EVALUATION OF PRODUCT SOUND DESIGN WITHIN THE CONTEXT OF EMOTION DESIGN AND EMOTIONAL BRANDING

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ABSTRACT

The main purpose of this thesis is to set out the relationships between the work of product designers and the perceptions of costumers regarding the acceptability of product sounds. Product design that provides aesthetic appeal, pleasure and satisfaction can greatly influence success of a product. Sound as a cognitive artifact, plays a significant role in the cognition of product interaction and in shaping its identity. This thesis will review emotion theories end their application to sound design and sound quality modeling, the measurement of emotional responses to sound, and the relationship between psycho-acoustical sound descriptions and emotions. In addition to that, affects of sounds to emotionally significant brands will be evaluated so as to examine marketing values.

One of the main purposes of chapter 2 is to prove knowledge about psychoacoustics; as product sound quality is a basic understanding of the underlying psychoacoustics phenomena. Perception; particularly sound perception and its elements are described during chapter 2. Starting with the description of sound wave and how our hear works, sound perception and auditory sensation is reviewed in continuation.

In chapter 3, product sound quality concept and its evaluation principles are reviewed. Thus, in order to understand the coupling between the acoustic perception and the product design; knowledge of general principles for product sound quality are required.

Chapter 4 can be considered as two main sections. “How does emotion act as a delighter in product design?” is examined to better understand customer and user experiences impacting pleasure-ability in first section. In the second section, emotion is evaluated through sound design. A qualitative evaluation is done so as to examine cognition and emotion in sound perception.

Chapter 5 leads subject through emotional branding. Sounds that carry the brand’s identity are evaluated within. Sound design is re-evaluated as marketing strategy and examined with several instances.

Keywords: Product sound design, psychoacoustics, product sound quality, emotion design, emotional branding.

ÖZET

Bu tezin asıl amacı, ürün seslerine ait kullanıcı algıları ile ürün tasarımcılarının işleri arasındaki ilişkiyi kurmaktır. Memnuniyet, zevk ve estetik, çekiciliği sağlayan ürün tasarımı, bir ürünün başarısını ciddi anlamda etkiler. Bilişsel özellik olarak ses, ürün etkileşiminin idrakınde ve ürün kimliğinin şekillendirilmesinde önemli rol oynar. Bu tez, psikoakustik ses tanımları ve duygular arasındaki ilişkileri, sese olan duygusal tepkilerin ölçümünü, duygu teorilerini ve bunların ses tasarımına ve ses kalitesi modellemesine uygulanmasını tekrar ele alacak. Buna ek olarak; sesin, duygusal olarak etkin markalara etkisi, pazarlama değerlerinin sınanması bağlamında değerlendirilecek.

Bölüm 2'nin temel amaçlarından bir tanesi, psikoakustik bilgiyi geliştirmektir; ki ürün ses kalitesi, psikoakustik olgunun altında yatan temel bir anlayıştır. Algı; özellikle ses algısı ve öğeleri, bölüm 2 boyunca açıklandı. Kulağımızın nasıl çalıştığı ve ses dalgasının tanımıyla başlayıp, devamında ses algısı ve işitsel duyarlılık gözden geçirildi.

Bölüm 3'te, ürün ses kalitesi kavramı ve değerlendirilme prensipleri ele alındı. Akustik algı ve ürün tasarımı arasındaki bağı anlamak için ürün ses kalitesinin genel prensipleri konusunun iyi bilinmesi gerekmektedir.

Bölüm 4, iki ana kesit olarak kabul edilebilir. Birinci kesitte, ürün tasarımında duygunun nasıl tat verici olarak rol oynadığı, kullanıcı ve müşterilerin keyif deneyimlerinin daha iyi anlaşılabilmesi için incelendi. İkinci kesitte de duygu, ses tasarımı doğrultusunda değerlendirildi. Ses ve duygu algısının kavranması için nitel bir değerlendirme yapıldı.

Bölüm 5 konuyu duygusal markalama ile sürdürdü. Ürün kimliğini taşıyan sesler değerlendirildi. Ses tasarımı, bir pazarlama stratejisi olarak tekrar değerlendirildi ve örneklerle incelendi.

Anahtar kelimeler: Ürün ses tasarımı, psikoakustik, ürün ses kalitesi, his tasarımı, duygusal markalama

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CHAPTER 1

INTRODUCTION

1.1. Definition of the Problem

How can sound feedback improve human-product interaction? Eventough, hearing and vision are two primary senses; most interfaces are today mainly visual. As vision and hearing are fundamentally different, sound is now in the process of being accorded its rightful importance as a dimension of design.

In modern society people are almost constantly surrounded by products, whether they are at home, at work, on vacation or on their way. Annoying sound of a car passing by, get tired by the constant fan noise in the office, enjoy the rumbling noise of a motorcycle in a street, be startled by the sudden noise of a door slamming, are all examples of how sound has come to ornament of existence. People are so used to and enveloped by constant sound and noise which are almost obvious-no longer appreciating sound as sound, but dismissing it as background noise to everyday lives. In the same way that an atmospheric soundtrack can add to the suspense in a horror film, the sound produced by a product can influence how people relate to it. The door of a new Mercedes for example, shuts with a velvety sound that bespeaks luxury. A cheaply made cassette player on the other hand, closes with an awkward 'clunk' reflective of its inferior quality. If sonorous presence carries such obvious influence, why has it remained consistently undervalued in industrial design? Most people agree that auditory sensations can arouse profound and deep emotional reactions. This seems surprising, since a primary goal of product sound design development is to elicit positive customer and user reactions. Following this definition *product sound design is also about emotion design.*

In order to understand this neglect, it is necessary to look to the past. History will tell that since its origins, the practice of industrial design has moved in three separate directions. The first, functionalism, concerns engineering and making products work. The second, aesthetics, concerns a product's form and appearance; and the third, human sciences, is concerned with communication and the relationship between the product and the user. In an ideal situation a 'united manifestation' of all three should occur, resulting in a well-designed product with 'a balance of social, intellectual and emotional experience. Design trends and changing societal values however, have meant that this has not always been the case. The degree of importance attached to each of these three aspects has changed considerably over time. As a result, design has more often been a strategy of form, or of function, than of satisfying the emotions.

The past few decades however, have seen the human sciences gain in importance in the design process. The emergence of a society anchored on consumerism and materialism has left many people craving a return to the more sensual things in life, namely interaction and emotional fulfillment. Designers have responded to this need by creating personalities for their products. In examining qualities such as texture, decoration and movement, designers can evoke emotional responses from the consumer that would never have been possible through the prevalence of functionalism or aestheticism. Sound can play a valuable role in providing this type of intimate interaction. While visual aesthetics are solid, sound is often momentary - lost as soon as it is gained. It is the intangibility of sound that makes it so intriguing and it is these intrigues that can make a product seem personal and precious. Sound, therefore, has emerged as a valuable entity in appealing to the needs of the modern consumer.

As emotion and “pleasure” engineering is beginning to occupy a critical role in product design, usability and cognitivity becomes more of a competitive differentiator. To understand how emotion can be captured and used as a design tool, it is necessary to understand the product sound quality, the visual quality, the tactile quality, the quality of user interfaces etc. For a product that generates sound as a part of its function, its sound quality should be evaluated in order to understand which kind of emotional reactions occurs.

When a product is first conceived as an idea, knowing what the product should sound like and making those design choices and "trade-offs" in the very beginning is what designing for Sound Quality is all about. Designing for Sound Quality is not derived from a single background rather it is an integrated blend of multiple disciplines that may be comprised of communication, psychoacoustics, acoustics, vibration, signal processing, music, psychology, physiology and experimental techniques.

The final judge of sound quality, of course, is the human ear, so any improvements of sound quality from either products or music systems must be based on a through understanding of human perception. As a consequence when verbally describing sound, people consistently use affect-laden words such as pleasant, tiring, annoying, irritating, happy and so forth. These emotional reactions to sound appear to be of importance for both evaluations and reactions.

The task of Product Sound Quality evaluation itself can have two different major aims - the evaluation of the overall Sound Quality and the evaluation of the contribution of specific components to Sound Quality. If a single component has to be evaluated, a further general problem arises - the judgments can depend on whether the subjects notice the component embedded in the total sound or not.

Just because a product may have a very low output of acoustic energy does not mean the sound will be acceptable to the end user. Overall product sound quality is achieved when the sound coming from the product is expected, pleasant or in some cases not even noticed by the user. If your designed product has a low rate of complaints from users, then most likely your product has a good sound quality design. If your product has received an unacceptable rate of complaints due to a "noisy" perception then the product is deficient in sound quality design.

In the car industry there are car lovers who recognize their car by the sound of the slamming door. This sound sometimes especially created by a multi disciplinary team of sound designers, engineers, product designers and psychologists is very characteristic for the brand it is created for. The sound enhances the values, for example sturdiness, safety, and trust that are the base of the specific brand. The car becomes a total concept from a form, touch and sound point of view.

Harley Davidson makes another clear sound statement. Although in this product the sound of the engine and components is loud and not really environmental friendly it is seen as the major selling point of the product. The sound of the bike is an essential element of the product, it creates the identity of the bike; tough, powerful, dynamic an incarnation of a wild and free life. Harley Davidson even had to patent their sound because competitors tried to copy it.

Figure 1.1. When starting up the Mac it welcomes you with a warm comforting boom.

(Source: http://www.everymac.com/images/cpu_pictures/)

In the software industry, the Apple Macintosh computer shows how sound design can contribute to giving a high quality, trustworthy brand image. When starting up the Mac it welcomes you with a warm comforting boom. A sound which gives you the feeling of entering the joyful, positive world of the Mac is easy and pleasant to use. The start sound sets the atmosphere in which you are going to work for the rest of the day.

In the food industry it is difficult trying to sell something because of its taste without being able to try it. Therefore the advertisements for food are very much focused, next to the visual image, on sound. The televisions adverts for a Dutch chips brand named Cocky focuses on the enormous crack of the chips. It sounds so extreme that it cracks your television screen. Crispy sounding chips become the embodiment of a fresh and tasty product.

Figure 1.2. The 7Up logo that indicates the "splash" sound.

(Source: Pepsi Inc. RO)

The same happens in the 7Up advertisement. The sound of opening your 7Up can changes your warm sunny environment into a cool and fresh, rainy place. The matter is just what you need on a boiling hot day.

1.2. Aims of the Study

The purpose of this thesis is to evaluate product sounds within emotional context. In order to expose the importance of the sound from a product for the perception of the overall quality of the product is the measurement and prediction of product emotions. The importance of considering affect in psychoacoustics, product sound quality and sound design by reviewing research relevant to affective reactions to everyday sounds. Concerning effects of sound and music to brand design will be mentioned so forth so as to evaluate emotional branding qualitatively.

Objectives of this thesis are;

- To evaluate the perceptive judgments of a population (annoyance, comfort, etc) so as to expose the existence of sound phenomena within product design process.
- To understand the relations between the physical characteristics of a sound and the sensations it causes.
- Identify the auditory attributes that comprise overall sound quality. (e.g. loudness, pitch, timbre)
- To review product sound quality concept in order to establish the relationship between physical characteristics of sound field and the identified individuals attributes.
- To review "measurement" methods in order to evaluate clearly of the sound qualities of the product
- Examine emotion and effect, interchangeably referring to the individual's reaction when exposed to sound
- To highlight prediction of product emotions within the context of "product sound" phenomenon

- To set out to present a comprehensive account of why and how brads be come (and can be designed to be) desirable and achieve emotional significance. And clarify sound place within
- To try to improve the knowledge of sound and music tool through emotional branding concept.

The implications for design are that emotion acts as a critical component of artifact sense-making and determines how artifacts are interpreted. Designers that understand how artifacts (aesthetic appeal, texture, sound, etc.) interchange with affective artifacts will be better able to support actual product use and perceived pleasure.

1.3. Method of the Study

Sound quality is an important factor in daily life: be it the quality of the sound from the hi-fi system, the mobile phone, the dishwasher, the hair dry or the newly acquired car. Sound can have functions from the pure enjoyment of music to signally the "well-being" of the engine in the car. In all of these situations it is the quality that is important in the contrast to the annoyance of the sound: when a sound is annoying, we want to reduce its level, where it is useful we want to increase or optimize its quality. The quest for optimal sound quality has for many years been the driving force behind the continuous improvement of system for the reproduction of music. The improved quality or need far a "tailored" sound moreover, has also become an issue for everyday utensils as we use products everyday, it affects the product identity so far. Therefore, the new fields of "sound quality evaluation" and "sound design" have emerged.

In this thesis, evaluation method is used so as to establish criteria of merit. However, the accepted definition of evaluation and other forms of research is that evaluators arrive at conclusions such as "X is a good program or has merit" whereas other researchers arrive at conclusions such as "X causes Y". This thesis helps other designers to take "sound and music" into account through product design to understand the art of accessing, with intelligence and sensitivity; the true power behind human emotions and their contribution to marketing with this evaluation.

CHAPTER 2

PRINCIPLES OF PSYCHOACOUSTICS:
WHAT IS SOUND?

2.1. Definition of Sound

Sound is the quickly varying pressure wave within a medium. It is usually meant audible sound, which is the sensation (as detected by the ear) of very small rapid changes in the air pressure above and below a static value. These pressure variances propagate as waves from a vibrating source. Changes in air pressure (air being a propagating medium) can be represented by a Waveform, which is a graphic representation of a sound, as in simple sinusoid (sine wave):

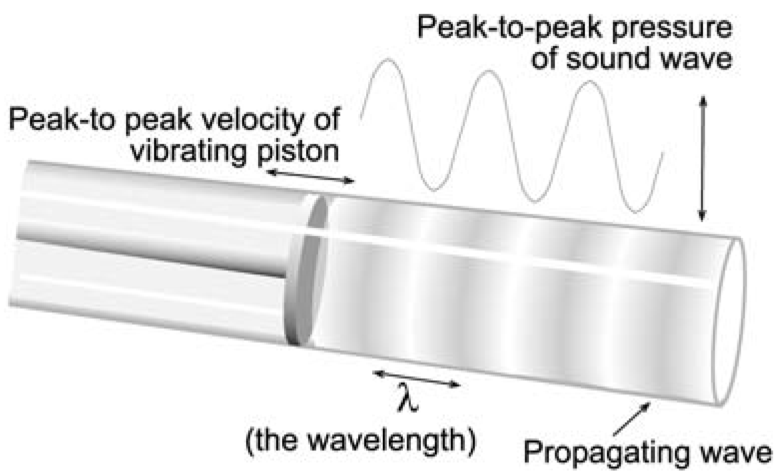

Figure 2.1. Illustrative demonstration of a sound wave

This is the strict physical definition of sound. More generally the term sound is restricted to be pressure variations which can be detected by the human ear. This "static" value is atmospheric pressure (about 100,000 Pascal’s) which does nevertheless vary slowly, as shown on a barometer. Associated with the sound pressure wave is a flow of energy. Sound is often represented diagrammatically as a sine wave, but physically sound (in air) is a longitudinal wave where the wave motion is in the direction of the movement of energy. The wave crests can be considered as the pressure maxima whilst the troughs represent the pressure minima.

How small and rapid are the changes of air pressure which cause sound? When the rapid variations in pressure occur between about 20 and 20,000 times per second (i.e. at a frequency between 20Hz and 20 kHz) sound is potentially audible even though the pressure variation can sometimes be as low as only a few tens of millionths of a Pascal. Movements of the ear drum as small as the diameter of a hydrogen atom can be audible. Louder sounds are caused by greater variation in pressure. A sound wave of one Pascal amplitude, for example, will sound quite loud, provided that most of the acoustic energy is in the mid-frequencies (1kHz - 4kHz) where the human ear is most sensitive. It is commonly accepted that the threshold of human hearing for a 1 kHz sound wave is about 20 micro-Pascal (WEB_4).

