems broadly acknowledged that context can affect processes occurring at every stage, from early sensory transduction, perceptual encoding to cognitive recoding and decision [31]. Those effects are often called *bias* interpreted as a kind of error indicating distortion in measuring the (true) perception. Simply said bias means a deviation from the norm. This interpretation is misleading, because those effects reveal the design of the human mind [32]. As Ariely and Carmon point out, people do care about properties of sequences other than simply the integral of utility that they provide, they do so knowingly and this should make us unapologetically wary of labeling their preference a bias [33].

3. HOW HUMANS FORM OVERALL NOISE ASSESSMENTS

Humans permanently face circumstances where they have to make choices, decisions, and assessments based on bounded affective episodes. Those assessments are strongly needed in order to be able to decide to repeat or to avoid already experienced episodes. But how is an overall assessment constructed? Are there certain moments an overall assessment is mostly related to? Do humans base their decisions on some unifying principles or do they possess a variety of cognitive schemas, each of which can be evoked or suppressed by subtle contextual features? [34] Do they use heuristic or normative principles? Although the nature of cognitive operations converting patterns of experiences into overall assessments is researched in various empirical contexts, there is still a lack of understanding of the fundamentals of those cognitive processes. What we seem to know is that “when people evaluate experiences retrospectively, they do not play back the equivalent of a movie but instead tend to recall specific salient features of the experience […].” [35]

Unfortunately, fundamental research in psychophysics focused mainly on ‘how something is just perceived?’ instead of ‘how a (bounded) dynamic episode was perceived?’. Why is it important to study how humans create overall assessments retrospectively? It is exceptionally typical to construct summary assessment of past episodes in everyday life – this reduces complexity of streams of varying momentary sensations by simply summarizing the respective stream into an overall assessment easy to remember and to communicate. It would likely lead to a cognitive overload, if we would to recount every moment of a ten-days trip to conclude whether you can recommend the trip to someone else, after being asked. This applies to almost every activity humans do in daily-life.

One of the most important aspects in the field of community noise and environmental noise assessment is the consideration of noise assessments based on recollections and memories. The exposure-effect relationships indicating the relationship between exposure (mainly expressed by sound pressure level) and human response (mainly expressed by the percentage of highly annoyed persons), are developed by asking “*Thinking about the last 12 months, when you are here at home, how much does noise from (a certain noise source) bother, disturb or annoy you?*” [36].

Most likely confronted with such a task the respondent does not weight equally all experienced events over the last 12 months in order to derive an overall assessment representing the overall level of annoyance in the experienced 12 month period. But, which events are then taken into account? That the human memory of last 12 months regarding overall noise annoyance is not perfect from a normative perspective was recently observed by Brink et al. [37]. Among several aspects influencing the result of self-reported annoyance, they found that the moment (season), where an interview with the question about the overall noise annoyance considering the last 12 months is held, has a significant effect on the reported noise annoyance, as figure 3 displays. Asking for the last 12 month should eliminate any seasonal effect, but the human mind works differently. Obviously, the experienced "end" of the last 12 months got a larger weighting changing the self-reported overall noise assessment. Brink et al. concluded that despite the clear instruction to consider the last 12 months, circumstances related to time of the year affect annoyance responses at the time of a survey [37]. However, this is not "accidently a deviation from the expected norm" but the way humans do summarize long-term experiences.

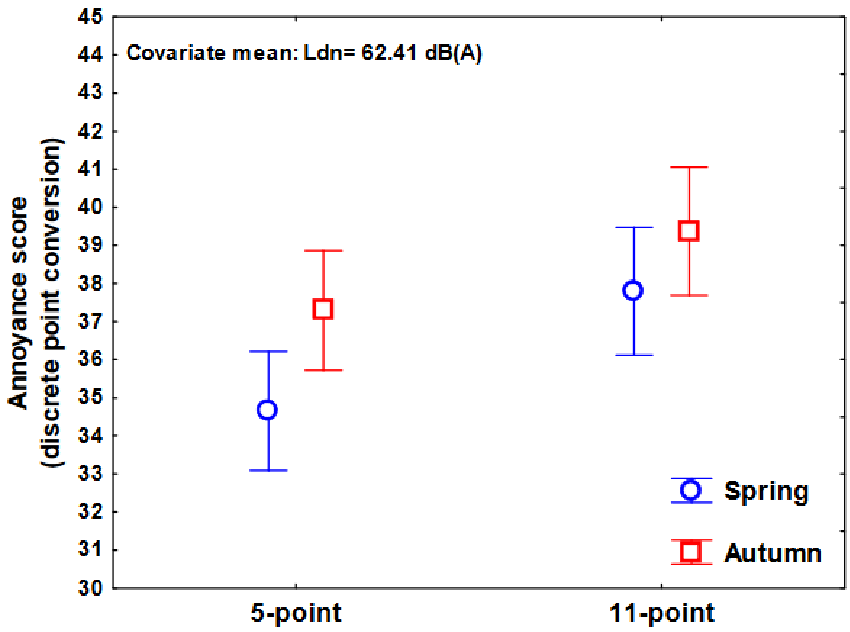

Fig. 3 – Annoyance score (discrete point conversion) by season measured by the 5-point and 11-point scales (± 95% confidence interval) [37]

