Auditory-Induced Emotion: A Neglected Channel for Communication in Human-Computer Interaction

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Abstract. Interpreting and responding to affective states of a user is crucial for future intelligent systems. Until recently, the role of sound in affective responses has been frequently ignored. This article provides a brief overview of the research targeting affective reactions to everyday, ecological sounds. This research shows that the subjective interpretation and meaning that listeners attribute to sound, the spatial dimension, or the interactions with other sensory modalities, are as important as the physical properties of sound in evoking an affective response. Situation appraisal and individual differences are also discussed as factors influencing the emotional reactions to auditory stimuli. A study with heartbeat sounds exemplifies some of the introduced ideas and research methodologies, and shows the potential of sound in inducing emotional states.

Keywords: Auditory induced-emotion, sound quality, self-representation sounds, embodiment, emotional intelligence

1 Introduction

Human communication is essentially emotional: most human interactions with the surrounding environment [1] entail affective processes, a natural predisposition of our organism to feel either attraction or rejection towards the objects, people or even ideas involved in these interactions. Emotions have a great impact on human behavior, since they influence processes such as perception, attention, learning, memory or decision-making [2]. The same mechanisms are activated in individual's interaction with all forms of media [3]. Thus, an efficient human-computer interaction (HCI) is highly dependant on the ability of computer-based applications to express emotions, interpret users' affective states and understand the role of external and internal influences on affective responses [4].

The link between HCI and emotional reactions is becoming an important new research area. While relatively much research has addressed the relation between visual media content and affective reactions, research on the link between auditory form/content and emotions is an under-researched area. It is also well established that sounds evoke emotions and can provide affective information, perhaps more effectively than many other forms of information channels that are available to HCI designers and researchers [5]. In our everyday life, sound often elicits emotional reactions in the listener. People can be startled by the sudden sound of a door slamming or a thunder in a storm, annoyed by the noise of cars in the street, pleased by the sound of a water stream in the forest, tired after a full day of work in a noisy environment, etc. Nowadays, sounds are used in many HCI scenarios. For instance, auditory information/feedback in the form of earcones (abstract musical sounds) and auditory icons (a sound caricature of the intended action the user is supposed to take or has taken) are used in desktop computers and many other applications. In some systems (i.e. vehicles and working environments) sounds are used to convey different form of alerts and warnings. Today, many of these signals have to be learned through statistical association between the sound going off and an event taking place. Designing sounds that immediately convey affective information (i.e. danger) and create an affective reaction (i.e. mild fear or anxiety) also helps facilitate correct action [6].

If we consider that humans are continuously exposed to sound, both in real world and when interacting with many media applications, it seems surprising that so little is known about how users respond to affective auditory stimuli. Therefore, there is a great need for a theory, a systematic approach and a consensus for measuring human emotional responses to sound [7]. Understanding the role of sound in evoking human affective responses might improve our quality of life by helping to design spaces and media applications which are emotionally optimized.

This chapter provides some examples of the research targeting affective reactions to everyday sounds. Up to date, research in this area has been trying to connect physical sound properties and basic emotions [7]. However, it seems more meaningful to divide ongoing research on affective reactions to sounds into several main categories including: 1) physical determinants, 2) psychological determinants, 3) spatial determinants and 4) cross-modal determinants [8].

Psychological determinants concern other variables related to subjective interpretation and meaning that should be considered because different sources evoke different subjective evaluations [9] (e.g. dog barking vs. rock music). Spatial determinants deal with the role of the auditory space in creating an emotional response (for instance, the barking dog will have different emotional effects if the spatial cues would suggest that the space is small versus big). Finally, cross-modal effects concern the relation between different modalities in producing an affective reaction [10]. While much research still is needed to fully understand the different determinants of affective reactions to different categories of sounds, we highlight these four categories in the presented case study. We show how reproduction parameters and meaning of sound, apart from physical features, can affect emotional experience.