2.1.1. How do we Hear?

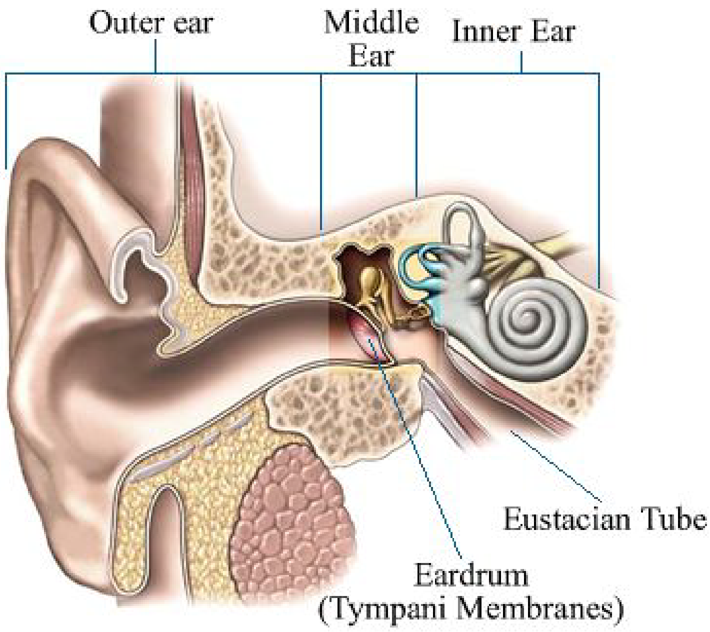

Figure 2.2. Human ear's structure.

(Source: http://www.ehealthmd.com/library/tinnitus/TIN_how.html)

The ears are on duty 24 hours a day. Unlike the eyes, the ears have no "lids" to shut out stimuli. Simply put, the ears collect vibrations from the air and change them into nerve impulses. The brain "hears" these impulses, making useful information of the pitch, volume, and timbre of the sound waves.

Steps:

1) Sound waves (vibrations) are collected by the outer ear (pinna) and channeled into the external auditory canal.

2) The sound waves travel down the external auditory canal (lined with hair and wax) to strike the circular tympanic membrane (ear drum) causing it to vibrate.

3) The tympanic membrane's vibrations are transmitted to the middle ear ossicles (stapes (stirrup), incus (anvil), and malleus (hammer)). The middle ear increases the intensity of the vibrations through these three bones which are the smallest bones in the human body.

4) The ossicles in turn transmit the vibrations to the oval window, the interface between the middle ear and cochlea (inner ear).

5) In the inner ear, the sound vibrations that were first transmitted through air and then through bone, are now transmitted in fluid called endolymph.

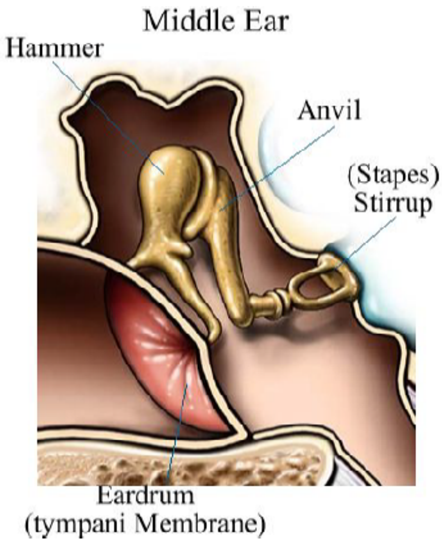

Figure 2.3. Middle Ear

(Source: http://www.ehealthmd.com/library/tinnitus/TIN_how.html)

6) The endolymph is divided into three compartments, the scala vestibuli (upper), the scala tympani (lower), and cochlear duct (middle). These three compartments are wound like a snail's shell to form the cochlea. Inside the cochlear duct are the hair cells that will convert the vibrations into neurochemical signals.

7) Each hair cell is coated with cilia – hair like projections that bend in response to particular frequencies and intensities of vibrations. As the cilia are bent by the vibrations in the endolymph, the hair cells generate a neurochemical signal.

8) The neurochemical signal is sent by the auditory nerve to the auditory cortex of the brain. The auditory cortex is located in the temporal lobes of the cerebrum.
Both ears have neural connections with both temporal lobes. It is in the temporal lobes that sound is perceived and interpreted. (WEB_5)

2.2. Sound Waves

Sound is a sensation produced when vibrations initiated in the external environment strike the tympanic membrane. The waves travel through the air at a speed of 344m/sec (775mph) at 20° C at sea level. The speed at which sound waves travel becomes faster with increased temperature and altitude. Other media also conduct sound waves, such as bone, water and other fluids, but at different velocities. For example, sound waves travel at a speed of 1428 m/sec (3215 mph) in water.

The amplitude of a wave determines loudness, whereas pitch is correlated with the frequency or number of waves per unit of time. The greater the amplitude, the louder the sound; the greater the frequency, the higher the pitch. The unit used for measuring the loudness of sound is known as a bel, a measure of air pressure changes. For convenience, 1/10 of a bel (or decibel) is normally used in describing noise levels associated with hearing. The threshold of hearing for humans is designated 0 decibels. Since the bel scale is logarithmic (and a given number of bels represents an exponent to the base 10), two bels (20 decibels) is 10 2 (100 times) louder than threshold and six bels (60 decibels) is 10 6 (one million) times louder than threshold. Normal conversation measures around 60 decibels.

Sound frequencies audible to the human ear range from 20 to 20,000 cycles/second. The threshold of hearing varies with the pitch of the sound, greatest sensitivity occur-ring between 1000 and 4000 cycles/sec. Bigger vibrations create louder sounds.

According to the Environmental Protection Agency, a person exposed to 90 dB for a quarter of an hour or more in a working day, five days a week, will suffer some hearing loss over time. It is generally considered that a noise of 140 dB would be painful to humans (WEB_6).

Table 2.1. Various activities ranked according to their decibel level.

Jet takeoff at 60 meters	120 dB	
Construction site	110 dB	DEAFENING
Shout at 1.5 meters	100 dB	
Heavy truck at 15 meters	90 dB	VERY NOISY
Urban street	80 dB	
Automobile interior	70 dB	NOISY
Normal conversation	60 dB	
Office, classroom	50 dB	MODERATE
Living room	40 dB	
Bedroom at night	30 dB	QUIET
Broadcast studio	20 dB	
Rustling leaves	10 dB	

2.3. Psychoacoustics

Psychoacoustics explains the subjective response to everything we hear. It investigates relationships between the physical properties of sounds (waveform, spectrum, level, frequency ...) and the way sounds are experienced (loudness, pitch, timbre, salience). The first stage of auditory perception involves spectral analysis in the cochlea, with specific time and frequency characteristics. Thereafter, analytical information is extracted by categorical perception, and holistic information (which can ambiguous, depending on context) is extracted by pattern recognition. In a psycho-acoustical approach, the perception of complex tones (and hence of ordinary environmental sound sources) involves the spontaneous recognition of harmonic patterns among the pitches of audible pure tone components. Consequently, the pitch of complex tones (and even of pure tones) can be ambiguous. Pitch may be measured and perceived on continuous scales (in Psychoacoustics) and categorical scales (in music); the latter case includes the recognition of both intervals (relative pitch) and notes (perfect pitch) by musicians.

2.3.1. Philosophy of Perception

2.3.1.1. Hardware and Software

Within limits, it is useful to draw an analogy between the brain and the hardware of a computer. The way we perceive, by this analogy, is like a computer program - a software package for the brain (Lilly 1974).

There is no sharp boundary between hardware and software in computing. A lot of what is called hardware is in some sense programmed to perform specific transformations on input signals. The same may be said for perception and behavior.

The software of perception develops quite differently from contemporary computer software. It is acquired ("learned") as the organism actively explores and interacts with its environment. In this respect, the brain may be said to be self-programming. The program by which it programs itself is "innate" or "instinctive". The self-programming process involves interaction of the whole organism with its various environments; it begins before birth, and continues throughout life.

Hardware and software can be remarkably independent of one another; the same computer can run completely different kinds of program (i.e. perform completely different algorithms), and the same program can be performed on completely different kinds of computer (e.g. serial versus parallel processors). Similarly, the nature of perception may be largely independent of the particular ways in which the human brain stores and processes information.

In particular, sound perception does not necessarily depend on brain physiology; (Roederer 1987) suspicion that "... 'Universal' characteristics of music are ... the result of built-in physiological or neuropsychological functions of the auditory system" probably applies only to the physiology of the ear (e.g., its frequency analyzing property). Instead, the nature of sound would appear to depend primarily on the way the auditory system, considered as a part of the interaction of the organism with its environment (Gibson 1979). Most aspects of the perception of music may be satisfactorily explained in terms of familiarity with environmental and musical sounds.

2.3.1.2. Matter, Experience and Information

A useful philosophical basis for the study of music perception is the three worlds concept of Karl Popper (Popper and Eccles 1977). World 1 is the world of matter (and energy): it comprises physical objects, states and processes, and includes musical instruments, tones, the ear and the brain. World 2 is the world of experience, or states of consciousness. It includes all aspects of musical experience - sensations of tone, harmony, rhythm, consonance and tonality, as well as the emotions evoked by a piece of music. The contents of world 3 may be variously described as symbols, descriptions, language, "objective knowledge", or simply information. World 3 include thoughts and ideas, literature, computer programs, musical scores, and music theory.

The degree to which correspondences exist between the three worlds is limited; each world is, to some extent, autonomous. The limited correspondence between worlds 1 and 3 (matter and information) is reflected by Heisenberg's uncertainty principle in quantum mechanics - a special case of the general rule that you can't measure something without in some way changing what you are measuring. The limited correspondence between worlds 2 and 3 (experience and information) is reflected by the existence of "feelings which cannot be put into words". In the case of worlds 1 and 2 (matter and experience), brain states and associated experiences are measured and expressed in fundamentally different ways, involving physical measurements (expressed in physical units) on the one hand and observers' introspective reports (expressed in natural language) on the other.

There is no clear a priori justification for the belief that all aspects of experience may someday be predictable on the basis of physiological measurements, no matter how sophisticated such measurements might become in the future. In the words of (Gibson 1979), "Perception cannot study by the so-called psychophysical experiment if that refers to physical stimuli and corresponding mental sensations. The theory of psychophysical parallelism that assumes that the dimensions of consciousness are in correspondence with the dimensions of physics and that the equations of such correspondence can be established is an expression of Cartesian dualism. Perceivers are not aware of the dimensions of physics. They are aware of the dimensions of information in the flowing array of stimulation that is relevant to their lives."

(Moore 1982) in his book aimed to specify the relationships between sounds and sensations "in terms of the underlying mechanisms", seeking to "understand how the auditory system works, at well as to look as what it does". The phrase "underlying mechanism" betrays Moore's belief in concrete relationships between stimulus and sensation at the level of brain function. In the light of Gibson's comments (above), Moore may well be asking unanswerable questions.

It is widely believed that only the physical world really exists, and that physical states and processes underlie both experience and information. This raises some thorny questions. If experiences don't really exist, for example, what is the point of funding the arts? And if information does not really exist, exactly what was it that Mozart bequeathed to humanity? A contrasting (and equally valid) view is that experience is the foundation and final arbiter of knowledge (Clifton 1983). According to this view, the existence of the physical world is just a hypothesis based on everyday experience of, and theories about, the environment. If this is the case, however, why is it that the physical world can be described and measured more precisely than the worlds of experience and information? In Popper's approach, philosophical problems such as these are avoided by regarding matter, experience and information as equally real.

Gödel’s theory in mathematics may be interpreted to imply that no theory or philosophy can explain itself: all abstract systems incorporate inconsistencies (Hofstadter 1980). Popper's three world’s concept is no exception. For example, a thought may be regarded as either a piece of information or an experience. On the other hand, all scientific research relies on some kind of paradigm (Kuhn 1962). The three worlds concept is chosen as a paradigm on which to base a theory of music perception, not because it is perfect (it isn't), but because it clarifies the multidisciplinary mosaic of sound perception research.

2.3.1.3. Perception, Sensation and Cognition

Perception is an active process by which organisms extract information from and interact with their environments (Gibson 1966). Sensation, by contrast, is passive. It involves experiencing or being aware of sensory input, without necessarily focusing on environmental objects.

In traditional psychological paradigms, perception is regarded as a two-stage process involving the sub processes sensation (as studied in psychophysics) and cognition. In the first stage, physical stimuli are "converted" into sensations. In the second stage, hypotheses about the environment are made on the basis of available sensations; the results may be called percepts of environmental objects. In the traditional approach, then, sensation is regarded as an essential prerequisite for perception.

(Gibson 1966) observed that most environmental interaction is almost entirely "automatic", occurring with little or no awareness of the analytic complexity of associated sensory patterns, cognitive processes and motor responses. This suggests that the perceptual extraction of information from the environment occurs much more directly than in the traditional two-stage model. Gibson consequently demoted sensations from their traditional status as prerequisites for perception to the more realistic status of mere byproducts of perception.

Perceptual theories may be divided into three kinds: those based on psychophysics (the interaction between worlds 1 and 2), cognition (2 and 3) and direct or ecological perception (1 and 3). In the present study, psychophysical and (to a lesser extent) direct or ecological explanations of sound perception are generally preferred to cognitive ones. Psychophysical and direct perceptual explanations have the advantage that they involve the physical world directly, and the physical world is more experimentally measurable and precisely specifiable than the worlds of experience and knowledge. Because cognitive theories relate the "subjective" worlds of experience and knowledge to each other, they lack the stability of being anchored to "objective" physical measurements.

2.3.1.4 Tone, Tone Sensation and Note

The word "tone" in this study refers to a physical entity: a periodic acoustical disturbance which can evoke pitch. A "note" is an instruction to play a tone. In addition, the term "tone sensation" is used to refer to the experience accompanying the perception of a tone.

In experimental acoustics, the basic measurement of a tone is its pressure waveform: a function of oscillatory pressure against time, recorded at some point in space by means of a microphone. The amplitude and phase spectra of a tone, obtained by Fourier (spectral) analysis of its waveform, may be used to recreate the original waveform by adding component waveforms.

Tone sensations or "sensory tones" (Terhardt 1979b) are defined to be experiences associated with the perception of tone sources, such as people speaking, musical instruments being played, and so on. Tone sensations have the attributes salience (perceptual importance), pitch, timbre, (apparent) onset time and (apparent) duration.

In music, loudness and timbre are notated separately from pitch, onset time and duration. Loudness is indicated categorically by dynamics corresponding to ordinary words such as "loud", "very soft", etc. Timbre is indicated categorically in music notation by orchestration: the names of musical instruments, and instructions for the use of mutes, special techniques, and effects such as pizzicato and flutter tonguing. The actual (experienced) loudness and timbre and corresponding physical characteristics of a tone played according to a particular musical score and on a particular instrument depend on pitch, context, player and so on.

The relationship between tones, tone sensations and notes may be regarded as a cycle of musical creation which links the performers, audiences and composers of music. Composers write instructions to performers in the form of scores. In sight-reading, the performer sees a musical note, "thinks" it, and then plays it; the result is called a tone. The performance of musical tones is controlled by a kind of feedback mechanism by which the performer hears what has been played, checks whether its sensory attributes correspond to those required by the notation, the performer's concept of the music, and expectations of a real or imagined audience, and then makes appropriate adjustments to the performance.

In the case of improvisation (e.g. in the Baroque period, and in jazz), the word "write" in the figure may be replaced by "decide". Improvisers decide which notes to play on the basis of the kinds of sounds they have just created, and the direction they wish to take in the music. Similarly, the word "note" in the figure may be interpreted as a kind of self-instruction on the part of an improviser, referring (in a rather analytical way) to decisions made and executed during improvisation.

Decisions made during musical improvisation need not be conscious, and experienced note-readers are not necessarily conscious of the individual notes of a score as it is being sight-read. The idea of unconscious decisions, regulated partly by tone sensations experienced during a musical performance, may be used to explain the kind of feedback mechanism by which both music readers and improvisers control their performances. An account of psychological aspects of music reading and improvisation is given by (Sloboda 1985).

From the physicist's point of view, tones are more important than the tone sensations which they evoke and the notes by which they are played. From the psychologist's point of view, tone sensations are basic, for without them we would never have developed the concepts of "tone" or "note". From the musician's point of view, notes are basic, because without notes no musical tones would be played and no musical tone sensations heard; even improvisers may be thought to imagine notes before playing them. These three views are internally coherent, but nonetheless limiting. It is preferable to assign tones, tone sensations and notes equal importance in an objective analysis of music perception.