As it was observed early in psychoacoustics, the average of instantaneous judgments of time-varying experiences does not simply correspond to the retrospective overall assessment. For example, Fastl observed that there is a mismatch between judged overall loudness and arithmetic mean of the judged loudness run over time and concluded that this effect is caused by an overemphasis of single loud events, which contribute greatly to the overall perception [38]. This leads to the introduction of percentile values for overall loudness representing the perceived overall loudness as a single value. Consequently, the ISO 532-1 proposes the percentile loudness N_5 as an indicator for overall loudness; this is the loudness value which is reached or exceeded in only 5% of the measuring time interval [39]. However, other information out of the stream of momentary experiences may be relevant for the overall (noise) assessments. Exemplarily, Steffens and Guastavino found that the linear trend of the temporal experience, whether rising or falling, contributes to the overall assessment as it can be considered as a "look into the future" and highlights the importance of expectation and anticipation [40]. Accordingly, Susini et al. observed the relevance of the end level of a sound episode, which heavily influenced the judgment of overall loudness [41].

Figure 4 illustrates the problem of overall loudness of time-variant noise sequences. We consider the loudness function over time on the left resulting from an aircraft overflight: In the beginning it was quiet, then considerably loud, and after the aircraft fly-over it was relatively quiet again. What is exactly the overall loudness of such an event? How is the overall loudness changed when we prolong the noise episode with a little bit more silence at the end? Do humans really work in a normative way, doing exact cognitive integration of the experienced moments regarding loudness? The simple question is, which signal with its respective loudness on the right matches perceptually the loudness of the aircraft overflight episode? The loudness functions on the right correspond to the single loudness values of N_1, N_5, N_{cubic_mean}, $N_{root\_mean\_square}$, N_{20}, $N_{average}$, and N_{50}. It is obvious that the choice of the respective loudness value as a single value representing the overall loudness of the experienced noise episode has a great impact on the loudness result. This question is further considered and discussed in chapter 3.2.

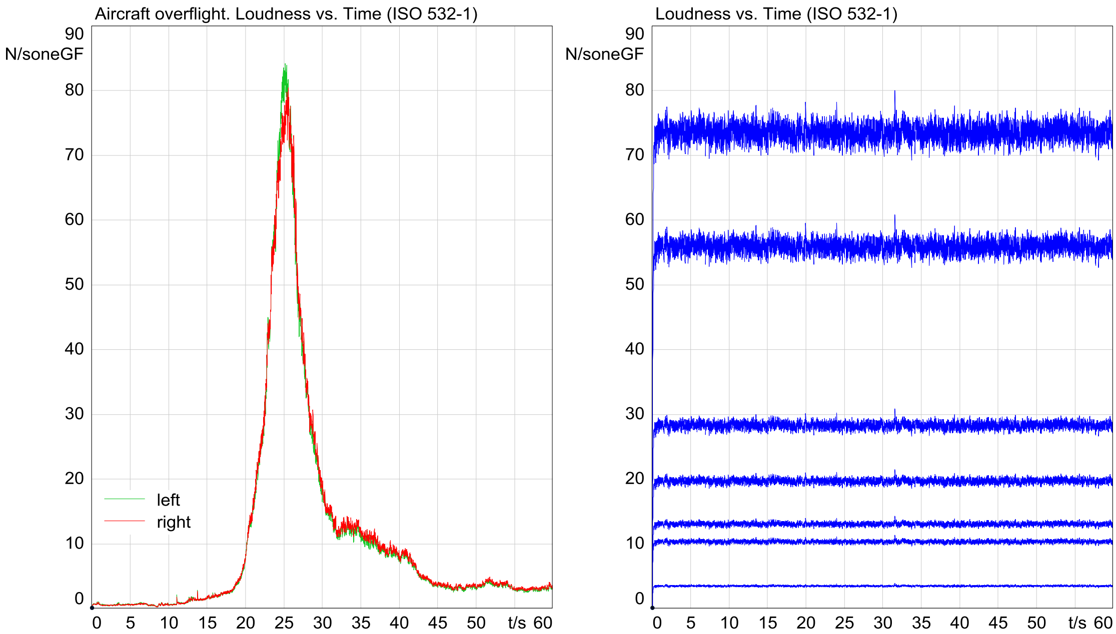

Fig. 4 – Loudness vs. time according to ISO 532-1. Left: Loudness of an aircraft overflight; right: Loudness of different broadband noises. The loudness functions on the right matches different single values of the loudness function displays on the left (from top to bottom: N_1, N_5, N_{cubic_mean}, $N_{root\_mean\_square}$, N_{20}, $N_{average}$, and N_{50})