2 Research on Affective Reactions to Sound

Frequently, emotional experience has been defined as either discrete feeling states or states that can be placed along dimensions of experience [7, 11]. The discrete approach assumes the existence of a limited number of fundamental emotions [12] which are universal, survival-related, spontaneous, uncontrollable, not necessarily consciously perceived [13] and combinable to form other more complex emotions. These fundamental emotions entail psychological and physiological changes which influence our attention, cognitive appraisal, behavior, facial and/or voice expressions [14], nervous system activity [15-16], self-reported experience, etc. On the contrary, other researchers prefer to characterize emotions using a dimensional model of affect [17-18] where emotional reactions can be placed in an affective space. The two dimensions most commonly used are *hedonic valence* (*pleasantness*) and *arousal* (activation, intensity or readiness to act) [7, 19-20]. Eventually, a third dimension, *dominance or potency,* can be added to form an affective space.

2.1 Physical Determinants

Regardless of the theoretical assumptions, research on affective reactions to sound has mainly explored physical determinants. Most work in this area has been carried out by sound designers for specific applications (e.g. car industry). In this framework, it is common to talk in terms of *sound quality* referring to “the adequacy of a sound in the context of a specific technical goal or task” [21]. For many years, research on sound design for systems has focused on the affective state of *annoyance*. Annoyance correlates moderately with objective metrics such as equivalent dB(A) level for community noise, and with psychoacoustics metrics such as loudness, sharpness and roughness [22-23]. *Equal pleasantness contours* for tones varying in frequency and intensity have been developed [24]. For instance, low frequencies are preferred when intensity is below 60 dB, otherwise high frequencies are more pleasant; for 50 dB of loudness tones with frequencies between 200 and 1000 Hz are preferred [7]. It has also been argued [1, 25] that intensity of sound and arousal might be analogous, since increasing loudness results in an increase in the orienting response. This assumption holds until a level where the intensity of the sound becomes highly aversive (85-90 dBA in [1]; see also [9, 26-27]).

2.2 Psychological Determinants

Even though the physical properties of the sound undoubtedly play a big role on the affective reactions induced, research on ecological sounds, i.e. sounds surrounding us in everyday environments, has shown that other psychological factors, related to subjective interpretation, need to be considered. Ecological sounds can be divided on artificial and natural sounds. Studies with artificial sounds comprise, for instance, the experiments by Bisping [28-29] with sounds in the interior of a car, or the ones by Västfjäll et al. [7] with sounds in the interior of a commercial aircraft. These studies showed the validity of a two-dimensional space (with *pleasantness* and either *powerfulness* [28-29] or *activation* [7] as coordinates) to classify different affective reactions to artificial sound. In addition, Bisping reported that the different classifications of the engine sounds in the affective space were mainly based in the envelope of the low frequency components. Västfjäll et al. found significant correlations between affective reactions and perceptual and cognitive ratings: pleasantness correlated with loudness and naturalness of the reproduced sound, while activation was related to sharpness (high frequency components), fluctuation strength (amplitude- and frequency modulation between 15 and 300 Hz) and prominence ratio (tonal vs. noise spectra components). Their experiments also showed that pleasantness increases with loudness and audibility of tones, while activation increases with noise spectra level.

Natural sounds have been also characterized in terms of their affective quality. For instance, Björk's [30] studies placed 15 natural sounds in the valence-arousal dimensional space and Jäncke et al. [9] observed the physiological effect of environmental sounds with different valences (bird song, church bell and baby's crying). In a more ambitious project, Bradley and Lang [31] used graphical scales and psychophysiological measures to characterize the affective experience when exposed to sixty naturally acoustic stimuli. Physiological changes showed to be highly correlated with self-reported emotional reactions in terms of valence, arousal and dominance. In addition, they looked at a physical determinant, the equivalent sound level, and found almost no correlation with valence ratings (r = .07) and only a moderate one with activation ratings (r = .38). These correlations only accounted for 14 % of the variance, thus supporting the suggestion made in this chapter that emotional reactions are due to other aspects of the stimuli apart from physical properties. The set of digitized sounds used by Bradley and Lang [17], together with their normative affective ratings, served to develop the *International Affective Digitized Sounds* (IADS) for use in emotions research[1] [32].