2.4. Auditory Sensation

2.4.1 Loudness and Timbre

The sensory attributes of tonal sounds (i.e. simultaneities) most commonly investigated in psychoacoustics are loudness, pitch, and timbre. In the case of individual tones perceived within tonal simultaneities, one speaks in psychoacoustics of salience (sensory importance) rather than loudness. Like all psycho-acoustical parameters, the sensory attributes of tonal sounds depend on listener and context.

The loudness, pitch and timbre of an isolated tone all depend on all the corresponding physical parameters: intensity, frequency and spectral composition (as a function of time) of the tone (Fletcher 1934), so any physical change in a sound is likely to produce a change in all its sensory attributes. For example, changing frequencies of the pure tone components of a sound changes its loudness and its timbre.

Of all the sensory attributes of tonal sounds, pitch is the most important for harmony, and is dealt with in detail in later sections.

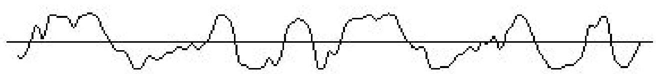

Figure 2.4. Oscilloscope scheme of Piano sound

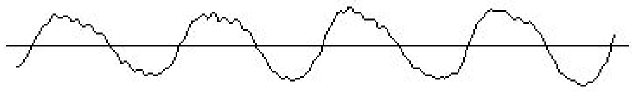

Figure 2.5. Oscilloscope scheme of Flute sound

The (subjective) loudness of a pure tone depends on its frequency as well as its sound pressure level (Fletcher and Munson 1933). The loudness of a complex tone or sound also depends on its spectral distribution. Loudness is measured in psychoacoustics by comparing the loudness of a test sound with that of a standard reference tone (American Standards Association 1960). The loudness level in phon of a sound is defined as the sound pressure level (SPL) in decibels (dB) of a (standard) 1 kHz pure tone when the sound and the standard tone are judged to be equally loud. For example, a sound which is just as loud as a pure tone of frequency 1 kHz and SPL 60 dB has a loudness level of 60 phon. Loudness level is an accurate, but not a proportional, measure of loudness. Doubling the (apparent) loudness of a sound doesn't double its loudness level, but increases it about 10 phon. The corresponding proportional scale is called simply loud-ness, and is measured in sone, such that a (test) sound of loudness n sone is judged to be n times louder than a pure tone of frequency 1 kHz and SPL 40 dB (the standard). A loudness of 1 sone corresponds to a loudness level of 40 phon, 2 sone corresponds (approximately) to 50 phon, 4 sone to 60 phon, 8 sone to 70 phon, and so on.

Timbre (tone quality) is associated with the identification of environmental sound sources (Bregman and Pinker 1978), including musical instruments (Saldanha and Corso 1964). Like vowel quality, timbre depends on the absolute frequencies and amplitudes of pure tone components. In addition, the physical characteristics of the onset of a musical tone are crucial for timbre and instrument identification. A powerful technique for the understanding of timbre is analysis-by-synthesis (Risset 1978). Like pitch (tonality) and loudness (dynamics), timbre can be used to delineate musical forms in contemporary styles (McAdams and Saariaho 1985).

Timbre is multidimensional (Wedin and Goude 1972). It may be quantified on various sensory scales such as "brightness" and "richness", and studied by multidimensional scaling of similarity ratings. Sensory dimensions of timbre which are important for the theory of harmony are roughness, associated with beating between pure tone components, and tonalness, the degree to which a sound has the sensory properties of a single complex tone such as a speech vowel (Terhardt 1983). Bad musical intonation (tuning) causes roughness to increase and tonalness to decrease; this explains the finding of (Madsen and Geringer 1981) that deliberate mistuning in flute, oboe duets is often misinterpreted by listeners as bad tone production on the part of the performers.

2.4.2. Spectral Analysis

According to Fourier's theorem in mathematics, any waveform of finite duration (not necessarily periodic) may be expressed as a sum of component waveforms which are sinusoidal over the same duration. In acoustical terms, this means that any sound may be expressed as a sum of pure tone components. Note that these components are not directly measurable, so - strictly - they do not exist as physical entities. Instead, they are found by subjecting the waveform of a sound to a mathematical procedure: spectral analysis.

The relationship between sound input to the ear and the information conveyed to the brain is essentially the same as the relationship between a sound and its pure tone components. In this sense, the ear subjects incoming sounds to spectral analysis (Ohm 1843, Terhardt 1985). This may be regarded as an early stage in the extraction of information from sound, in order to enable and facilitate interaction with the environment.

The cochlea is a bony, snail-like hollow in the petrous bone. The basilar membrane, which it houses, may be regarded as the receptor surface of the peripheral auditory nervous system. The basilar membrane is tapered: broad at one end and narrow at the other. When a pure tone is detected, waves travel along the membrane, reaching maximum amplitude at a point depending on the frequency of the tone. This spectral information is maintained in the peripheral nervous system (Evans 1975).The importance of place on the basilar membrane in determining the pitch of pure tone sensations is supported by work with the partially deaf. Damage to part of the basilar membrane can cause deafness in a corresponding frequency range, and electrodes implanted at different places in the auditory nerve of a deaf person produce tone sensations of different pitch (Simmons et al. 1965). However, some experimental pitch data cannot be accounted for by place alone: it appears that both place information (e.g.

which parts of the basilar membrane experience maximum displacement) and temporal information (e.g. the rate at which a particular part of the membrane oscillates) contribute to the pitch of pure tone components (Moore 1982). For example, below about 50 Hz, the position of maximum amplitude is independent of frequency. In this region, the pitch of a pure tone may depend on the rate of neuron firing in the auditory nerve. In any case, Ohm's acoustical law, as described above, holds regardless of how the complex motion of the basilar membrane is translated into the pitch of pure tone components.

Like any spectral analysis system, the ear has limited frequency resolution. Simultaneous pure tone components must differ in frequency by a certain minimum amount before they can be resolved (or discriminated). Such minimum frequency differences are determined by the effective time constants (i.e. effective durations of the analysis interval) of the ear, which vary as a function of frequency (Terhardt 1985). Simultaneous pure tones must be at least 1.0-1.5 semitones apart (considerably more than this at low frequencies) to be resolved, i.e. to produce distinct tone sensations.

The ear is not a perfect spectrum analyzer. Under certain spectral conditions, single pure tones of high sound level can produce harmonic distortion, and simultaneous pure tones can produce combination tones.

The output of the ear's spectral analysis is influenced mainly by that part of the incoming waveform immediately preceding the time of observation; earlier and earlier parts of the waveform influence perception less and less. An appropriate mathematical procedure for modeling this kind of spectral analysis is the Fourier-t-transform (or FTT), in which sound waveforms are multiplied by an exponential decay function, and spectral analysis is subsequently performed on a window extending from negative infinity to the present. In psycho-acoustical applications, the variable amplitude and frequency dependencies of the FTT may be adjusted to fit those of the auditory system (Terhardt 1985). When this is done, only audible pure tone components are output by the procedure, i.e. masking is automatically accounted for.

The masked threshold (or audiogram) of a pure tone is a graph of the sound pressure level (SPL) of a second, simultaneous, barely audible pure tone, as a function of its frequency (Wegel and Lane 1924). It is roughly triangular in shape, peaking at the frequency and amplitude of the first tone: the closer the second tone lies to the first in frequency, the more it is masked, so the higher its SPL needs to be before it can be heard. For pure tones above about 500 Hz (C5), the gradient of the lower-frequency side of the masked threshold is constant at roughly 9 dB per semitone.

As a rule, a change can be heard in a sound if part of its masked threshold undergoes a vertical shift of 0.5- 1.0 dB (Zwicker 1970). This implies that a change can be heard in a pure tone if it is shifted in frequency by 0.06-0.12 semitone. Difference thresholds of frequency as low as 0.02 semitone for the best listeners under ideal conditions (Fastl and Hesse 1984) may be due to the added role of temporal information in pitch perception. Alternatively, they may be explicable in terms of musical experience: small pitch changes are more important in music than small loudness changes, and discrimination improves with practice.

2.4.3. Sensory Memory

Sensory memory is spontaneous memory, i.e. memory in the absence of attention, noticing, categorization, abstraction, semantic processing, etc. In a sense, this is not memory at all - it is a kind of spontaneous decay characteristic of the sensory system for which "memory" is the conventional psychological metaphor. To measure the duration of sensory memory it is necessary to ensure that a stimulus remains unnoticed for a specified time after its real-time occurrence.

The duration of visual sensory memory is about 0.1 -0.2 s. Decay times in this range are also characteristic of forward masking effects (masking between sequential sounds) in psychoacoustics (Moore 1982). Auditory sensory memory, otherwise known as echoic memory (Neisser 1967) or precategorical acoustic storage (Crowder and Morton 1969) lasts much longer than both visual sensory memory and acoustical masking effects. (Eriksen and Johnson 1964) estimated its duration at 10s. Later researchers reported lower values such as 5 s (Glucksberg and Cowen 1970) and 2s (Crowder 1970), suggesting that Eriksen and Johnson's experiment was influenced by ordinary, non-sensory memory.

Sensory memory linkage may be regarded as an essential prerequisite for the spontaneous perception of pitch relationships between sequential sounds (pitch commonality and proximity). This is no problem in music, as the chords that make up chord progressions are normally much less than 2 s apart. In experiments to investigate pitch relationships, the pairs of sounds presented in each trial followed each other at time intervals much shorter than 2 s. On the other hand, the time intervals between different trials in the experiments generally exceeded 2 s, so that sensory interference between trials was unlikely to affect results.

The duration of auditory memory increases considerably if sounds are noticed as they occur in real time. Sensory material persists longer in memory the more it is "processed through semantic levels", i.e. the higher it is abstracted in a perceptual hierarchy.

Memory for a particular sound is disrupted by intervening sounds (Massaro 1978, Dewar et al. 1977, Olsen and Hanson 1977). Duration of memory for tones in an unfamiliar musical context tends to fall as the apparent rate of sensory information in that context increases. These effects are neglected in the present study, which is mainly concerned with sensory auditory memory in the absence of interference.

2.5. Extraction of Information

2.5.1. Noticing and Salience

To notice something is to become aware or conscious of it. This often involves assigning a verbal label to it. There is a large grey area between "noticed" and "unnoticed", in which objects and stimuli influence experience and environmental interaction, but are not necessarily assigned verbal labels.

In this section, the salience of an environmental object or stimulus is defined quantitatively as the probability that it will be noticed. In other words, the salience of the corresponding percept or sensation is its probability of occurring. If a sensation or percept already exists, then its salience may be regarded as a measure of its apparent importance or strength. For example, a chord may evoke several tone sensations, but some may sound more important than others.

The pure tone components of a complex tone are seldom directly noticed, yet each contributes to the perception of the tone as a whole. The degree to which each contributes depends on its salience. Similarly, the degree to which (unnoticed) tone components contribute to the strength of sequential pitch relationships depends on their salience.

Relatively salient tone sensations in a musical chord normally correspond to actual tones, and are recognized as such by musicians. Tone sensations with low salience do not normally correspond to actual tones, but to implied or harmonically related pitches such as the root of a chord in inversion.

2.5.2. Categorical Perception

Categorical perception refers to the division of a perceptual continuum into labeled categories, specified by their centers and widths, or by the positions of their boundaries. Categorical perception may be regarded as the most elementary or analytical way of extracting information from a perceptual continuum.

The concept of categorical perception was originally developed to explain phoneme boundaries in speech sounds. Perceptual discrimination is normally easier across category boundaries. In other words, stimuli are more likely to be judged as "different" if they fall into different perceptual categories. A familiar example of categorical perception is the perception of color. Electromagnetic radiation in particular frequency bands evokes particular colors. The band of frequencies corresponding to a particular color (red, orange, yellow, etc.) corresponds to a perceptual category.

The position of the boundary between two neighboring perceptual categories is always somewhat vague or flexible. In a rainbow, for example, one cannot see exactly where "red" stops and "orange" begins. The position of the boundary between two categories also depends on the observer and on the context in which a stimulus is presented. For example, the color aqua will sometimes be called blue, sometimes green, depending on observer and background color.

The positions of category boundaries may be either innate or learned. Boundaries between colors appear to be primarily innate (due to the physiology of the eye). Boundaries between speech phonemes appear to be primarily learned by exposure to speech: adults' discrimination at phoneme boundaries is sharper than infants' (Eimas et al. 1971). Similarly, the musical interval discrimination functions of musicians are sharper than those of untrained listeners, implying that boundaries between musical scale degrees are also learned. Innate forms of categorical perception are universal. For example, primary color labels have similar or identical meanings in different languages.

Learned forms, such as the categorical perception of speech vowels and musical intervals, are culture-specific.

The width of a perceptual category generally exceeds one difference threshold (or just noticeable difference, or difference limen). For example, optical frequencies which can be distinguished in only 50% of experimental trials may be regarded as one difference threshold apart; in ordinary perception, such frequencies normally fall in the same category, i.e. they have the same color.

2.5.3. Holistic Perception and Pattern Recognition

Holistic (synthetic, global) perception is the perception of whole objects or scenes. It involves the direct extraction of high-level information from the environment. By contrast, analytic perception occurs only when a specific object or stimulus, or part thereof, is attended to. How holistically or analytically an even will be perceived depends on the observer (Zenatti 1985) and on the context of the event.

Both percepts and sensations may be either holistic or analytic. An analytic sensation is defined to be the experience accompanying the "sensing", with an analytic attitude, of a stimulus. Holistic sensations are generally more meaningful than analytic sensations. They are also more likely to be linked to environmental objects, in which case they become "holistic percepts".

Holistic perception normally occurs quite spontaneously, with little or no apparent effort on the part of the observer. This is readily explained in the direct perceptual approach of (Gibson 1966), according to which holistic sensations are merely experiences accompanying the direct perception of whole objects. Analytic perception requires an "analytic attitude", and can be quite difficult, even though the information being sought is more closely related to the information output by the sense organs than that sought in holistic perception. For example, it is quite difficult to hear out the harmonics of a complex tone.

Traditional psychophysics tends to regard analytic sensations as more fundamental than holistic sensations. This is because psychophysics is concerned with the relationship between sensations and the stimuli (such as light and sound patterns) which evoke them. This relationship is held to be mediated first by the physical-physiological transducing properties of the sense organs, and secondly by perceptual grouping processes, by which analytic sensations corresponding to physiological output of the sense organs are grouped by stages into holistic sensations.

General principles of perceptual grouping were described by (Wertheimer 1923). The principles cover the grouping of both simultaneous and sequential events in music, i.e. both chords and melodies.

If the same sensation occurs at different times, the two events may be perceived to be related (and therefore to be likely candidates for perceptual grouping) due to their identity. Different stimuli are perceived as identical if their difference is not perceived, i.e. if they are close enough to be assigned to the same perceptual category.

Sensations in different categories may be grouped by proximity if they are close on some psychophysical scale. Visual sensations are grouped if corresponding regions of excitation are nearby on the retina. For example, a dotted or broken line is perceived as such because the dots or line segments making it up are close to each other. Stars which in three dimensions are relatively far from each other are nevertheless perceived as constellations because corresponding points on the retina are close to each other. Spontaneous grouping of auditory sensations by proximity is called streaming.

Grouping of sensations by familiarity is called pattern recognition. Familiar patterns of sensations correspond to regularities or invariance's in the environment (Gibson 1966). Pattern recognition normally occurs quite spontaneously, with no conscious effort by the observer. The recognition of familiar patterns is an essential ingredient in the interaction of an organism with its various environments.

Instinctive behavior in animals and humans is evidence that some aspects of pattern recognition are innate. However, most perceptual patterns become familiar by spontaneous learning and exploration in early life, implying that most aspects of pattern recognition are acquired. Later in life, pattern recognition processes become increasingly resistant to change: new perceptual patterns become increasingly difficult to learn and recognize.