3.1 The role of duration with respect to noise assessments

Interestingly, duration of a noise sequence does not play a significant role with respect to the assessment of the overall loudness, annoyance or unpleasantness, as studies has shown [42, 43]. This phenomenon is frequently called *'violation of temporal monotonicity*'. According to Schafer et al. temporal monotonicity means that any affect, strong or weak, always increases with time the proportion of the total affect felt – as long as the affect does not change its valence; but the conjecture of temporal monotonicity and temporal integration (graphically the area-under-the-curve on a plot of affect intensity over time) has received no empirical support [44]. Although there might be special cases, where 'temporal monotonicity' is conceivable in principle (e.g. a vacation is more restorative if it lasts longer, pathogenic noise effects will occur more likely with longer noise exposure), duration plays a minor role on summarized assessments in most cases.

3.2 The role of peak and background intensities regarding the perception of short noise sequences

The mechanisms of developing overall assessments regarding different psychoacoustic metrics have been studied based on three different within-subjects factorial designs of experiments. The role of peak and background magnitudes in overall loudness [30], overall sharpness and overall tonality within 10 s-long noise sequences were investigated. The considered noise samples were systematically varied with respect to the medium (background) and peak magnitudes of loudness (based on DIN 45631/A1 [45]), sharpness (based on DIN 45692 [46]) and tonality (based on the implementation of Kamp [47]). Exemplarily, figure 5 shows the manipulated synthetic diotic noise samples, where three peak magnitudes were factorially crossed with three background levels. The experiment was repeated several times changing the experimental conditions in order to investigate potential demand characteristics assumed to be critical in within-subjects factorial design of experiments as claimed by Ariely et al. [35].

Figure 6 displays the resulting assessments regarding overall loudness, overall sharpness, and overall tonality. It can be seen how the peak and background magnitudes of different stimuli contribute to overall assessments over the different experimental conditions. In the first experiments, only the factorially crossed signals were played back and judged on a single category scale regarding the evaluation criterion under scrutiny.

In the second series of experiments, the relevant signals were hidden in a set of 32 different synthetic and natural sounds. Finally, the experiment was repeated twice, where ratings on multiple category scales were requested.

First of all, it can be seen that the change of evaluation type (single vs. multiple) or the further obfuscation of the study aim by adding 23 sounds to the 9 systematically manipulated stimuli obviously did not lead to a substantially different assessment behavior. However, the general relevance of peak and background magnitudes changed to a certain extent with the experimental conditions. One reason is the different use of the category scale due to the presence of further stimuli expected due to the range-frequency theory [48]. Such shift of categorical ratings due to adding more samples to an experiment is generally expected, because any category rating of a stimulus depends on both its location in the range as well as its rank in the distribution of the contextual stimuli [49]. In particular, the addition of filler material to the stimuli set with noises with less distinctive characteristics led consequently to a shift and a decrease of the used range for the nine sounds of interest (see fig. 6, loudness and sharpness).