Human speech and vocal cues are more complex acoustic stimuli which are often included in human-computer interfaces and have also been often used in emotion research (e.g. emotional speech synthesis [34]). Wexler et al. [35] designed an experiment with semantically emotional words. Emotional and neutral words were overlapped to form dichotic stimulus pairs and presented in such a way that in many cases emotional words were not consciously heard. Physiological measures (electroencephalography and facial electromyography) provided evidence that emotional processing occurred even in the cases where words did not reached conscious awareness. In another study, Hietanen et al. [36] explored how tendencies to approach or withdraw varied in response to vocal affective expressions. Results suggested that emotional expressions may be contained in vocal cues. In human social interaction, vocal cues are as important as visual cues, and human speech contains many features (melody, rate, pauses, intonation, etc.) which inform us about the speaker's affective state. It should however be noted that vocal cues often exhibit the same properties as sounds [5, 37].

A particular case of ecological sounds is *self-representation sounds* which can be associated with a person's own body (e.g. heartbeat, breathing) and its embodied activity (e.g. footsteps, chewing and smoking) [38]. These sounds increase body awareness in listeners and they might have a stronger potential for inducing an emotional experience. In [39], adding naturally breath intake sounds to synthetic speech aided listeners to recall sentences. Albers [40] describes eating as an emotional

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[1] Caution should be taken if considering to use the sounds in the IADS, since a number of these sounds are clipped, an issue addressed by the developers [33].

experience which involves *"being aware of and listening to the crunch of each bite and noise of the chewing sound in your head"*. Fast heartbeat sounds have been shown to increase self-reported arousal (e.g. [41]). In particular, body sounds such as a heartbeat may force a listener to physiologically mimic the external auditory stimulation, due both to the fundamental tendency of our organism to couple internal biophysiological rhythm to external auditory drivers, and also to additional cognitive effects (self-identification with that sound or empathy, see next section, [42] and references therein). These changes at the physiological level can affect one's emotional experience (e.g. [43-44]) or induce a particular mood state.

Finally, music has the ability both to *express* and to *produce* emotions in listeners, even though it does not have obvious implications for our life goals [45]. Its role in evoking emotions is still not understood, but music is already used in many applications which try to elicit affective responses such as film music, marketing and music therapy [46]. There are a number of studies giving evidence of emotional responses to music (for an extensive overview see [47]). In general, results of these studies indicate that judgments of musical emotions are quick, innate, hard-wired and automatic, i.e. attention does not need to be involved.

2.3 Spatial Determinants

New media applications, such as computer games, home theatre systems or virtual reality, incorporate the most advanced digital sound reproduction systems. However, there are few studies exploring the impact of sound rendering or spatial reproduction techniques on emotional responses. Lang et al. [1] measured the startle response when using auditory probes presented by means of different techniques; binaural sound or monaural sound stimulating either the left or right ear were tested. Their results showed that binaural cues have the largest startle effect. It was also found that the monaural-left ear stimulation was more effective in producing a startle effect than the right ear. The authors suggested that this finding might be due to the typically hypothesized dominance of the right-hemisphere when processing affective stimuli. Other studies have also shown a bigger sensitivity of the left ear to emotional speech and music (see [1] and references therein).

Västfjäll [48] investigated the experienced emotions and the subjective sense of presence in auditory virtual environments. Presence can be defined as the sensation of 'being there' in mediated environments such as virtual reality, simulators, cinema, television, etc. [49]. In this study, mono, stereo and six-channel loudspeaker reproductions were used. Results showed that emotion and presence were unavoidably linked, and that they both increase when improving sound spatial resolution (see also [50-52]).

Another study on this topic was done by Kallinen and Ravaja [53], who compared the loudspeaker and headphone reproduction conditions when listening to news. They hypothesized that the close sound condition (headphones) would provide a more immersive experience and shorten the interpersonal distance between the user and the news anchor, thus providing a more intense, arousing and pleasant experience. Generally, results showed that the headphone listening was preferred over loudspeakers, even being judged as ‘less realistic’ by the participants. However, no significant differences in elicited arousal were found between both conditions.