Patterns may be recognized if they are incomplete, or if extra components are included. For example, a written word may still be recognized if some letters are added or taken away (i.e. if it is misspelled); the more letters are added or deleted, the less likely it is that the original word will be recognized. Melodies may be recognized if appropriate pitches are heard at appropriate times, in spite of missing or added notes: a melody whose notes are interleaved with distracter notes can still be recognized (Dowling et al. 1987).

The recognition of incomplete or superposed patterns may be modeled by template matching. A template (or prototype) is an idealized representation of the perceptually relevant features of a familiar pattern of sensations. Pattern recognition may be regarded as a process whereby matches are sought between the components of a template and configurations of sensations occurring in real time. The more components of the real-time configuration match those of the template, the more likely it is that the corresponding pattern will be recognized. Note that pattern recognition templates exist only as parts of perceptual models; they have no actual physiological correlates in the peripheral or central nervous system.

The classification of perceptual grouping criteria into identity, proximity and familiarity is not always clear cut. Familiar patterns are identical to or close to previously experienced patterns, and there is no sharp dividing line between identical and proximate sensations, due to the flexibility of perceptual categories.

2.5.4. Ambiguity, Multiplicity and Context

A stimulus is ambiguous if it may be interpreted in two or more different ways. Consider again the example of a misspelled word. The more letters are added or taken away from the original word, the more ambiguous the interpretation of the word becomes - unless, of course, a new word is formed with a new, unambiguous meaning. In the template approach to pattern recognition, a stimulus pattern is ambiguous if it may be matched by a number of different templates or by the same template in a number of different ways.

Perceptual ambiguity is normally associated with holistic perception, in which a perceptual event can have only one meaning at a time. In analytical perception, an event is analyzed into a number of simultaneous percepts: the event exhibits perceptual multiplicity. In the case of a written word, for example, the reader's attention can switch from holistic to analytical perception, resulting in awareness of individual letters.

The same stimulus may be ambiguous or multiple or both, depending on its context. A single word on a blank page (e.g. "can") is ambiguous - it has several possible meanings. It is also multiple in the sense that one's attention is focused on the individual letters of the word. In context (e.g. "I drank a can of beer after work"), both ambiguity and multiplicity are reduced. Similarly, the pitch of a single complex tone in isolation may correspond to the pitch of its first or second harmonic (or both, or a number of other possibilities), but in the context of a melody the pitch rarely differs from that of the fundamental.

By reducing ambiguity, context facilitates comprehension. Letters are easier to read in words than they are in isolation, and words are easier to read in grammatical than in non-grammatical phrases (Cattell 1886). Similarly, musical notes are easier to read in more "grammatical" tonal contexts (Sloboda 1976).

Ambiguity is relatively unusual in perception and language. In ordinary settings, perceptual patterns are over specified: much of the information in the patterns is redundant (Garner 1970). In natural language, ambiguity is normally avoided, for obvious reasons. In music, however, ambiguity plays an important role, maintaining interest and generating multiple expectations (Thomson 1983). From this point of view, it is inappropriate to describe music as a language. If music is a language, it is more similar to poetry than to prose.

Pure and complex tone sensations, like all tone sensations, also have the attributes timbre and salience. This fact is hard to express using the terms spectral and virtual pitch. To refer to the timbre or salience of a spectral or virtual pitch is to refer to an attribute of an attribute. It is more logical to speak instead of the timbre or the salience of a (pure or complex) tone sensation.

A complex tone, in the proposed terminology, may evoke several different pure tone sensations (corresponding to its audible harmonics) and several different complex tone sensations (corresponding to implied fundamentals of different groups of harmonics). However, a (pure or complex) tone sensation is in all cases a single entity in the experience of the listener, with just one pitch, one timbre and one salience.

2.6. Tone Sensation

2.6.1. Terminology

(Pipping 1895) distinguished between two kinds of pitch: the pitch of an individual pure tone component, such as a harmonic of a complex tone (which he called "tone pitch") and the overall pitch of a complex tone, corresponding to the fundamental frequency ("clang pitch"). Pipping thought that clang pitch was due to nonlinear

distortion in the form of difference tones. (Schouten 1940) observed that a complex tone appears to have two sensory components at the pitch of the fundamental, "one of which, having a pure tone-quality is identical with the fundamental tone, whereas the other, having a sharp tone quality and great loudness, is of different origin". Schouten called this additional subjective component the residue, hypothesizing that its pitch corresponded to the periodicity of upper, unresolved components of the complex tone.
(Terhardt 1974a) made the same distinction as Pipping and Schouten, but used different terms and a different explanation for the two kinds of pitch. He proposed that virtual (clang/residue) pitch was formed by the spontaneous recognition of the familiar pattern of spectral (tone) pitches of a complex tone. The term virtual pitch added to a whole array of names for clang/residue pitch which had come into use in the meantime, among them fundamental pitch, periodicity pitch, and low pitch.

According to the American Standards Association (1960), there is only one kind of pitch: "Pitch is that attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from low to high". This definition states that pitch is an attribute of auditory sensation - not a sensation in itself. The definition implies that there may be different kinds of sensation which have pitch, but there is only one kind of pitch. It is therefore appropriate in the above discussion to refer to two kinds of tone sensation rather than two kinds of pitch.

For this purpose, I have coined the terms pure tone sensation and complex tone sensation, as they refer directly to the types of tone which normally produce the two kinds of tone sensation. Spectral pitch may be defined using this terminology as the pitch of a pure tone sensation; virtual pitch, as the pitch of a complex tone sensation.

2.6.2. Pure Tone Sensations

Pure tone sensations are single sensations normally evoked by pure tones or pure tone components. They may also be produced by noise, because noise can evoke pitch. Narrower bands of noise are more tone-like or "tonal" than wider bands.

Figure 2.6. Psychoacoustics test in an anechoic chamber.

(Source: http://www.acoustics.salford.ac.uk/research/arc/cox/sound_quality/)

Complex tones are overwhelmingly heard as single wholes. The hearing out of pure tone components requires an unusually analytical listening attitude. Consequently, most people are unaware that this is possible. As hearing out of pure tone components is rarely necessary in musical performance, even musicians do not always develop the skill. For example, Rameau developed his theory of the basse fondamentale by experimenting with a Pythagorean monochord, and only afterwards learned that the harmonics of a tone could be individually heard (Christensen 1987).

Interestingly, Rameau believed that octave multiples of the fundamental frequency (the second, fourth, eighth, harmonics) were inaudible in ordinary complex tones. Stumpf expose that the second and fourth harmonics were harder to hear out than the third and fifth. This effect has not been backed up by experimental data. Perhaps it is due to musical conditioning, via octave equivalence. In any case, the effect is neither expected nor explained on the basis of (Terhardt's 1974a) pitch theory.

The configuration of pure tone sensations in a sound may be represented by a graph of salience (perceptual importance) against time, called the spectral pitch pattern. This may be regarded as the ultimate basis for the sensory attributes (pitch, timbre, salience, etc.) of complex tone sensations (Stoll 1982). The spectral pitch pattern may be modeled as a continuous function of time by Fourier time transform (Terhardt 1985, Heinbach 1986). The recognition of patterns (and hence sound sources) among the contours of the spectral pitches in the pattern is remarkably analogous to the recognition of visual objects from the contours of their edges and boundaries (Gibson 1979).

The salience of a pure tone component (and hence of a pure tone sensation) may be defined as its probability of being noticed, or the degree to which it contributes to the perception of complex tones. It depends on audibility (level above masked threshold) and, to a lesser extent, on frequency. It also depends on context. For example, pure tone components are easier to hear, and therefore more salient, if they move relative to each other (Brink 1982) this indicates that they do not come from the same source (e.g. they are unlikely to be harmonics of the same fundamental (McAdams 1984)).

The exact pitches of pure tone components within a complex sound depend not only on frequency but also on level and masking (Terhardt 1979a, Hesse 1987). Variations of pitch with masking and changes of level are called pitch shifts. The pitch of a low-frequency pure tone falls slightly as its level is increased. For example, the pitch of the electric bass of a rock band can sound sharp relative to the rest of the music when the music is damped to barely audible level by walls and/or distance. Two simultaneous pure tones which partially mask each other have the effect of pushing each other apart in pitch by a small (but perceptible) amount. The effect of masking on pitch is seldom noticeable, as the pure tones concerned are normally perceived as components of complex tones, and the pitch of a complex tone is affected relatively little by masking (Stoll 1985).

2.6.3. Complex Tone Sensations

Complex tone sensations are generally associated with percepts (or "auditory images" (McAdams 1984)) of complex tones, such as people talking, and musical instruments being played. Most tone sensations in music and in everyday sounds are of the complex kind.

With respect to pure tone sensations, complex tone sensations are holistic: they are associated with the grouping or "fusion" of pure tone sensations. Complex tone sensations may themselves combine to form other sensations such as chord and melody sensations in music. With respect to such higher order sensations, complex tone sensations are analytical.

A complex tone may be perceived as a whole even if its fundamental is missing, i.e. if it is a residue tone. (Schouten 1940) theorized that the pitch of a residue tone depends on the periodicity of irresolvable higher frequency components - the "residue".

This inspired decades of psycho-acoustical research into the detection of periodicity among spectral components of complex tones (Moore 1982). Periodicity was supposed to be detected in time intervals between peaks in the fine structure of the waveform of a sound, and coded as synchronies (phase-locking) in neural firing patterns.

Figure 2.7. The sound localization facility at Wright Patterson Air Force Base in Dayton, Ohio, is a geodesic sphere, nearly 5 m in diameter, housing an array of 277 loudspeakers. Each speaker has a dedicated power amplifier, and the switching logic allows the simultaneous use of as many as 15 sources. The array is enclosed in a 6 m cubical anechoic room: Foam wedges 1.2 m long on the walls of the room make the room strongly absorbing for wavelengths longer than 5 m, or frequencies above 70 Hz. Listeners in localization experiments indicate perceived source directions by placing an electromagnetic stylus on a small globe.

The periodicity model explains the spectral pitch of low-frequency pure tones, and the residue pitch produced by (apparently) irresolvable high harmonies. However, the model has some serious drawbacks. The underlying assumption that a direct correspondence exists between experience and brain; states or processes are unscientific or at best premature. No physiological or anatomical evidence has been found for an appropriate time measuring mechanism. And as yet no one has been able to establish a model based on periodicity which makes sensible predictions concerning the pitch properties of complex sounds in the general way that the model of (Terhardt et al. 1982b) does according to (Terhardt 1974a), the (virtual) pitch of a complex tone results from the recognition of a harmonic pattern among the (spectral) pitches of its resolvable (i.e. audible) pure tone components. Terhardt's model differs from the others in that it is based on familiarity with the pitch pattern produced by ordinary complex tones. In Terhardt's version of pitch pattern recognition, the physiology of the perception of pure tones - in particular, whether their pitch is determined by place or time information on the basilar membrane - is not relevant. The basic data of the model are in no sense the "temporal patterns of firing in different groups of auditory neurons", as suggested by (Moore 1982). The pattern recognition part of the model is concerned with the functional relationship between two sets of experiential, not physical parameters: the (spectral) pitches and audibilities of the pure tone components of a sound, and the (virtual) pitches and salience's of the complex tone sensations it evokes.

Why does the pitch of a complex tone correspond to the lowest component of the pattern (the fundamental) rather than some other component? A possible reason is that the pitch of the fundamental corresponds to the period of the complex tone's waveform (Rasch and Plomp 1982). According to the pattern recognition model, however, the auditory system is not sensitive to the period of the waveform as a whole; temporal patterns are reflected by the roughness of a tone, not its pitch. Another possible reason is that the fundamental is normally the most audible (or salient) of the harmonics of a typical complex tone: it is only masked from one side, and from a considerable pitch distance (an octave), whereas the other harmonics are masked from both sides, and at smaller intervals (Terhardt 1979a). (Note that the fundamental does not necessarily have the highest sound pressure level, SPL. Often, a higher harmonic has the highest SPL, e.g. if it falls in the centre of a speech vowel formant.) However, the audibility of the fundamental differs from that of the other components only by degree. Perhaps the unique property which distinguishes the lowest component from the others is simply that it is the lowest. The harmonic number of the highest audible component of a typical complex tone varies over a wide range - say, from about 5 to 15 - but the harmonic number of the lowest audible component is almost always one.

The recognition of harmonic patterns among spectral pitches may be modeled by means of a harmonic template incorporating the salient features of the spectral pitch pattern of a typical complex tone (Cohen 1984). The pitch distances between the components of the template are slightly stretched relative to a harmonic series of frequencies, due to pitch shifts (Terhardt 1979a). The dependence of virtual pitches on spectral pitches (Houtsma and Rossing 1987) may be modeled by shifting the template across the pitch range and looking for matches between template components and real-time spectral pitches. The pitch of modeled complex tone sensations corresponds to that of the lowest template component; their salience, to how many spectral pitches match template components and how closely they match. Salience depends also on the context of other (pure and complex) tone sensations. Optimal fit is more important in the spectral pitch dominance region between about 300 and 2000 Hz (Terhardt et al. 1982b) than in higher or lower regions. So the virtual pitch of a complex tone does not necessarily correspond exactly to the spectral pitch of its fundamental, especially if the spectrum of the tone is slightly inharmonic. The template approach may be used to explain why and how, and to estimate to what extent, complex tones exhibit pitch shifts (Terhardt and Grubert 1987).

The recognition of harmonic pitch patterns in ordinary complex tones is universal. A remarkably analogous cultural aspect of tone perception is the assignment of tones in a musical context to particular steps of a diatonic scale, i.e. the recognition of diatonic pitch patterns. (Jordan and Shepard 1987) studied this by presenting listeners with major scales whose intervals had been uniformly stretched (so that the octave was noticeably larger than normal) or equalized (to produce 7-tone equal temperament). The resultant shifts in the pitches of other scale steps (notably the tonic) could be explained by postulating a rigid diatonic template (or tonal schema) consisting of scale steps separated by the familiar intervals of the major scale.

Harmonic and diatonic pitch pattern recognition are similar in the following ways. Features of the pattern-recognition template are acquired by experience of regularly recurring pitch patterns; pitch intervals between template elements remain the same in spite of irregularities in input stimuli; modeling involves finding the best fit between the template and some configuration of pitches heard in real time (Moore et al. 1985); pitch ambiguity effects (of both complex tone sensations and tonics) may be explained in terms of alternative template fits; and pitch shift effects (again, of both complex tone sensations and tonics) may be accounted for in terms of the lining up of template components. In both cases, it should be emphasized that the template is no more than part of a model and has no physiological reality.

The musical pitch of tone sensations becomes difficult to judge above a frequency of 4-5 kHz. Proponents of the periodicity approach to pitch perception believe this is due to uncertainty in the time at which nerve impulses begin, which prevents phase-locking above 4-5 kHz (Rose et al. 1967). Proponents of the pattern-recognition approach point out that speech harmonics rarely have audible harmonics above 4-5 kHz (e.g. the eighth harmonic of 500 Hz) and so the auditory system is not familiar with harmonic pitch patterns in this region (Terhardt 1979a). Whatever the reason, pure tone sensations above 4-5 kHz (i.e. above the top end of the modern piano) practically never play a harmonic role in music. The tones of the top two octaves of the piano are normally heard not as complex but as pure tone sensations, corresponding to their fundamental pure tone components; the second and higher harmonics of these tones contribute to timbre, but not to pitch.

A clear complex tone sensation may be evoked by three successive harmonics not including the fundamental. The complex tone sensation evoked by two such harmonics is weaker, but can still be heard under suitable conditions (Houtsma 1979). There is even evidence for the existence of sub harmonic complex tone sensations of single pure tone sensations (Houtgast 1976).

2.6.4. Melodic Streaming

A complex tone sensation may be regarded as a grouping of pure tone sensations resulting from the spontaneous recognition of a familiar, harmonic pattern. A melodic stream is another kind of perceptual grouping, either of pure or of complex tone sensations, due to proximity in one or more tonal attributes (loudness, pitch, timbre, duration) or in time.