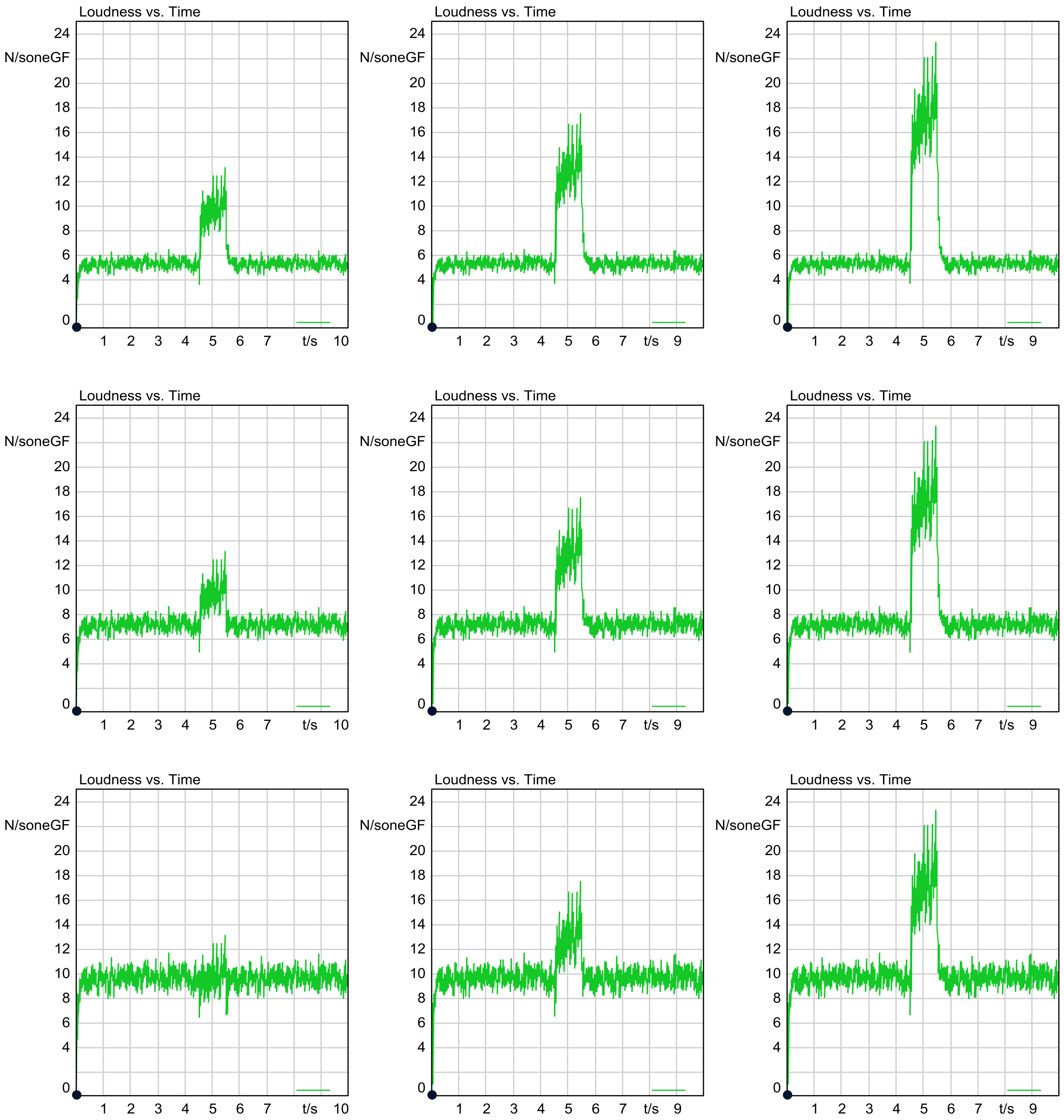

Fig. 5 – Loudness vs. time of random broad-band noises according to DIN 45631/A1. Rows display sounds of fixed background noise but varying magnitude of the middle sequence (peak magnitude 1, peak magnitude 2, peak magnitude 3). Columns show sounds of fixed peak magnitude but varying background levels (background magnitude 1 to 3).

The role of the factor *peak* and the factor *background* was studied by means of multiple two-way ANOVA tests for repeated measures design on both factors. In all cases, both factors influence highly statistically significant the assessments of overall loudness [50]. In contrast to the overall loudness assessments, the meaning of the factors peak and background changed with respect to the overall sharpness and overall tonality assessments. Whereas in all cases the background factor contributes statistically significant to the overall assessment, the factor 'peak' showed in few cases no statistically significant influence on the overall assessments. The factor peak lost its importance with increasing complexity of the evaluation task as shown in table 1. Apparently, the role of the short intensive tonal and sharp events in the middle of the sequence is less meaningful compared to short loud events with respect to the assessment of overall loudness. These observations are underlined by taking a look at the effect sizes of both factors, which are displayed in table 1.