2.4 Cross-Modal Determinants

Recent studies in multisensory research have shown that information which is only available in one sensory modality is in many cases integrated and used by other sensory modalities (for a recent review see [54]). This is also true for emotional information. An example can be found in the multisensory integration of the information expressing emotions in seen faces and heard speech, where the perceived hedonic valence of stimuli in one sensory modality is altered by the valence of stimuli in other sensory modality [10]. Another study [55] showed how emotional arousal evoked by pictures depicting threatening stimuli (snakes and spiders) is transferred to the tactile modality. Similarly, results from the Bradley and Lang experiment with natural sounds described above [31] were similar to the ones obtained with pictorial stimuli what proves that affective processing and reactivity are not sensory modality specific. Future research needs to address the issue of how emotion is transferred or interact between sensory modalities.

2.5 Other Determinants

The ongoing mood can affect the responses to subsequent emotional events (situation appraisal). For instance, pre-existing cognitive processes and emotional states may influence the judgment of an auditory event [21]. Västfjäll [56] successfully showed that both current mood and individual noise sensitivity are as important as noise characteristics when judging noise annoyance. Lang et al.’s experiments [1] also show that affective responses can vary in magnitude depending on the previously induced emotional state: a reflex with the same valence than the current emotional state will be increased and inhibited otherwise.

Individual differences, such as personality traits, may also play a role in the response to sound. In studies considering factors such as speech rate, loudness and distance to sound [53], it was shown that people preferentially process auditory stimuli emotionally congruent with their personality traits. In the same way that speech can express a variety of emotional states (e.g. arousal is revealed in increased pitch, loudness and rate), and individual characteristics (e.g. fast speech can be related to extraversion), people tend to prefer voices which matches their personality traits or their current emotional state. This can be extrapolated to other audio characteristics (e.g. background music) and to media messages (see [53] and references therein).

3 Affecting Emotions Using Heartbeat Sounds

To illustrate the concepts introduced above, in this section we report on a recent study [57] carried out in our laboratory which highlights aspects corresponding to the four categories of determinants of affective reactions. The motivation of this study was found in the theory that a specifically induced physiological state can influence one's emotional responses to stimuli (e.g. [43]). We tested how the presentation of heartbeat sounds might alter participants' own heartbeat and, in turn, affect their emotional attitude to pictures. In particular, the study explored the specific effect on emotional experience of the perceived distance to heartbeat sounds. For this purpose, distant versus close sound reproduction conditions (loudspeakers versus headphones) were used. It was hypothesized that when heartbeat sounds are perceived close, it would be more likely that subjects identify them with their own heartbeat or integrate them in their own body-image (embodiment).

Twenty-four naïve participants, eighteen male (mean age 24.4; SD = 4.6) took part in the experiment. All subjects had normal hearing. They were informed that during the experiment they would be exposed to heartbeat sounds.

In each trial heart beat sounds were presented during 50 seconds, and subjects' task was to rate a photograph viewed during the last 6 seconds of the trial. Heart beat sounds could be presented at a medium or high rate (60 versus 110 beats per minute), and at close or far distance (headphones versus loudspeakers). Sound level was set at approximately 60 dBA. Silence conditions were also included as a baseline for comparisons. 34 photographs, with positive or negative valence, were selected from the International Affective Picture System (IAPS, a set of normative pictures rated in an arousal/valence/dominance dimensional affective scale [58]), according to their medium-arousal value (5 on a 9-point scale) and valence (moderate negative and positive valence – 3 and 7 respectively on a 9-point scale) and presented on a flat projection screen placed at 1.7 meters distance from participants (768x576 pixels resolution and 33°×26° field-of-view).

Participants' peripheral heartbeat signals were collected by means of a heart rate sensor attached to an earclip. Self-reported valence and arousal ratings for the pictures were collected by using the Self-Assessment manikin (SAM), a 9-point pictorial scale developed by Lang [59]. Finally, a free-recall task for the photographs shown was implemented at the end of the experiment and memory performance scores were collected.