Streaming of pure tone sensations due to proximity in pitch and time occurs both for adults and for infants (Demany 1982). A directly analogous effect occurs in vision: a pair of lights switched on and off in alternation in a dark room look like a single, moving light, provided they are close enough and they alternate fast enough (Kubovy 1981).

Complex tones, when perceived as wholes, may stream if they are similar in timbre (Bregman and Pinker 1978, Wessel 1979). In orchestration, woodwind parts blend better if they are "dovetailed" (e.g. if one oboe plays higher than the first clarinet and one lower) as this inhibits streaming by timbre. In ambiguous cases, a tradeoff occurs between streaming of pure tone sensations by pitch and of complex tone sensations by timbre, depending on the relative saliences of the tone sensations.

Two or three auditory streams may be heard simultaneously, but it is difficult to attend to more than one (Bregman and Campbell 1971). It is difficult to separate streams that cross over in pitch: interleaved melodies, in which the tones of two different melodies alternate merge into a single, unrecognizable sequence if the melodies overlap in pitch (Dowling 1973). However, the interleaved melodies are easier to recognize if they are already familiar.

Streaming is affected by timing and source direction. Simultaneous sounds are easier to discriminate (i.e. to segregate into different streams) if their onset times are not quite the same, as is usually the case in musical performance. Sounds from similar directions stream (e.g. the "cocktail party effect", stereo reproduction of orchestral music). Perception of the direction of a sound source is assisted by head movements and vision (Gibson 1966).

Sound sources (e.g. musical instruments against an orchestral texture) may often be identified by coherent variation of physical characteristics such as amplitude and frequency of harmonics (McAdams 1984) otherwise known as vibrato. Vibrato makes it easier to follow a particular voice against to contrapuntal background. In Romantic opera, for example, vibrato enables solo voices to penetrate loud (or thick) orchestral textures. However, vibrato also inhibits blending of voices. This may explain why less vibrato was used in Baroque opera, where harmonizing was more important, and the music less passionate (Galliver 1969). The blending of vibrato voices is improved if the vibrato is synchronized (e.g. in string quartets).

Like complex tone perception, melodic streaming may be regarded as consequence of familiarity with the auditory environment. In general, sounds stream if they appear to come from the same source. Such sounds are often close in tonal attributes (loudness, pitch, timbre) and in time and direction, but not always. For example, the timbre of the clarinet differs markedly between its registers, but this does not necessarily inhibit the streaming of clarinet tones in music.

Sounds from different sources can stream, if it appears that they could have originated from the same source. In musical hocket the notes of a melody are played alternately on different instruments or sung by different voices. Because the timbre of the instruments or voices varies relatively little, the result sounds like a single melody. Examples are to be found in some African and Indonesian music's and, in the West, in medieval music (including Gregorian chant) and among the compositions of Western (Dalglish 1978, Erickson 1982).

When two tones of different pitch and loudness alternate in legato (i.e. with no silent gap between them), the quiet tone may be perceived to remain sounding through the loud tone even though it is physically absent. This is an example of the effect called closure by the Gestalt psychologists. In this example, closure occurs only if the louder tone would have completely masked the quieter tone had the quieter tone actually been present. Intelligibility of speech in a noisy environment is enhanced by the effect of closure. Like other streaming effects, this effect arises from familiarization with the audible world. It differs from other streaming effects in that it is determined not solely by regularities of the auditory environment but to a large extent by physiological limitations of the ear (i.e. masking). In other words, it is determined by the nature of the interaction between the organism and its environment.

After considering the available experimental evidence on streaming, (Sloboda 1985) concluded that "pitch streaming is a real 'pre-musical' phenomenon, although musical knowledge may interact with and modify its effects." Streaming may thus be regarded as a sensory basis for melodic perception, and so for the theory of counterpoint (Wright 1986). Just as melodic streaming occurs when sounds are somehow close in their sensory attributes, melodic continuity and unity are enhanced in musical performance by maintaining a relatively constant dynamic (loudness); and in composition, melodic continuity and unity are maintained by the use of small pitch and time intervals, and by maintaining a particular orchestration. In mainstream music theory and practice, wide leaps are avoided in melodies and in the voices making up a harmonic progression; when wide leaps do occur, their disruptive effect is reduced by resolving the second note by stepwise movement in the direction of the first note.

2.7. Pitch Perception

2.7.1. Dimensionality

The generally accepted definition of pitch implies that it is a one-dimensional sensory continuum. The psychological reality of such a continuum is apparent from such elementary perceptual skills as the ability to identify the higher of two pure tones (an ability which is shared by infants (Trehub 1987)) and the ability to estimate the magnitude of the pitch distance between two pure tones (Stevens et al. 1937).

Musical pitch may be described as multidimensional; its two main dimensions being pitch height (as in the one-dimensional model) and tone chroma (Shepard 1982).

This may be concluded from multidimensional scaling solutions of experimental results on the similarity or relative height of complex tones. However, such experimental results depend on the spectra of the tones presented to listeners (Ueda and Ohgushi 1987). It would seem more straightforward to describe the pitch of complex tones (including octave-spaced tones) as ambiguous relative to a one-dimensional pitch continuum (Terhardt 1974a, 1979b). This clarifies the distinction between sensory and cultural effects in musical pitch perception, especially the perception of octave equivalence, and makes it unnecessary to postulate the existence of "cognitive structures" in order to account for experimental results.

2.7.2. Continuous Pitch Scales

(Fletcher 1934) proposed measuring the pitch of a sound in terms of the frequency of a pure reference tone of constant loudness, whose pitch is judged to be the same as that of the sound. This measure of pitch, which may be called equivalent frequency, was also used by (Terhardt 1974a). Terhardt's method was identical to that of Fletcher, except that he held the sound pressure level of the pure tone constant instead of its loudness. This procedure is analogous to that for measuring loudness level, in which the frequency of a pure reference tone is held constant (at 1 kHz) and its SPL is varied; loudness level could be called "equivalent SPL".

Equivalent frequency and equivalent SPL are not proportional scales: doubling equivalent frequency does not necessarily make a sound seem twice as high, nor does doubling equivalent SPL make a sound seem twice as loud. (Stevens et al. 1937) developed a proportional pitch scale (analogous to loudness in some) called the met scale, in which equal scalar intervals (measured in met) corresponded to equal apparent interval sizes (Stevens and Volkmann 1940). The mel scale is roughly proportional to the logarithm of frequency above about 1 kHz, and approaches a linear relationship with frequency at low frequencies. Like loudness in sone, pitch in mel is quite imprecise; it is unsuitable for measuring small pitch effects such as pitch shifts.

The mel scale is an appropriate measure of pitch only when pure tones are heard in a non-musical context by musically untrained listeners. For example, (Attneave and Olsen 1971) found the scale to be inappropriate for the musical task of melodic transposition. Moreover, the mel scale, as originally defined by (Stevens et al. 1937),

only applies to the apparent size of intervals between pure tones of equal loudness, not equal SPL as in the experiments of (Elmasian and Birnbaum 1984).
Pitch in mel may be scaled by the rule that equal sensory intervals contain roughly equal numbers of difference thresholds. The difference threshold of frequency depends considerably on the listener, both for pure tones (Fastl and Hesse 1984) and complex tones (Meyer 1979). On average, the difference threshold of frequency for sequential pure tones is around 0.05 semitones in the region above 500 Hz (cf. 1.0-1.5 semitones for simultaneous pure tones). At lower frequencies, it is about 1 Hz (Fastl and Hesse 1984).

The difference threshold of frequency for complex tones is about the same as that for pure tones, with the exception that it retains its lowest (high-frequency) value (about 0.05 semitones) right down to about 100 Hz, or G2, the bottom line of the bass clef. This may be understood in terms of spectral pitch dominance. The pitch of a complex tone of fundamental frequency 100-400 Hz normally depends only on the pitches of the 3rd, 4th and 5th harmonics. Complex tones with fundamental frequencies lower than about 100 Hz no longer have dominant harmonics above 500 Hz.

So the pitch difference threshold for a complex tone, measured in semitones, increases as its frequency falls below 100 Hz, i.e. as the frequencies of its dominant harmonics fall below 500 Hz.

Above 100 Hz, the apparent size of melodic intervals is proportional to their size in semitones. The log frequency or frequency level scale is therefore appropriate for the pitch of complex tones across almost all of the musical range. Only when melodies are transposed into the deep bass (below the bass clef) do melodic intervals sound smaller than normal.

2.7.3. Categorical Pitch Perception

The diatonic scales (major and minor) are familiar to members of Western culture, musicians and non-musicians alike. Also familiar are the non-scale notes which occur in diatonic music. In other words, the entire chromatic scale is familiar, provided a certain subset of that scale (the diatonic scale) is emphasized. Consequently, a pitch interval of random size is perceived by musicians to belong to a particular semitone category (m2, M2, m3, etc.) (Siegel and Siegel 1977 a, b). Similarly, a complex tone of random frequency, presented in a tonal musical context, is perceived as belonging to a particular scale step.

The perceptual categorization of musical pitches and intervals may be regarded as a prerequisite for the understanding of pitch relationships and structures. Categorization reduces the amount of information carried by the pitches of a passage of music to a manageable level, removing information about the precise tuning of a pitch or interval, and retaining only its semitone category. Even under ideal listening conditions, mistunings of 0.1-0.3 semitones (depending on the interval) are acceptable (Moran and Pratt 1926, Vos 1982, Hall and Hess 1984); even larger variations are acceptible in musical performances. Perceptible out-of-tuneness does not necessarily affect musical meaning and function. For example, an out of tune subdominant chord still has a subdomi-nant function within its key context, provided, of course, that it is not so out of tune that it is perceived as another chord. Mistuning is more disturbing for more salient pitches, e.g. those of a melody as opposed to its accompaniment (Rasch 1985).

The categorical perception of musical pitch begins when the auditory system "decides" whether a particular audible harmonic belongs to a complex tone (Moore et al. 1985), (Terhardt et al. 1982b) accounted for this decision-making process by assigning a "harmonicity" value to the interval between an audible component of a complex tone and its fundamental. In their model, calculated harmonicity falls gradually to zero when an interval is mistuned by 8% in frequency, or a little over a semitone. The harmonicity of the interval between a tone component and an assumed fundamental may be regarded as a measure of the probability that the component will be perceived as belonging to a complex tone with that fundamental.

In well-tuned Western harmonic progressions, the frequencies of audible pure tone components are close enough to equal temperament that all spectral pitches may be unambiguously assigned to degrees of the chromatic scale. The further models take advantage of this by defining all pitches and intervals (including intervals between harmonics and fundamentals) relative to the pitch categories of the chromatic scale. This simplifies the above decision-making procedure: the probability that a particular tone component is perceived as belonging to a particular complex tone in the model is effectively either 100% or zero. Categorization of pitch is also appropriate for modeling pitch commonality and pitch distance. Pitch commonality is concerned with sequential tone sensations in the same pitch category; pitch distance, with sequential tone sensations in different pitch categories.

2.7.4. Perfect Pitch

Everyone has absolute pitch in that they can discriminate male and female adult voices by their pitch alone (e.g. on the telephone). This kind of absolute pitch has an uncertainty or category-width of, say, three to six semitones. Like other aspects of absolute pitch, it is based on experience. Experiments with infants (Clarkson and Clifton 1985) suggest that the minimum uncertainty of "universal" absolute pitch is probably about three semitones. The fact that this is about the same as the width of a critical band in the most important range of pitch is probably coincidental: critical bandwidth is only important for simultaneous tones, whereas absolute pitch applies to isolated tones.

In music, the pitch continuum is divided up into absolute pitch categories much smaller than those of speech, corresponding to steps of the chromatic scale. Normally, only the performer of a piece of music is aware of the names of these categories ("F", "Ab", etc.). Therefore, only musicians are in a position to develop that kind of absolute pitch, called perfect pitch, in which pitch is identified absolutely in semitone categories. Perfect pitch is normally acquired in childhood. With sufficient practice, it can also be acquired later in life.

There are many theoretical approaches to the origins and nature of perfect pitch (Heyde 1987). They mostly concentrate on perfect pitch in Western music. However, Western music is more highly developed regarding relative pitch (i.e. harmony) than absolute pitch. It may therefore be fruitful to look at perfect pitch (i.e. absolute pitch identification with accuracy of a semitone or less) in musical cultures where harmony is less important. For example, unaccompanied melodies in Australian aboriginal music are sung in different places and at different times at the same frequencies, with an uncertainty of less than a semitone.

A surprising thing about perfect pitch is that so few musicians develop the ability, considering that absolute identification of stimulus properties is normal in the other senses. The reason why so few Western musicians have perfect pitch may be due in part to a conflict between the spontaneity of absolute pitch judgments and the analytical attitude to pitch required of the Western musician. The verbalization of musical note names requires quite an analytical attitude, perhaps because there are so many notes to distinguish between. In spite of this, perfect pitch often occurs quite spontaneously, in the following ways. Folk and ethnic music's in which a kind of perfect pitch is in evidence tends to be performed in a more spontaneous manner than Western art music. Perfect pitch is aided by other, relatively spontaneous experiences such as strong emotive associations (Ellis 1985), chromesthesia or "color hearing" (Rogers 1987), and the realization that a familiar passage of music is being played in the right or the wrong key (Terhardt and Seewann 1983).

Composers who identify familiar musical tones (e.g. piano tones) with great reliability are not so good at identifying the pitches of pure tones (Lockhead and Byrd 1981), suggesting that timbre plays an important role in perfect pitch. Absolute timbre perception and absolute pitch perception are hard to separate; this may be regarded as an example of the general fuzziness of the distinction between pitch and timbre.

In a "direct perception" approach (Gibson 1966), absolute pitch involves the identification of sound sources according to their pitch. This explains the spontaneity of absolute pitch judgments. Further, since sound sources which differ in pitch (e.g. different piano strings) also differ in timbre; it also explains why timbre sometimes interferes with absolute pitch judgments.

(Terhardt's 1974 a) approach to pitch perception yields new insights into perfect pitch. According to Terhardt, musical tones exhibit octave ambiguity (the octave position of the pitch of an isolated complex tone is somewhat uncertain) and pitch shifts (the pitch of a complex tone is slightly different from that of pure tone of the same frequency). As perfect pitch possessors "memorize" the sensory properties of musical tones, they inevitably "memorize" the tones' octave ambiguity and pitch shifts, and these properties inevitably affect absolute pitch judgments. This readily explains the octave and semitone errors found by (Balzano 1984) in experiments on the absolute pitch of pure tones.

As a result of psychoacoustic research, a set of psychoacoustic indices has been developed which allow for an instrumental prediction of attributes of sound perception. These indices offer a powerful tool for the assessment, evaluation, and improvement of sound. In order to understand "product sound quality" concept, it's essential to utilize those psycho-acoustical indices.

CHAPTER 3

ENHANCING PRODUCT SOUND: PRODUCT SOUND QUALITY

3.1. Introduction to Sound Quality

In modern society people are almost constantly surrounded by products, whether they are at home, at work, on vacation, or on their way. One essential determinant of "quality of life" is the noise or the sound produced by these ubiquitous sound sources. A product that rattles, rumbles, or screeches unpleasantly has a very different effect than one that puts out the various signals and sounds that the user expects.

Quality of life is based on a range of values, which are expressed as basic needs that must be fulfilled for a person to experience a high quality of life. (Fog 1999) Increased interest in product sound is not only due to the psychometrics of product sound perception or the mechanical design, but also to the fact that it is only during the last few years it has been realized the importance of product sound to the user assessment and satisfaction and hence also to the market acceptance of the products. There is a rubbing-off effect from marketing of one type of product to marketing of a completely different type. As product sound has more and more become a sales factor as far as cars are concerned, this has been transferred to a large number of other products, first and foremost on the consumer market and especially regarding every conceivable “electrical product”, as e.g. vacuum cleaners, dishwashers, hair dryers, small fans, audio products, etc., etc.

Thus, manufacturers wanting to keep their market position have on most markets gradually been forced to be sensitive as to how their customers feel and are affected by the sounds from the products.