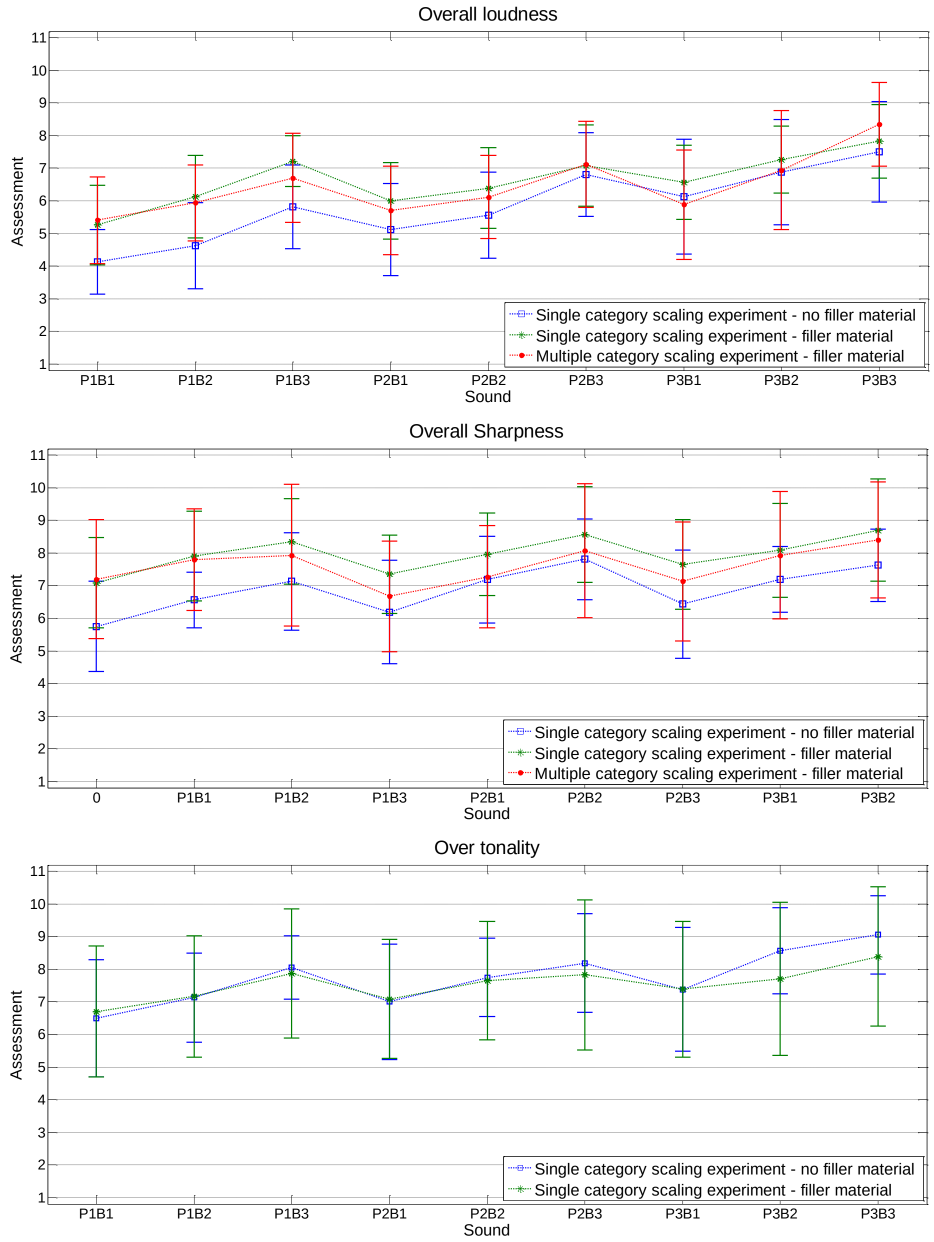

Fig. 6 – Overall assessments (arithmetic mean values and standard deviation) of sounds varying in the magnitude of peak (P1 to P3) and background (B1 to B3) with respect to overall loudness (top), overall sharpness (middle) and overall tonality (bottom) judged under different experimental conditions ((a) only sounds of interest (single category scaling experiment no filler material), (b) sounds of interest in the context of additional 23 sounds (single category scaling experiment filler material) and (c) sounds of interest in the context of additional 23 sounds and in the presence of several category scales (multiple category scaling experiment with filler material))

The observations regarding overall loudness are confirmed by other studies. For example Schlittenlacher et al. observed that the concept of an ordinal value such as N_5 is not universally acceptable and a kind of energy mean based on a loudness model LL_P provides a good measure of overall loudness, taking into account the entire loudness distribution over time [51]. This is confirmed by the experimental results presented above. However, the mechanisms of performing cognitive algebra to derive an overall assessment seem to depend on the respective context as well as on the evaluation criteria, which was observed by comparing three different psychoacoustic measures. However, it is evident that the presented results cannot simply be transferred to everyday life episodes, which usually last much longer. Thus, potential unifying principles regarding overall noise assessments observed in laboratory context must be further scrutinized with respect their ecological validity [50].