Results showed a small but significant ($p < 0.05$) effect of sound on physiology (heart beat changes around one beat per minute after forty seconds of heartbeat sound presentation). The influence of sound was significant as observed on the emotional responses to pictures: fast heart rate made people rate pictures as more arousing, and increased memory performance, while slow heart rate showed a relaxing effect when facing negative pictures. As hypothesized, there was a stronger effect of rate for the close sound reproduction condition (headphones); the effect was observed both at the physiological level and on the self-reported arousal ratings.

In summary, the presented results give further support to the idea of the amodal character (in terms of sensory modality) of affective reactions, since here sounds affected emotional judgments of visual stimuli. They also suggest that the emotion eliciting power of auditory modality is influenced by the perceived distance, with close stimulation being more affective than distant one. Close is intimate, arousing, engaging [3]. Moreover, this study highlights the possibility of considering the affective power of self-representation sounds or other stimuli related to one's body (here body sounds). Future research needs to clarify whether the effects found can be accounted only to the distance cues or to the fact that the sound used was from the *self-representation* category. The implications of these findings for the design of media applications are discussed in the next section.

4 Conclusions

Traditionally visual domain has captured the main interest in multimedia applications. In search of pictorial realism other sensory modalities were often neglected. However, there is evidence to affirm that people are much more sensitive to audio fidelity than to visual fidelity [3]. This means that sound may compensate for visual imperfections. Therefore, audiovisual applications can be optimized by making use of audio technologies, which tend to be technically less complex than visual rendering systems. In particular, sound might be considered in the designed of affective human-computer interfaces. Sound is capable of eliciting a full range of emotions, which can vary according to factors such as the physical properties of the acoustical signal, the subjective interpretation and meaning of the sound, sound rendering techniques (the spatial dimension), situation appraisal and as a result of cross-modal interaction.

An open question in this area is the possibility for reliable predictions of the emotional response to sound. Research has shown that it is possible to separate cognitive evaluations and emotional reactions to auditory stimuli, and thus, in theory we might potentially establish a relation between sound physical properties and affective response [7]. When considering the meaning attributed to sound, this chapter provides some examples showing that both artificial and natural sounds have an affective power which is not only dependant on the physical properties. For instance, self-representation sounds like a heartbeat, breath or footsteps might facilitate self-identification with that sound (an embodied experience) and this might induce strong affective processes. In particular, this type of sounds might be used in the design of multimodal virtual environments, where research has already shown that visual cues representing one's body increase engagement [60]. In these virtual environments, self-representation sounds would form part or user's multimodal virtual body [38].

Sound spatial dimension (resolution, distance to sound) has also been mentioned as a determinant of listener's emotional arousal. Arousing or intense emotional experiences accompany engagement in media applications [61], something desired, for instance, in e-learning environments, because arousal and positive experiences facilitate memory for events and encourage users to go on with the tasks [62].

In addition, the result of using different sensory modalities in combination needs to be considered, given the amodal character of emotional processes. Future research should also consider other factors which may influence emotional reactions to auditory stimuli, such as situation appraisal and individual differences, personality traits or individual goals.

Although the present review covers only a small sample of everyday sounds, the principles considered here are likely to be virtually extended to any kind of sound perception, and therefore, to the design of any system interacting with humans. Research in human affective responses might help to improve our quality of life by contributing to design of spaces, objects and applications which are emotionally optimized. For instance, our personal everyday life can be enhanced by including affective human-computer interfaces in workplace systems, because they increase motivation and persistency of users [62-64]; in the area of health they can help in telemedicine applications [65] or in tools to fight against stress [66] or fear (e.g. of public speaking [67]); in e-learning environments, they may enhance memory [62]; and they can even be useful in telerobotics, where adding an affective value make people understand and empathize with the tasks and needs of robots [68].