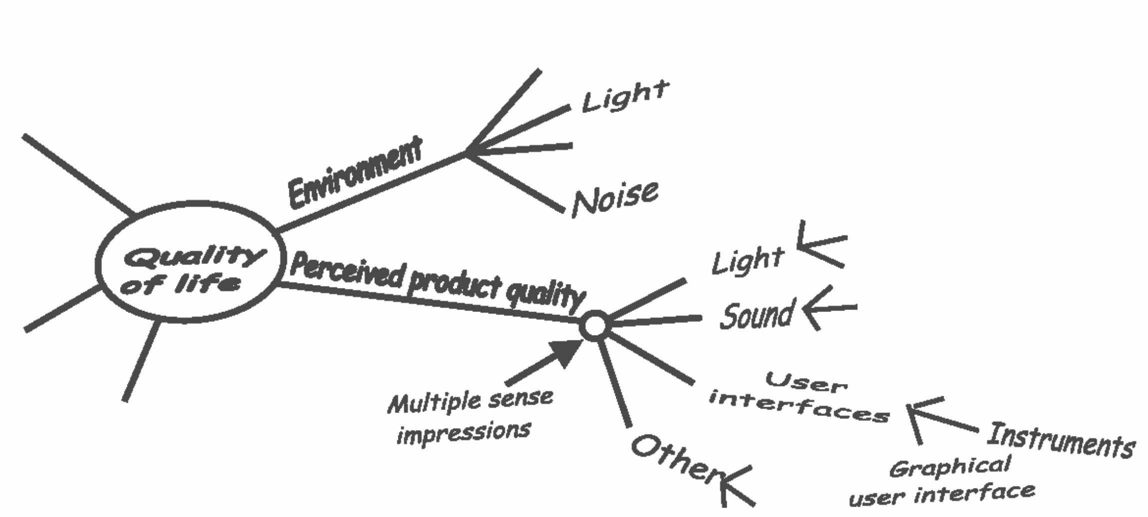

Figure 3.1. Perceived product quality - one element of quality of life

(Source: Fog and Pedersen 1999)

How the quality of a product is perceived by users and other observers in the vicinity of the product depends of course on a number of product attributes such as appearance, response to user activities, function, noise/sound, weight, smell, taste/flavor, and tactile characteristics. Even it is told about the sound quality, the visual quality, the tactile quality, the quality of user interfaces, etc., See Figure 3.1.

Product sound optimization is a method for making "optimal product development" in a broad sense (Bernsen 1999). It contains disciplines within perception psychology, psychoacoustics, and acoustics especially in relation to mechanical design.

The overall objective in the product development is to utilize future consumers' attitudes, expectations, and preferences so that the sound from a product becomes a positive attribute to the user instead of an annoying problem.(Blauert and Jekosch 1996) As all hearing persons can perceive acoustic quality and thus can be said to be experts, there is a need for good acoustic design and development. Totally, this represents a special opportunity to make sure that the product has the desired success with the users.

3.2. Measurements Involving Human Subjects

Until now two mainstreams have directed acoustic measurements involving human subjects: Psychoacoustics on one hand where any kind of bias from the subjects' expectations, mood, preferences, etc., is avoided or minimized and consumer surveys on the other hand where mainly preferences are sought. (Stone and Sidel 1993). In the field of **product sound quality** a basic understanding of the underlying psychoacoustics phenomena – also for rather complex signals – is essential. But in contrast to the pure psychoacoustics research the influence of stimuli from other senses and influence from the listening panel's preferences are not regarded as unwanted bias.

Figure 3.2. gives a simple illustration of the concepts.(Fog 1998) With technical measuring devices, from Input to "Filter 1" is measured at the (point 1). With the instruments, finest details could be measured, but without knowing if they are relevant for the perception and preferences. The input to "Filter 2" may be measured by psychoacoustic methods and is an objective measurement. By carefully planning and performing the tests, we can obtain reproducible results. From this kind of measurements it can be understood which details can be heard. The measurements at point 3 are purely subjective. The measurements show what a certain group of people will hear and what they will prefer. The result will depend on the selected group.

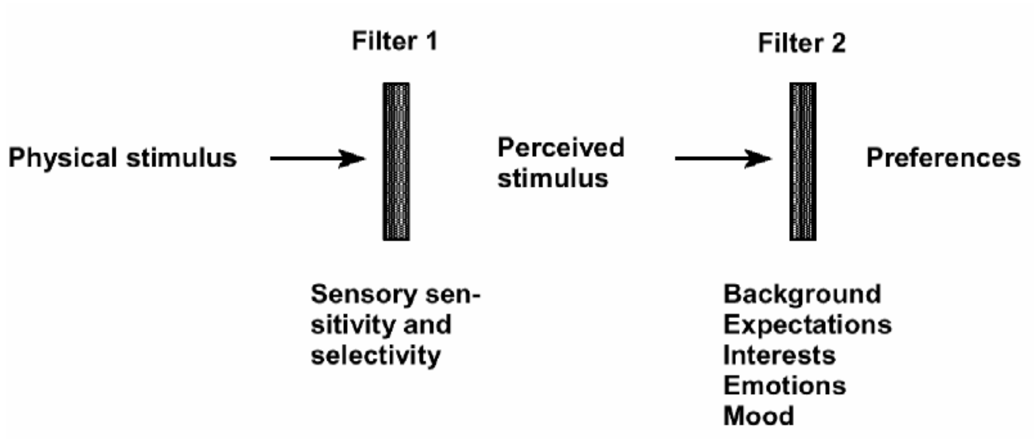

Figure 3.2. From stimuli to preferences

In designing and developing new methods involving human subjects a clarification of these phenomena is essential for assessing the product sound quality. The same goes for evaluating the annoyance of noise.

Before defining sound wheel, It should be pointed for the time being with a project addressing the below four phenomena of human perception of sound:

1) Perception directly related to the physics of the sound.

How to establish a simple correlation – for instance a loudness value – between the physics and the perception (measurement point 2) which can be measured with sound analysis equipment.

2) Perception of complicated phenomena of the sound, common to humans. Needs measurements based on human subjects and cannot be measured with instruments

3) Multimodal perception

- Other senses as moderators of the sound perception or combined stimuli (part of filter one)

4) Perception influenced by mental processing

- This is the output of the preferences at measurement point 3.

3.3. Definition Product Sound Quality

Product sound can be thought of as a kind of symbolic language that varies with culture, context, and a variety of other factors. Furthermore, it has a tendency to change over time, partly because of technical advancements, but also because of changing tastes and fashions. This means that the task of optimizing product sound is a highly iterative process.

Product Sound is defined as the perceived sound from a product.

The term Product Sound Quality refers to the adequacy of the sound from a product. This is evaluated on the basis of the totality of the sound's auditory characteristics; with reference to the set of desirable product features that are apparent in the user's cognitive and emotional situation.

Product Sound, Product Sound Quality, and Sound Quality are often used indiscriminately to refer to a variety of related qualities. Term Product Sound is chosen to use as defined above to emphasize the characteristic of the product. This is different from "sound quality" or other terms that refer to the performance of speakers, telephones, amplifiers, and other products that are specifically built to reproduce sound.

It has also been defined the following categories of Product Sound:

Passive Sounds are the sounds that are produced when the product is touched (knocked, pressed, etc.).(Fog 1999)

In contrast, Active Sounds are put out by the product itself. These active sounds can be further categorized as Running/Operating Sounds, Action Sounds, and Signal Sounds.

These terms are best illustrated by an example using a washing machine:
The machine generates a Running/Operating Sound when it is in a given part of its cycle (wash, spin, rinse, etc.). The sounds may vary with the different stages of the cycle, and they may be continuous, stationary, or irregular.

When switching from the wash stage to the spin stage, the machine generates an Action Sound that has to do with its inner workings and is not intended as a direct signal of anything. (Pedersen and Fog 1998).This kind of sound can be continuous or impulsive, but is not generally stationary over long periods of time.

A washing machine puts out a humming sound at the end of the cycle. The primary purpose of this sound is to indicate that the machine is finished, and therefore the humming is a Signal Sound.

3.3.1. Sound in Design: The Product Sound Wheel

The outer path in the Product Sound Wheel describes the fundamental process of optimizing the Product Sound Quality. First, alternative sounds from a product, simulated sounds, or sounds from similar products are presented to a test panel. The panel gives their response either in answering forms prepared for statistical computations or directly, e.g. by setting sliders or pressing buttons. The same sounds are measured by analyzers, software, etc., and a number of metrics for each sound is the result. The metrics may be any relevant traditional noise measure or may be more psycho-acoustically related as loudness, sharpness, fluctuation, strength, roughness, etc., or any combination of these.

By graphical or statistical methods the connections and correlations between the two kinds of measurements are sought, and usually it is possible to describe the preferred sound by objective metrics. (Pedersen and Fog 1998) By analysis of the physical characteristics of the sound-generating mechanisms, the necessary design changes to obtain the defined values of the metrics may be implemented. Tools for “sound tailoring”, sound editing, and simulation exist, and the lower inner path is often an attractive shortcut to test different versions of possible sounds for further analysis or subjective tests. (Fog and Pedersen 1999)

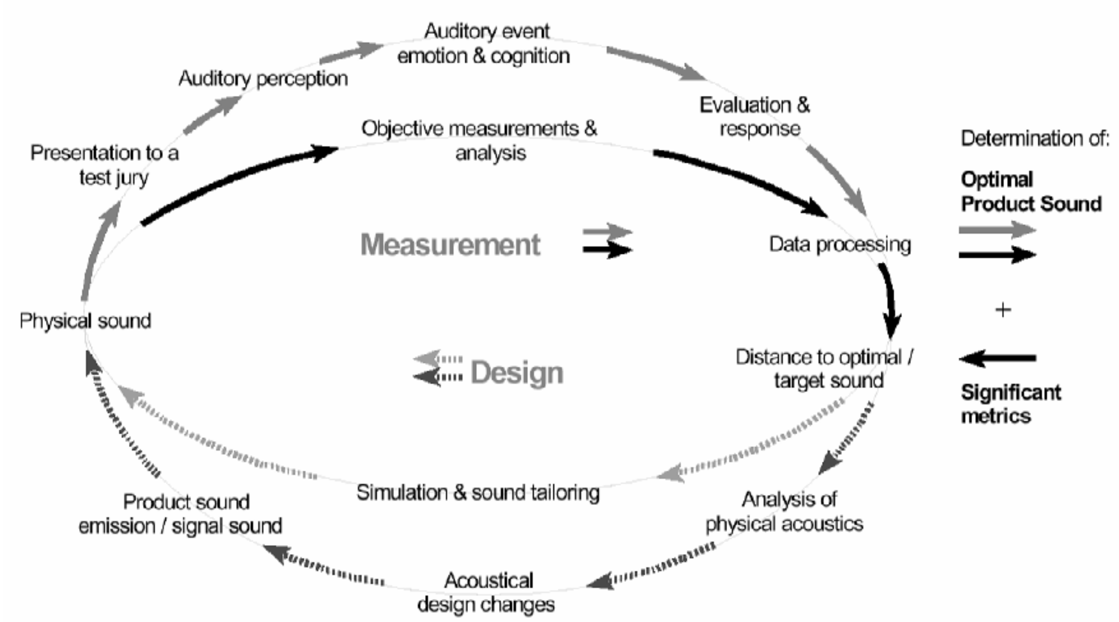

Figure 3.3. The Product Sound Wheel – a model for optimizing Product Sound Quality.
(Source: Fog and Pedersen 1999)

- A carmaker wanted a silent power steering with a faint quality sound. The sub-supplier asked for an analysis of the sound from the existing power steering systems, and specifications of the desired "sound" and suggestions to design changes. As a result of this project, new owners of that make can pride themselves on the quiet and harmonious sound of their power steering.
- All CD-players contain movable parts and, hence, all produce some small amount of noise. Whether this noise is heard or not depends on two things: How loud it is and how it is composed. Even when noise levels measured may be the same, certain combinations of frequencies can be annoying while others are scarcely audible. Even in low background situations using a team of trained listeners it was possible to come up with a set of metrics which reflect the findings of these listeners. So, now introduction of an on-line QC-system in the production based on these metrics is under consideration for this new product. The key issue is that the product sound tools with listening tests as a central part have been used to design changes into the products in order to improve their product sound and hence their acceptability to the users.

3.4. Sound Quality Evaluation Methodology

For a long period of time sound design basically dealt with the reduction of the overall sound level that is emitted by a product. But, within the last decade the focus started to switch more and more towards the aspect of the quality of the resulting sound. This development of sound design results in the fact that sound designers have to cope with completely different tasks and methods - the requirements for this profession have been significantly extended. In contrast to traditional mechanical sound design which is restricted to the investigation of pure physical and mechanical dimensions, sound quality design also has to consider human perception. Thus besides the traditional mechanical and physical knowledge Sound Quality designers also have to acquire knowledge in psychoacoustics and even in psychology.

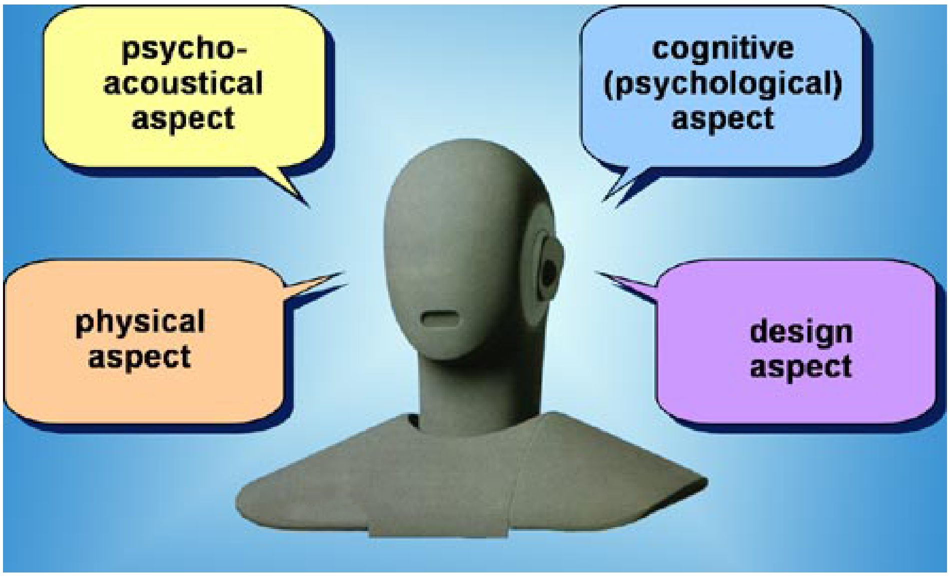

Figure 3.4. A picture to help to demonstrate the multi-dimensional aspects of sound.

A basic problem resulting form this change is that completely different measurement procedures are necessary. While physical signals like the overall sound pressure level can directly be measured with an instrument and following a method well defined in international standards, now human perception has to be measured. From the view of the traditional engineering education it might even be stated that such a "measurement"is impossible, because no instrument can directly measure this perception. But, instead of an instrument here different measurements methods have to be applied, methods which are based on perceptual test with subjects. The development of these tests have a long tradition in the field of psychoacoustics, which offers the basic solution for the problem of Sound Quality evaluation: physical signal parameters are related to aspects of human perception. These methods can thus be used to build the bridge between parameters which can be measured with traditional instruments and human perception. But, the methods have to be extended in order to cope for non-acoustical and even non-sensory moderators, so that they can not be standardized as traditional sound engineering methods - knowledge in human perception is required

3.4.1 Moderating Factors for Sound Quality

In contrast to other quality measures which can be defined by pure physical quantities, Sound Quality is based on human perception. Human perception itself is not only based on the acoustical signal which is received by the two ears of listener, is also depends on other sensorial modalities like visual, tactile or haptic information. Furthermore and even more complicated, also non-sensorial aspects have an influence on the judgment of Sound Quality - cognition controls our perception.

The cognitive influences can be divided into three groups:

- Source (product) -related: a source/product usually represents an image;
- Situation-related: a product is used in a specific activity situation; the user can interact with the source;
- Person-related: people have their personal expectation, motivation, taste, preference or aversion.