Table 1 – Effect sizes in generalized eta-squared η_g^2 for the same factors over different experiments

		Single category scaling experiment without filler sounds	**Single category scaling experiment with filler sounds**	**Multiple category scaling experiment with filler sounds**
overall loudness	peak factor	0.25	0.12	0.09
	background factor	0.18	0.21	0.20
overall sharpness	peak factor	0.04	0.01	0.01
	background factor	0.16	0.11	0.06
overall tonality	peak factor	0.09	0.01	x
	background factor	0.14	0.04	x

4. CONCLUSIONS

It is easy to understand that a fixed relation between the physical stimulus and the perception of it does not exist, because perception is quintessentially contextual. Today, it is widely accepted that mapping of physical intensity into perception and mental events cannot be considered as a merely bottom-up process. Fortunately, the tools that psychophysics has developed are eminently suited for this kind of investigation as remarked by Schneider and Parker [7].

In general, it is clearly accepted that the perception of sound is always an interplay of different senses, biased by the contextual set of stimuli presented in an experiment, influenced by memory, and dependent on the specific focus of attention individually chosen by test participants. To derive a universal theory of context seems too demanding, because a full and viable theory of context would simply mean a theory of everything [52].

According to Ariely and Carmon, the remaining challenge is to identify the specific gestalt characteristics determining human perception and to understand how these characteristics are encoded in memory and how they influence judgments and decisions [53]. A deeper understanding will increase the predictive quality of the models aiming to estimate overall noise assessments based on acoustical data, such as overall noise annoyance. For it, it is important to thoroughly investigate bias effects and understand the human mind in detail. The challenge is that a bias is not easily detected. The assertion that a cognitive bias is present is not so easy to make when there is no normative model specifying the expected response in the reference situation [54]. To know the nature and extent of biases helps to understand human perception and to check the validity of experimental results. In particular, in the context of noise annoyance further research must explore the complex relationships between stimulus, place and context influencing the perception and assessment of noise in order to predict human responses reliably. For a long time it is known that the reaction to a stimulus is not fixed and predetermined, it is an act of interpretation when it comes to annoyance and it also depends on the way people accept those who expose them to the noise [55].

6. REFERENCES

1. George A. Gescheider, "*Psychophysics. Method and Theory*", Lawrence Erlbaum Associates (1976)
2. Stanley S. Stevens, "*Psychophysics. Introduction to its perceptual, neural, and social prospects*", Wiley (1975)
3. E. Bruce Goldstein, "*Sensation and Perception*", Wadsworth Publishing Company (1989)
4. Stanley A. Gelfand, "*Hearing: An Introduction to Psychological and Physiological Acoustics*", Informa Healthcare (2010)
5. Jeffrey D. Fisher, Paul A. Bell, Andrew Baum, "*Environmental Psychology*", CBS College Publishing (1984)
6. James J. Gibson "*Wahrnehmung und Umwelt. Der ökologische Ansatz in der visuellen Wahrnehmung*", Urban & Schwarzenberg (1982)
7. Bruce A. Schneider, Scott Parker, "*The Evolution of Psychophysics: From Sensation to Cognition and Back*", In: Fechner day 2010, Proc. of Fechner day, Vol. 26 (2010)
8. Lawrence E. Marks, "*The Slippery Context Effect in Psychophysics: Intensive, Extensive and, Qualitative Continua*", Perception & Psychophysics, 51 (2), 187-198 (1992)
9. Lawrence E. Marks "*Magnitude Estimation and Sensory Matching*", Perception & Psychophysics, 43 (6), 511-525 (1988)
10. Scott Parker, Bruce A. Schneider, "*The Stimulus Range Effect: Evidence for Top-Down Control of Sensory Intensity in Audition*", Perception & Psychophysics, 56 (1), 1-11 (1994)
11. Sabine J. Schlittmeier, Jürgen Hellbrück, Maria Klatte, "*Does Irrelevant Music Cause an Irrelevant Sound Effect for Auditory Items?"* European Journal of Cognitive Psychology, 20:2, 252-271 (2008)
12. Aline Bronzaft, "*The Effect of a Noise Abatement Program on Reading Ability*", J. Environ. Psychol. 1: 215-222 (1981)
13. Bridget Shield, Julie Shield, "*The Effects of Classroom and Environmental Noise on Children's Academic Performance*", Int. Congress on Noise as a Public Health Problem (ICBEN), Foxwoods (2008)
14. Gabriel Moser, David Uzzell, "*Environmental Psychology*", In: Theodor Millon, Melvin J. Lerner (eds), Handbook of Psychology, Vol. 5: Personality and Social Psychology, John Wiley & Sons, 419 – 445 (2003)
15. Charles Korte, Rosalyn Grant, "*Traffic Noise, Environmental Awareness and Pedestrian Behaviour*", Environment and Behavior, 12(3), 408-420 (1980)
16. Lisa Lavia, Harry J. Witchel, Francesco Aletta, Jochen Steffens, André Fiebig, Jian Kang, Chris Howes, Patrick G. Healey, "*Non-participant Observation Methods for*