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References

1. Lang, P.J., Bradley, M.M., Cuthbert, B.N.: Emotion, Attention, and the Startle reflex. Psychological Review, 97, 377-395 (1990)
2. Phelps, E.A., LeDoux, J.E.: Contributions of the Amygdala to Emotion Processing: From Animal Models to Human Behavior. Neuron, 48, 175-187 (2005)
3. Reeves, B., Nass, C.: The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places. New York: Cambridge University Press (1996)
4. Picard, R.W., Daily, S.B.: Evaluating Affective Interactions: Alternatives to Asking What Users Feel. CHI Workshop on "Evaluating Affective interfaces: Innovative Approaches". Portland, April 2005
5. Juslin, P., Västfjäll, D.: All Emotions are not Created Equal: Mechanism Underlying Musical Emotions. Behavioral Brain Sciences (in press).
6. Sköld, A., Bergman, P., Västfjäll, D., Tajadura-Jiménez, A., Larsson, P.: Emotional Reactions to Information and Warning Sounds. Acta Acustica (submitted)
7. Västfjäll, D., Kleiner, M.: Emotion in Product Sound Design. Proceedings of Journées Design Sonore, Paris, March 20-21, 2002.
8. Västfjäll, D., Tajadura-Jiménez, A., Väljamäe, A., Juslin, P.: Non-Vocal, Non-Musical Determinants of Auditory Induced Emotions (in preparation)
9. Jäncke, L., Vogt, J., Musial, F., Lutz, K., Kalveram, K.T.: Facial EMG Responses to Auditory Stimuli. International Journal of Psychophysiology, 22, 85-96 (1996).
10. De Gelder, B., Bertelson, P.: Multisensory Integration, Perception and Ecological Validity. Trends in Cognitive Sciences, 7, 460–467 (2003)
11. Levenson, R. W. Human emotions: A functional view. In P. Ekman & R. J. Davidson (Eds.), The Nature of Emotion: Fundamental Questions (pp. 123-126). New York: Oxford University Press (1994).
12. Lazarus, R.S.: Emotion and Qdaptation. New York: Oxford University Press (1991)
13. Shiv, B., Fedorikhin, A.: Heart and Mind in Conflict: Interplay of Affect and Cognition in Consumer Decision Making. Journal of Consumer Research, 26, 278-282 (1999)
14. Ekman, P., Friesen, W.V., Ancoli, S.: Facial Signs of Emotional Experience. Journal of Personality and Social Psychology, 39, 1125-1134 (1980)
15. LeDoux, J.E.: The Emotional Brain: The mysterious Underpinnings of Emotional Life. New York: Simon & Schuster (1996)
16. Levenson, R.W.: Emotion and the Autonomic Nervous System: A Prospectus for Research on Autonomic Specificity. In H. Wagner (Ed.), Social Psychology: Perspectives of Theory and Clinical Applications (pp. 17-42). London: Wiley (1988)