Sound Quality thus is a multidimensional consisting of three different factor groups:

- Physical factors (the acoustical signal);
- Psycho-acoustical factors (describing acoustical sensorial aspects, e.g., loudness, sharpness, fluctuation strength); (Fastl 1997)
- Psychological factors.

An important point is that humans only use three to four of these factors to create their judgment. The selection of the respective factors is driven by cognition. As a consequence, the same physical sound can result in completely different Sound Qualities.

Sound Quality is product specific, which means that each product (or class of products) has its own specific requirements for Sound Quality. It is the first step of Sound-Quality Evaluation to identify these product-specific requirements. Sound Quality evaluation thus is a complex task, and that it requires multidisciplinary knowledge. The appropriate methods have to be selected based on the specific product and task.

3.4.2. Procedures of Sound Quality Evaluation

In each type of measurement all factors which have an influence on the quantity to be measured have to be controlled. This is also true for measurements of Sound Quality. Thus the first task in setting up an experiment is to identify the moderating factors for the specific product or sounds to be evaluated. This can be a tedious task, because in most cases it is not known in advance which factors do have an influence and which do not. Once the factors are known, it can either be decided if they can be controlled in the experiment or, if this is not possible, if they at least can be kept constant during the experiment and for all subjects. The methods to evaluate Sound Quality can thus not only restrict themselves to the pure acoustical signal, they also have to consider other modalities and the specific situation and background of the subjects. Although they are based on traditional psychoacoustics, these basic methods have to be extended to cope with the requirements. Usually Sound Quality evaluation test are performed in a laboratory. It is obvious that the moderating factors in a such a laboratory situation can significantly differ from those which are present in the normal life situation where the product is handled by a user. This context information is better considered by field tests, but this type of test shows some drawbacks compared to laboratory tests. Advantages of laboratory tests are:

- The test is reproducible;
- All subjects have identical test conditions;
- If products are compared, they can be evaluated in identical states of operation;
- Different sounds can directly be compared;

- Stimuli can adaptively be modified depending on the subjects answer, e.g., to efficiently

Identify target sounds;

- The test is time-efficient.

In contrast a field test shows the following advantages:

- It is a representative situation for the usage of a product in daily life;
- A typical handling of the product is possible;
- Interaction with the product is possible;
- Subjects can individually select typical or critical states of operation.

If Sound Quality should be evaluated with regard to customer relevance, in general a field test is indispensable. But, especially due to the effort and time consumption such an investigation often is not possible or practicable.

If the experiments have to be conducted in the laboratory, they have to be carefully planned and in general it has to be checked if the results can be transferred to the field. Differences in judgments in the field and laboratory are usually due to the fact that subjects can derive different information in both cases, so that their cognition might select different factors to build their judgment.

Resulting from the discussion of moderating factors above in general the following aspects have to be considered for a laboratory experiment.

With regard to the physics sophisticated methods for aurally-adequate sound recording and playback are available. Using for example a dummy head for recording and equalized headphones for playback the acoustical signal at the eardrums of a listener can nearly perfectly be reproduced. But, since humans also perceive low frequencies by the whole body, a pure headphone reproduction does not lead to authentic perception. To avoid this sometimes subwoofers are used if sounds have strong low frequency components. The acoustical channel can thus normally be reproduced in a satisfactory manner. This is different for other modalities since corresponding reproduction methods are either still missing or very expensive. Optical information can be presented by images or videos, but true 3-dimensional reproduction is not applicable. Other modalities can only be presented as with strong simplifications or restrictions (Blauert et al. 2000).

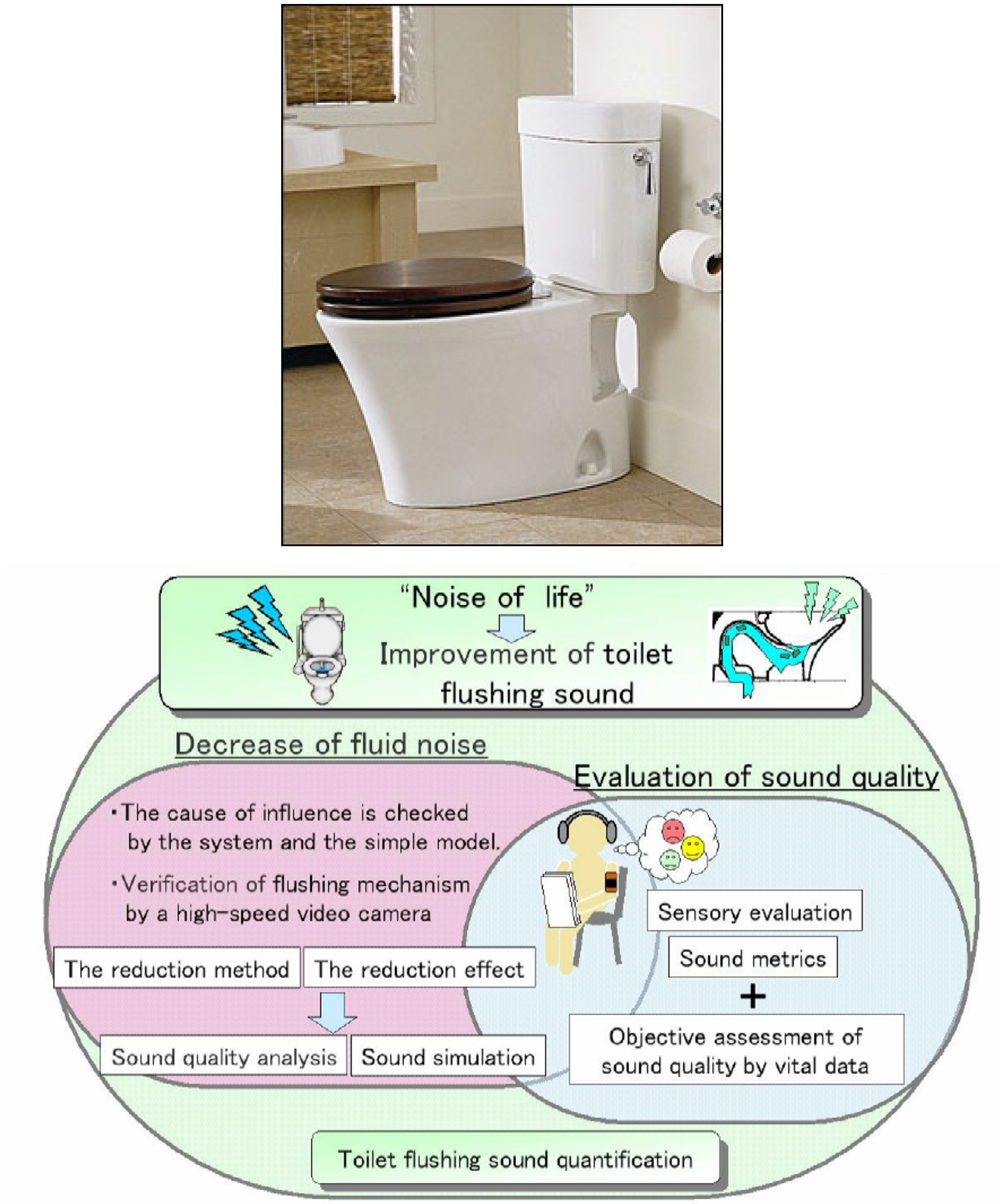

Figure 3.5. Development of comfortable toilet flashing sound based on sound quality evaluation.

The most problematic factor group is the cognitive factors. In the laboratory a reduced amount of information is available for the subjects, and this specially concerns non-acoustical and the non-sensory information.

The source-related factors are not present in a pure acoustical experiment, so that they have to be made available by presenting additional information about the product, e.g., in form of a verbal description, pictures, videos, or models.

Situation-related factors are hard to reproduce in the laboratory. Here subjects usually are passive in listening to a sound, so that they are not included into the activity. Furthermore, interaction with the source usually is not possible. It is thus necessary to explain the situation carefully to subjects.

Person-related factors have a stronger influence the more the subject knows about the product and the situation, so that the remarks above have to be applied. It is important for the interpretation of the results to identify and record these factors, e.g., in form of a questionnaire.

As a consequence a general applicable and standardized method to evaluate Sound Quality does not exist. The specific aspects of the product, its application, and the target group have to be well considered in planning and running evaluation experiments. An appropriate evaluation method consists of two blocks: a kernel procedure, usually implemented as one of the standard or modified psychoacoustic test methods, and a framework which contains the presentation and documentation of all non-acoustical information.

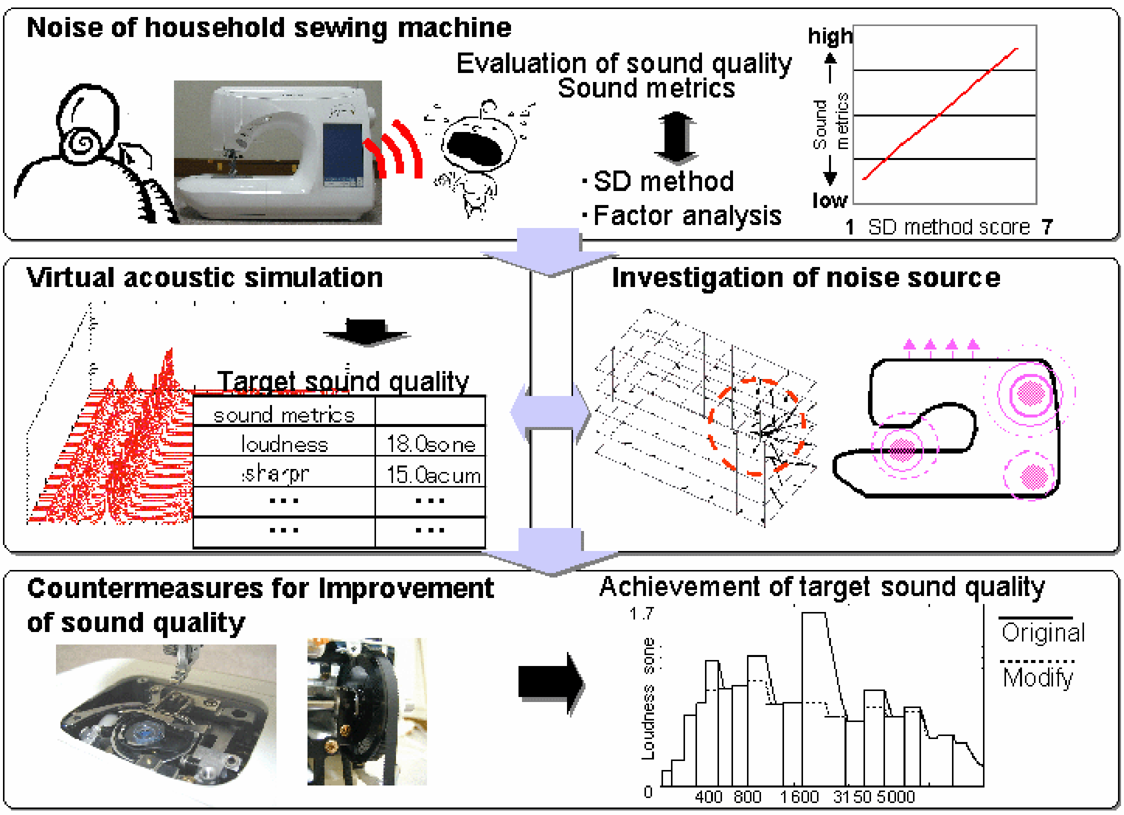

Figure 3.6. Evaluation procedure of sound quality and improvement for Household sewing machine

A variety of different psychoacoustic test methods are available from literature (Green and Swets 1974), and the selection of the appropriate method depends on the character and number of stimuli and the required type of output. Most common methods are absolute and relative methods. An example of an absolute method is direct-magnitude estimation tests, in which subjects listen to a stimulus and directly quantify the feature to be evaluated. The most popular relative method is pair-comparison, in which two stimuli are presented as a pair, and the subject has to select the one which better fulfills a given criterion. Anyhow, both methods have their advantages and disadvantages. Especially for the application in the industrial environment the corresponding needs and restrictions have to be considered: methods have to be time-efficient, render results with a sufficient accuracy, and give direct clues on how to improve products.

An appropriate method was presented in (Bodden and Heinrichs 1998). The so-called individual test combines the advantages of pair comparisons (direct comparison of the feature to be evaluated) and direct estimation (absolute judgment of the feature) but avoids their disadvantages (time consumption and difficulty for similar stimuli).

In this test the subject has access to all stimuli, and he can decide by himself how often and in which order he wants to listen to sounds. His task is to arrange the stimuli on a graphic board in such a manner that the feature to be evaluated is rated on a scale, e.g., from bad (bottom) to good (top). The result thus represents both, a ranking and an absolute judgment. The experiment is time-efficient since subjects can perform pair-comparisons only for those stimuli which are similar. A further advantage of the individual test is that the subject controls the experiment himself. He thus is actively involved in the experiment, which usually results in a higher motivation. Furthermore the subject has no longer the impression to be controlled by the test, so that his self-reliance increases and his stress are reduced.

CHAPTER 4

EMOTION & DESIGN

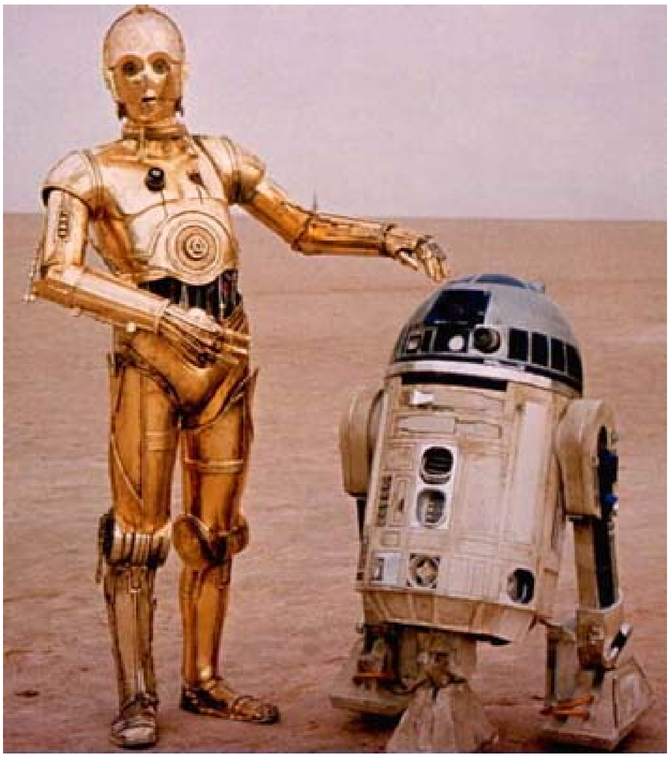

Figure 4.1. C3PO (left) and R2D2 (right) of Star Wars fame is two of emotionally significant designs ever.

(Source: http://www.renn-stey-team.de/pics/Teams/R2D2_C3PO.jpg)

4.1. Emotional Designs

Until recently, emotion was an ill-explored part of human psychology. Some people thought it an evolutionary leftover from our animal origins. Most thought of emotions as a problem has to be overcome by rational, logical thinking. And most of the research focused upon negative emotions such as stress, fear, anxiety, and anger. Modern work has completely reversed this view. Science now knows that evolutionarily more advanced animals are more emotional than primitive ones, the human being the most emotional of all. Moreover, emotions play a critical role in daily lives, helping assess situations as good or bad, safe or dangerous. As discussed in the prologue, emotions aid in decision making. Positive emotions are as important as negative ones; positive emotions are critical to learning, curiosity, and creative thought, and today research is turning toward this dimension. (Fredrickson 1998). One finding particularly intrigued me: The psychologist Alice Isen has shown that being happy broadens the thought processes and facilitates creative thinking. Isen discovered that when people were asked to solve difficult problems, ones that required unusual "out of the box "thinking, they did much better when they had just been given a small gift not much of a gift, but enough to make them feel good. When you feel good, Isen discovered, you are better at brain-storming, at examining multiple alternatives. And it doesn't take much to make people feel good. All (Isen 1993) had to do was ask people to watch a few minutes of a comedy film or receive a small bag of candy.