Soundscape Design and Urban Planning", In: Francesco Aletta, Jieling Xiao (eds.), Handbook of research on perception-driven approaches to urban assessment and design, IGI Global, 73-99 (2018)

17. Lisa Lavia, Max Dixon, Harry J. Witchel, Mike Goldsmith, "*Applied Soundscape Practices*", In: Jian Kang, Brigitte Schulte-Fortkamp (eds.), Soundscape and the built environment, CRC Press, Taylor & Francis Group (2016)
18. Francesco Aletta, Federica Lepore, Eirini Kostara-Konstantinou, Jian Kang, Arianna Astolfi, "*An Experimental Study on the Influence of Soundscapes on People's Behaviour in an Open Public Space*", Appl. Sci. 2016, 6, 276 (2016)
19. Daniel Steele, Cynthia Tarlao, Edda Bild, Catherine Guastavino, "*Evaluation of an Urban Soundscape Intervention with Music: Quantitative Results from Questionnaires*", Internoise 2016, Proc., Hamburg (2016)
20. Murray R. Schafer, "*The Soundscape: Our Sonic Environment and the Tuning of the World*", Destiny Books (1977)
21. A. Lex Brown, Truls Gjestland, Danièle Dubois, "*Acoustic Environments and Soundscapes*", In: Jian Kang, Brigitte Schulte-Fortkamp (ed.), "Soundscape and the Built Environment", CRC Press Taylor & Francis Group (2016)
22. ISO 12913-1. *Acoustics. Soundscape. Part 1: Definition and Conceptual Framework*, International Standardization Organization, Geneva, Switzerland (2014)
23. Jian Kang, Francesco Aletta, Truls Gjestland, Lex. A. Brown, Dick Botteldooren, Brigitte Schulte-Fortkamp, Peter Lercher, Irene v. Kamp, Klaus Genuit, André Fiebig, José Luis Bento Coelho, Luigi Maffei, Lisa Lavia, "*Ten Questions on the Soundscapes of the Built Environment",* Building and Environment, Vol. 108, Nov. 2016, 284-294 (2016)
24. Klaus Genuit, "*The Need for Transdisciplinary Actions – Psychoacoustics, Sound Quality, Soundscape and Environmental Noise*", Internoise 2013, Proc., Innsbruck (2013)
25. Eric I. Knudsen, "*Fundamental Components of Attention*", Annu. Rev. Neurosci. 30, 57–78, doi:10.1146/annurev.neuro.30.051606.094256 (2007)
26. Catherine Guastavino, Brian F.G. Katz, Jean-Dominique Polack, Daniel L. Levitin, Daniele Dubois, "*Ecological Validity of Soundscape Reproduction*", Acta Acustica united with Acustica, Vol. 91(2), 333-341 (2005)
27. Jürgen Hellbrück, Hugo Fastl, Barbara Keller, "*Does Meaning of Sound Influence Loudness Judgments*", ICA 2004, Proc., Kyoto, Japan (2004)
28. E. Colin Cherry, "*Some Experiments on the Recognition of Speech, with one and two Ears*", J. Acoust. Soc. Am., 25 (5), 975-979 (1953)
29. Bert de Coensel, Dick Botteldooren, "*A Model of Saliency-based Auditory Attention to Environmental Sound*", International Congress on Acoustics 2010, Proc., Sydney, Australia
30. Andre Fiebig, "*Cognitive Stimulus Integration in the Context of Auditory Sensations and Sound Perceptions*", epubli, (2015)
31. Lawrence E. Marks, Daniel Algom, "*Psychophysical Scaling*", In: Michael H. Birnbaum (eds.). Measurement, Judgment and Decision Making, Academic Press (1998)
32. Martie G. Haselton, Daniel Nettle, Paul W. Andrews, "*The Evolution of Cognitive Bias*", In: D. M. Buss (Ed.). The Handbook of Evolutionary Psychology, John Wiley & Sons Inc., Hoboken (2005)

33. Daniel Ariely, Ziv Carmon, "*Summary Assessment of Experiences: The Whole is Different from the Sum of its Parts*", In: Loewenstein, G., Read, D., Baumeister, F. (eds.) (2003). Time and decision. Economic and Psychological Perspectives on Intertemporal Choice, Russel Sage Foundation (2003)

34. Daniel Kahneman, "*Evaluation by Moments: Past and Future*", In: D. Kahneman, and A. Tversky (Eds). "Choices, Values and Frames", Cambridge University Press (2000)