17. Wundt, W.: Lectures on Human and Animal Psychology (J.E. Creighton & E.B Titchener, Trans.). New York: Macmillan (1896)
18. Osgood, C., Suci, G., Tannenbaum, P.: The Measurement of Meaning. Urbana, IL: University of Illinois Press (1957)
19. Lang, P. J.: The Emotion Probe: Studies of Motivation and Attention. American Psychologist, 50, 372-385 (1995)
20. Russell, J. A.: The Circumplex Model of Affect. Journal of Personality and Social Psychology, 39, 1161-1178 (1980)
21. Blauert, J., Jekosch, U.: Sound-Quality Evaluation: A Multi-Layered Problem. Acta Acustica, 83, 747-753 (1997)
22. Guski, R.: Psychological Methods for Evaluating Sound Quality and Assessing Acoustic Information. Acta Acustica, 83, 765-774 (1997)
23. Widman, U.: Aurally Adequate Evaluation of Sounds. In Proc. of Euro Noise 98, 29-46 (1998)
24. Todd, N.: Evidence for a Behavioral Significance of Saccular Acoustic Sensitivity in Humans. Journal of the Acoustical Society of America, 110, 380-390 (2001)
25. Sokolov, E.N: Perception and the Conditioned Reflex. Pergamon Press (1963)
26. Dimberg, U.: Facial Electromyography and Emotional Reactions. Psychophysiology, 27(5), 481-94 (1990)
27. Kjellberg, A., Skoldstrom, B., Tesarz, M., Dallner, M. Facial EMG Responses to Noise. Percept Mot Skills, 79(3 Pt 1):1203-16 (1994)
28. Bisping, R.: Emotional Effect of Car Interior Sounds: Pleasantness and Power and their Relation to Acoustic Key Features. SAE paper 951284, 1203-1209 (1995)
29. Bisping, R.: Car Interior Sound Quality: Experimental Analysis by Synthesis. Acta Acustica, 83, 813-818 (1997)
30. Björk, E.A.: The Perceived Quality of Natural Sounds. Acustica, 57, 185-188 (1985)
31. Bradley, M.M., Lang, P.J.: Affective Reactions to Acoustic Stimuli. Psychophysiology, 37, 204-215 (2000)
32. Bradley, M.M., Lang, P.J.: International Affective Digitized Sounds (IADS): Stimuli, Instruction Manual and Affective Ratings (Tech. Rep. No. B-2). Gainesville, FL: The Center for Research in Psychophysiology, University of Florida (1999)
33. Owren, M-J., Bachorowski, J.A.: Measuring Emotion-Related Vocal Acoustics. In J. A. Coan & J. J. B. Allen (Eds.), The Handbook of Emotion Elicitation and Assessment. New York: Oxford University (2007)
34. Schröder, M.: Emotional Speech Synthesis: A Review. In Proceedings of Eurospeech 2001, Scandinavia (2001)
35. Wexler, B.E., Warrenburg, S., Schwartz, G.E. Janer, L.D.: EEG and EMG Responses to Emotion-Evoking Stimuli Processed Without Conscious Awareness Neuropsychologia, 30 (12), 1065-79 (1992)
36. Hietanen, J.K., Surakka, V., Linnankoski, L.: Facial Electromyographic Responses to Vocal Affect Expressions. Psychophysiology, 35, 530–536 (1998)
37. Scherer, K.R.: Acoustic Concomitants of Emotion Dimensions: Judging Affect from Synthesized Tone Sequences. In S. Weitz (Ed.), Nonverbal Communication: Readings with Commentary (pp. 249–253). New York: Oxford University Press (1974)
38. Väljamäe, A., Larsson, P., Västfjäll, D., Kleiner, M.: Sound Representing Self-Motion in Virtual Environments Enhances Linear Vection. To appear in Presence: Teleoperators and Virtual Environments.
39. Whalen, D.H., Hoequist, C.E. Sheffert, S.M.: The Effects of Breath Sounds on the Perception of Synthetic Speech. Journal of Acoustic Society of America, 97, 3147-53 (1995)
40. Albers, S.: Eating Mindfully: How to End Mindless Eating and Enjoy a Balanced Relationship with Food. New Harbinger Publications (2003)

41. Woll, S.B., McFall, M.E.: The Effects of False Feedback on Attributed Arousal and Rated Attractiveness in Female Subjects. Journal of Personality, 47, 214-229 (1979)
42. Scherer, K.R., Zentner, M.R.: Emotional Effects of Music: Production Rules. In Juslin, P.N., Sloboda, J.A. (ed.) Music and Emotion: Theory and Research. New York: Oxford University Press (2001)
43. James, W.: The Principles of Psychology. New York: Holt (1890)
44. Schachter, S., Singer, J.E.: Cognitive, Social and Physiological Determinants of Emotional State. Psychol. Review, 69, 379-99 (1962)
45. Juslin P.N., Västfjäll, D.: Lost in a Feeling? A Model that can Guide the Study of Music and Emotion (submitted)
46. Thaut, M.H.: Neuropsychological Processes in Music Perception and their Relevance in Music Therapy. In R.F. Unkeler (Ed.), Music Therapy in the Treatment of Adults with Mental disorders (pp. 3-31). New York: Schirmer books (1990)
47. Juslin, P.N., Sloboda, J.A.: Music and Emotion. Theory and Research. New York: Oxford University Press (2001)
48. Västfjäll, D.: The Subjective Sense of Presence, Emotion Recognition, and Experienced Emotions in Auditory Virtual Environments. CyberPsychology & Behavior, 6(2), 181-188 (2003)
49. Freeman, J., Avons, S.E., Pearson, D.E., Ijsselsteijn, W.A.: Effects of Sensory Information and Prior Experience on Direct Subjective Ratings of Presence. Presence: Teleoperators and Virtual Environments, 8(1), 1-13 (1999)
50. Frijda, N. H.: Emotions are Functional, Most of the Time. In Ekman, P., Davidson, R. J. (eds.): The nature of emotion (pp. 112-122). New York: Oxford University Press (1994)
51. Hendrix, C., Barfield, W.: The sense of Presence Within Auditory Virtual Environments. Presence: Teleoperators and Virtual Environments 3:290–301 (1996)
52. Larsson, P., Väjamäe, Västfjäll, D., Kleiner, M.: Auditory Induced Presence in Mediated Environments and Related Technology. In F. Biocca, W.A. IJsselsteijn, & J., Freeman, J. (eds.) Handbook of Presence. Lawrence Erlbaum (in press)
53. Kallinen K, Ravaja N.: Comparing Speakers versus Headphones in Listening to News from a Computer: Individual Differences and Psychophysiological Responses. Computers in Human Behavior 23:303-317 (2007)
54. Spence, C., Driver, J. (Eds.): Crossmodal Space and Cross-modal Attention. Oxford: Oxford University Press (2004)
55. Poliakoff, E., Miles, E., Li, X., Blanchette, I.: The effect of Visual Threat on Spatial Attention to Touch. Cognition, 102(3): 405-14 (2007)
56. Västfjäll, D.: Influences of Current Mood and Noise Sensitivity on Judgments of noise annoyance. The Journal of Psychology, 136, 357-370 (2002)
57. Tajadura-Jiménez, A., Väljamäe, A., Västfjäll, D. Self-Representation in Mediated Environments: The Experience of Emotions Modulated by Auditory-Vibrotactile Heartbeat. CyberPsychology and Behavior (in press)
58. Lang, P.J., Bradley, M.M., Cuthbert, B.N.: International Affective Picture System (IAPS): Affective Ratings of Pictures and Instruction Manual. Technical Report A-6. Univ. Florida, Gainesville, FL. (2005)
59. Lang P.J.: Behavioral Treatment and Bio-Behavioral Assessment: Computer Applications. In J.B. Sidowski, J.H. Johnson, T.A. Williams (eds.). Technology in Mental Health Care Delivery Systems (pp. 119–137). Norwood, NJ: Ablex Publishing (1980)
60. Slater, M., Usoh, M: Body Centred Interaction in Immersive Virtual Environments. In N. Magnenat Thalmann, D. Thalmann (eds.). Artificial Life and Virtual Reality (pp. 125-148). John Wiley and Sons (1994)
61. Watson, D., Tellegen,A.: Toward a Consensual Structure of Mood. Psychological Bulletin, 98: 219-235 (1985)

62. Graf, C., Niebuhr, S., Kohler, K.: Enhancing Business Software through Fun-of-Use: A Pattern-based approach. Position Paper for Workshop on The Role of Emotion in HCI 2006, 12-15 September 2006, London (2006)
63. Walkinshaw, O.: A Photo a Day: Is it Work, Rest or Play?. Position Paper for Workshop on The Role of Emotion in HCI 2006, 12-15 September 2006, London (2006).
64. Harbich, S.: Software that Motivates: Basic Needs at the Working Wnvironment. Position Paper for Workshop on The Role of Emotion in HCI, 12-15 September 2006, London.
65. Creed, C., Beale, R.: Multiple and Extended Interactions with Affective Embodied Agents. Position Paper for Workshop on The Role of Emotion in HCI 2006, 12-15 September 2006, London.
66. Millard, N., Hole, L.: In the Moodie: Using 'Affective Widgets' to Help Contact Centre Advisors Fight Stress. Position Paper for Workshop on the Role of Emotion in HCI 2006, 12-15 September 2006, London (2006)
67. Pertaub, D.P., Slater, M., Barker, C.: An Experiment on Public Speaking Anxiety in Response to Three Different Types of Virtual Audience. Presence: Teleoperators and Virtual Environments, 11:68–78 (2002)
68. Shick, A.: Duckie and Dudle: a preliminary demonstration using affective display to communicate task status. Position Paper for Workshop on the Role of Emotion in HCI 2006: Engage, 12-15 September 2006, London