35. Dan Ariely, Daniel Kahneman, George Loewenstein, "*Joint Comment on „When Does Duration Matter in Judgment and Decision Making?*" (Ariely & Loewenstein, 2000), Journal of Experimental Psychology: General, Vol. 129, No.4, 524-529 (2000)

36. ISO/TS 15666. *Acoustics. Assessment of Noise Annoyance by Means of Social and Socio-Acoustic Surveys*, International Standardization Organization, Geneva, Switzerland (2003)

37. Mark Brink, Dirk Schreckenberg, Danielle Vienneau, Christian Cajochen, Jean-Marc Wunderli, Nicole Probst-Hensch, Martin Röösli, "*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 2016, 13, 1163 (2016)

38. Hugo Fastl, "*Beurteilung und Messung der äquivalenten Dauerlautheit*", Z. f. Lärmbekämpf. 38, Springer-Verlag, 98-103 (1991)

39. ISO 532-1. *Acoustics - Methods for calculating loudness - Part 1: Zwicker method*, International Standardization Organization, Geneva, Switzerland (2017)

40. Jochen Steffens, Catherine Guastavino, "*Trend Effects in Momentary and Retrospective Soundscape Judgments*", Acta Acustica united with Acustica 101: 713-722 (2015)

41. Patrick Susini, Stephen McAdams, Bennett K. Smith, "*Loudness Asymmetries for Tones with Increasing and Decreasing Levels Using Continuous and Global Ratings*", Acta Acustica united with Acustica 93: 623-631 (2007)

42. Reimer Paulsen, "*On the Influence of the Stimulus Duration on Psychophysical Judgment of Environmental Noises Taken in the Laboratory*", Internoise 1997, Proc., Budapest (1997)

43. Charles A. Schreiber, Daniel Kahneman, "*Determinants of the Remembered Utility of Aversive Sounds*", Journal of Experimental Psychology, General, 129 (1), 27-42 (2000)

44. Thomas Schäfer, Doreen Zimmermann, Peter Sedlmeier, "*How we Remember the Emotional Intensity of Past Musical Experiences*", Front. Psychol., August 2014, doi: 10.3389/fpsyg.2014.00911 (2014).

45. DIN 45631/A1. *Calculation of loudness level and loudness from the sound spectrum - Zwicker method - Amendment 1: Calculation of the loudness of time-variant sound*, Deutsches Institut für Normung, Beuth Verlag, Berlin (2010)

46. DIN 45692. *Measurement Technique for the Simulation of the Auditory Sensation of Sharpness*, Deutsches Institut für Normung, Beuth Verlag, Berlin (2009)

47. Fabian Kamp, "*Modellierung der Wahrnehmung tonaler Geräuschkomponenten*", Aachen (2012)

48. Allen Parducci, "*Perceptual and Judgmental Relativity*", In: Viktor Sarris, Allen Parducci (eds.), Perspectives in psychological experimentation: Toward the year 2000, Lawrence Erlbaum Associates, Hillsdale, New Jersey, USA (1984)

49. Douglas H. Wedell, Allen Parducci, "*The Category Effect in Social Judgment: Experimental Ratings of Happiness*", Journal of Personality and Social Psychology, 55 (3), 341-356 (1988)

50. Andre Fiebig, Roland Sottek, "*Contribution of Peak Events to Overall Loudness*", Acta Acustica united with Acustica 101(6):1116-1129 (2015)

51. Josef Schlittenlacher, Takeo Hashimoto, Sonoko Kuwano, Seiichiro Namba, "*Overall Judgment of Loudness of Time-varying Sounds*", The Journal of the Acoustical Society of America 142(4):1841-1847 (2017)

52. Daniel Algom, Lawrence E. Marks, "*Range and Regression, Loudness Scales, and Loudness Processing: Toward a Context-Bound Psychophysics*", Journal of Experimental Psychology, Human Perception and Performance, Vol. 16, No. 4, 706-727 (1990)

53. Dan Ariely, Ziv Carmon, "*Gestalt Characteristics of Experiences: The Defining Features of Summarized Events*", J. of Behav. Dec. Making, Vol. 13, 191-201 (2000)

54. Jean Paul Caverni, Jean-Marc Fabre, Michel Gonzales, "*Introduction. Cognitive Biases: Their Contribution for Understanding Human Cognitive Processes*", In: Jean Paul Caverni, Jean-Marc Fabre, Michel Gonzales (Eds.). Cognitive Biases, Advances in psychology, 68, Elsevier Science Publisher (1990)

55. Brigitte Schulte-Fortkamp, André Fiebig, "*Soundscape Analysis in a Residential Area: An Evaluation of Noise and People's Mind*", Acta Acustica united with Acustica, Vol. 92 (6): 875-880 (2006)