When people are anxious they tend to narrow their thought processes, concentrating upon aspects directly relevant to a problem (Damasio 1999). This is a useful strategy in escaping from danger, but not in thinking of imaginative new approaches to a problem. Isen's results show that when people are relaxed and happy, their thought processes expand, becoming more creative, more imaginative.

These and related findings suggest the role of aesthetics in product design: attractive things make people feel good, which in turn makes them think more creatively. How does that make something easier to use? Simple, by making it easier for people to find solutions to the problems they encounter. With most products, if the first thing you try fails to produce the desired result, the most natural response is to try again, only with more effort. In today's world of computer-controlled products, doing the same operation over again is very unlikely to yield better results. The correct response is to look for alternative solutions. The tendency to repeat the same operation over again is especially likely for those who are anxious or tense. This state of negative affect leads people to focus upon the problematic details, and if this strategy fails to provide a solution, they get even tenser, more anxious, and increase their concentration upon those troublesome details. Contrast this behavior with those who are in a positive emotional state, but encountering the same problem. These people are apt to look around for alternative approaches, which is very likely to lead to a satisfying end. Afterward, the tense and anxious people will complain about the difficulties whereas the relaxed, happy ones will probably not even remember them. In other words, happy people are more effective in finding alternative solutions and, as a result, are tolerant of minor difficulties. In order to connect beauty and function, a mystical theory is needed.

(Read 1953) Well, it took one hundred years, but today we have that theory, one based in biology, neuroscience, and psychology, not mysticism.

Human beings have evolved over millions of years to function effectively in the rich and complex environment of the world. Our perceptual systems, our limbs, the motor system which means the control of all our muscles; everything has evolved to make us function better in the world. Affect, emotion, and cognition have also evolved to interact with and complement one another. Cognition interprets the world, leading to increased understanding and knowledge. Affect, which includes emotion, is a system of judging what's good or bad, safe or dangerous. It makes value judgments, the better to survive. The affective system also controls the muscles of the body and, through chemical neurotransmitters, changes how the brain functions. The muscle actions get us ready to respond, but they also serve as a signal to others we encounter, which provides yet another powerful role of emotion as communication: our body posture and facial expression give others clues to our emotional state. Cognition and affect, understanding and evaluation together they form a powerful team..(Krumhansl 2002)

4.2. Three Levels of Processing: Visceral, Behavioral, and Reflective

Human beings are, of course, the most complex of all animals, with accordingly complex brain structures. A lot of preferences are present at birth, part of the body's basic protective mechanisms. But we also have powerful brain mechanisms for accomplishing things, for creating, and for acting. We can be skilled artists, musicians, athletes, writers, or carpenters. All this requires a much more complex brain structure than is involved in automatic responses to the world. And finally, unique among animals, we have language and art, humor and music. We are conscious of our role in the world and we can reflect upon past experiences, the better to learn; toward the future, the better to be prepared; and inwardly, the better to deal with current activities.

Andrew Ortony and William Revelle, professors in the Psychology Department at Northwestern University, suggest that these human attributes result from three different levels of the brain: the automatic, pre-wired layer, called the visceral level, the part that contains the brain processes that control everyday behavior, known as the behavioral level; and the contemplative part of the brain, or the reflective level. Each level plays a different role in the total functioning of people. (Ortony et al 1988)

The three levels in part reflect the biological origins of the brain, starting with primitive one-celled organisms and slowly evolving to more complex animals, to the vertebrates, the mammals, and finally, apes and humans. For simple animals, life is a continuing set of threats and opportunities, and an animal must learn how to respond appropriately to each. The basic brain circuits, then, are really response mechanisms: analyze a situation and respond. This system is tightly coupled to the animal's muscles. If something is bad or dangerous, the muscles tense in preparation for running, attacking, or freezing. If something is good or desirable, the animal can relax and take advantage of the situation.

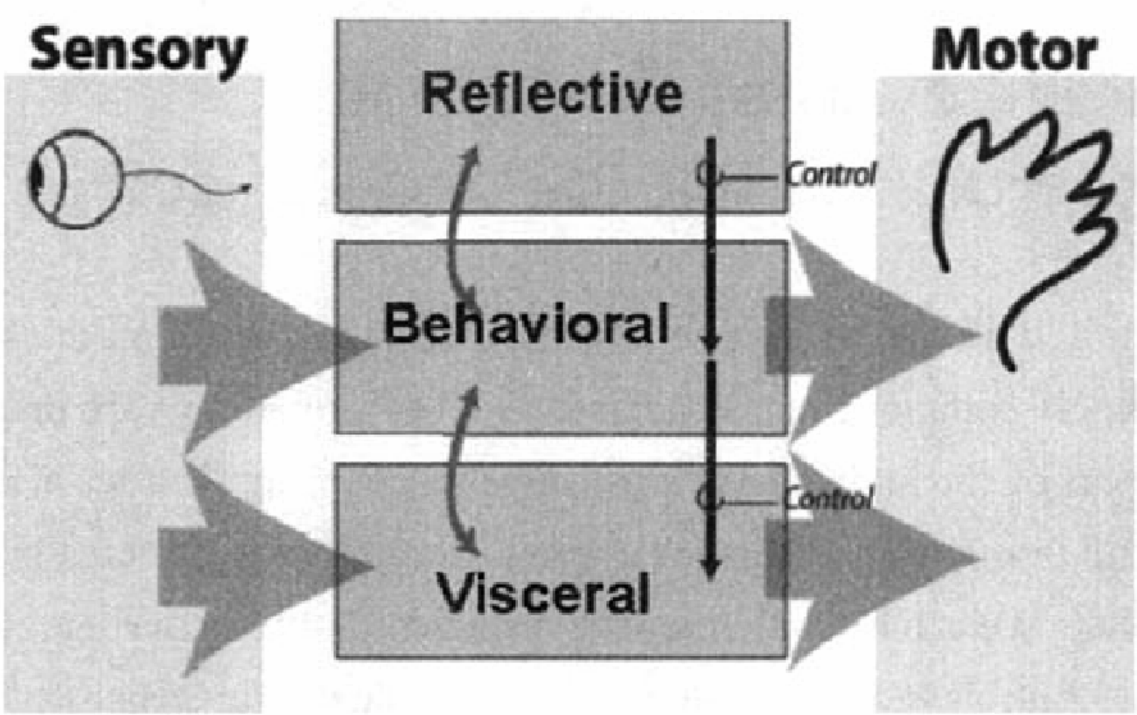

Figure 4.2. Three levels of processing: Visceral, Behavioral, and Reflective.

The visceral level is fast: it makes rapid judgments of what is good or bad, safe or dangerous, and sends appropriate signals to the muscles (the motor system) and alerts the rest of the brain. This is the start of affective processing. These are biologically determined and can be inhibited or enhanced through control signals from above. The behavioral level is the site of most human behavior. Its actions can be enhanced or inhibited by the reflective layer and, in turn, it can enhance or inhibit the visceral layer.

The highest layer is that of reflective thought. Note that it does not have direct access either to sensory input or to the control of behavior. Instead it watches over, reflects upon, and tries to bias the behavioral level.

As evolution continued, the circuits for analyzing and responding improved and became more sophisticated. Put a section of wire mesh fence between an animal and some desirable food: a chicken is likely to be stuck forever, straining at the fence, but unable to get to the food; a dog simply runs around it. Human beings have an even more developed set of brain structures. They can reflect upon their experiences and communicate them to others. Thus, not only do we walk around fences to get to our goals, but we can then think back about the experience -reflect upon it- and decide to move the fence or the food, so we don't have to walk around the next time. We can also tell other people about the problem, so they will know what to do even before they get there.

Figure 4.3. The Maybach Brabus: Viscerally exciting. This automobile is a classic example of the power of visceral design: sleek, elegant, exciting.
(Source: http://www.rsportscars.com/foto/09/maybachbrabus05_01_1024.jpg)

Animals such as lizards operate primarily at the visceral level. This is the level of fixed routines, where the brain analyzes the world and responds. Dogs and other mammals, however, have a higher level of analysis, the behavioral level, with a complex and powerful brain that can analyze a situation and alter behavior accordingly.

The behavioral level in human beings is especially valuable for well-learned, routine operations. This is where the skilled performer excels.

Figure 4.4. A Visceral component: Sound. Nokia's tune in its mobile phones carries its identity.

Figure 4.5. The sensual component of behavioral design. Behavioral design emphasizes the use of objects, in this case, the sensual feel of the shower: Its relaxing sound and comfortable feeling.

(Source: Norman 2003)

At the highest evolutionary level of development, the human brain can think about its own operations. This is the home of reflection, of conscious thought, of the learning of new concepts and generalizations about the world.

The behavioral level is not conscious, which is why you can successfully drive your automobile subconsciously at the behavioral level while consciously thinking of something else at the reflective level. Skilled performers make use of this facility. Thus, skilled piano players can let their fingers play automatically while they reflect upon the higher-order structure of the music. This is why they can hold conversations while playing and why performers sometimes lose their place in the music and have to listen to themselves play to find out where they are. That is, the reflective level was lost, but the behavioral level did just fine. (Papanek and Hennessey 1977)

Now let's look at some examples of these three levels in action: riding a roller coaster; chopping and dicing food with a sharp, balanced knife and a solid cutting board; and contemplating a serious work of literature or art. These three activities impact us in different ways. The first is the most primitive, the visceral reaction to falling, excessive speed, and heights. The second, the pleasure of using a good tool effectively, refers to the feelings accompanying skilled accomplishment, and derives from the behavioral level. This is the pleasure any expert feels when doing something well, such as driving a difficult course or playing a complex piece of music. This behavioral pleasure, in turn, is different from that provided by serious literature or art, whose enjoyment derives from the reflective level, and requires study and interpretation. (Norman 2003)

Figure 4.6. Three levels of processing: Visceral, Behavioral, and Reflective. The roller coaster pits one level of affect -the visceral sense of fear -against another level the reflective pride of accomplishment.

Most interesting of all is when one level plays off of another, as in the roller coaster. If the roller coaster is so frightening, why is it so popular? There are at least two reasons. First, some people seem to love fear itself: they enjoy the high arousal and increased adrenaline rush that accompanies danger. (Blythe et al. 2003).The second reason comes from the feelings that follow the ride: the pride in conquering fear and of being able to brag about it to others. In both cases, the visceral angst competes with the reflective pleasure -not always successfully, for many people refuse to go on those rides or, having done it once, refuse to do it again. But this adds to the pleasure of those who do go on the ride: their self image is enhanced because they have dared do an action that others reject. (Mitnick and Simon 2002)

4.3. The Prepared Brain

Although the visceral level is the simplest and most primitive part of the brain, it is sensitive to a very wide range of conditions. These are genetically determined, with the conditions evolving slowly over the time course of evolution. They all share one property, however: the condition can be recognized simply by the sensory information. The visceral level is incapable of reasoning, of comparing a situation with past history. It works by what cognitive scientists call "pattern matching. (Fredrickson 1998)

Table 4.1. ”What are people genetically programmed for? Those situations and objects that, throughout evolutionary history, offer food, warmth, or protection give rise to positive affect are indicated.

Warm, comfortably lit places
Temperate climate
Sweet tastes and smells
Bright, highly saturated hues
"Soothing” sounds and simple melodies and rhythms
Harmonious music and sounds
Caresses
Smiling faces
Rhythmic beats
"Attractive” people
Symmetrical objects
rounded, smooth objects
"Sensuous" feelings, sounds, and shapes

Table 4.2. Some conditions that appear to produce automatic negative affects.

Heights
Sudden, unexpected loud sounds or bright lights
"Looming" objects (objects that appear to be about to hit the observer)
Extreme hot or cold
Darkness
Extremely bright lights or loud sounds
Empty, flat terrain (deserts)
Crowded dense terrain (jungles or forests)
Crowds of people
Rotting smells, decaying foods
Bitter tastes
Sharp objects
Harsh, abrupt sounds
Grating and discordant sounds
Misshapen human bodies
Snakes and spiders
Human feces (and its smell)
Other people's body fluids
Vomit

Some of the items are still under dispute; others will probably have to be added. Some are politically incorrect in that they appear to produce value judgments on dimensions society has deemed to be irrelevant. The advantage human beings have over other animals is our powerful reflective level that enables us to overcome the dictates of the visceral, pure biological level. We can overcome our biological heritage.

It should be noted that some biological mechanisms are only predispositions rather than full-fledged systems. Thus, although we are predisposed to be afraid of snakes and spiders, the actual fear is not present in all people: it needs to be triggered through experience. Although human language comes from the behavioral and reflective levels, it provides a good example of how biological predispositions mix with experience. (Goleman 1995) The human brain comes ready for language: the architecture of the brain, the way the different components are structured and interact, constrains the very nature of language. Children do not come into the world with language, but they do come predisposed and ready. That is the biological part. But the particular languages that one learns, and the accent with which one speak it, are determined through experience. Because the brain is prepared to learn language, everyone does so unless they have severe neurological or physical deficits. Moreover, the learning is automatic: we may have to go to school to learn to read and write, but not to listen and speak. Spoken language -or signing, for those who are deaf -is natural. Although languages differ, they all follow certain universal regularities. But once the first language has been learned, it highly influences later language acquisition. If you have ever tried to learn a second language beyond your teenage years, you know how different it is from learning the first, how much harder, how reflective and conscious it seems compared to the subconscious, relatively effortless experience of learning the first language. (Jordan 2000) Accents are the hardest thing to learn for the older language -learner, so that people who learn a language later in life may be completely fluent in their speech, understanding, and writing, but maintain the accent of their first language.

Tinko and losse are two words in the mythical language Elvish, invented by the British philologist J.R.R.Tolkien for his trilogy, The Lord of the Rings. Which of the words "tinko "and "losse "means "metal," which "snow"? How could you possibly know? The surprise is that when forced to guess, most people can get the choices right, even if they have never read the books, never experienced the words. Tinko has two hard, "plosive" sounds –the "t"and the "k." Losse has soft, liquid sounds, starting with the "1"and continuing through the vowels and the sibilant "ss." Note the similar pattern in the English words where the hard "t" in "metal" contrasts with the soft sounds of "snow." Yes, in Elvish, tinko is metal and losse is snow. (Tolkien 1954b)

The Elvish demonstration points out the relationship between the sounds of a language and the meaning of words. At first glance, this sounds nonsensical -after all, words are arbitrary. But more and more evidence piles up linking sounds to particular general meanings. For instance, vowels are warm and soft: feminine is the term frequently used. Harsh sounds are, well, harsh -just like the word "harsh" itself and the "sh" sound in particular. Snakes hiss and slither; and note the sibilants, the hissing of the "s" sounds. Plosives, sounds caused when the air is stopped briefly, then released -explosively -are hard, metallic; the word "masculine" is often applied to them. The "k" of "mosquito" and the "p" in "happy" are plosive. And, yes, there is evidence that word choices are not arbitrary: a sound symbolism governs the development of a language. This is another instance where artists, poets in this case, have long known the power of sounds to evoke affect and emotions within the readers of or, more accurately, listeners to poetry. (Tolkien 1954a)

All these pre-wired mechanisms are vital to daily life and our interactions with people and things. Accordingly, they are important for design. While designers can use this knowledge of the brain to make designs more effective, there is no simple set of rules. The human mind is incredibly complex, and although all people have basically the same form of body and brain, they also have huge individual differences.

Emotions, moods, traits, and personality are all aspects of the different ways in which people's minds work, especially along the affective, emotional domain. Emotions change behavior over a relatively short term, for they are responsive to the immediate events. Emotions last for relatively short periods minutes or hours. Moods are longer lasting, measured perhaps in hours or days. Traits are very long-lasting, years or even a lifetime. And personality is the particular collection of traits of a person that last a lifetime. But all of these are changeable as well. We all have multiple personalities, emphasizing some traits when with families, a different set when with friends. We all change our operating parameters to be appropriate for the situation we are in.

Ever watch a movie with great enjoyment, then watch it a second time and wonder what on earth you saw in it the first time? The same phenomenon occurs in almost all aspects of life, whether in interactions with people, in a sport, a book, or even a walk in the woods. This phenomenon can bedevil the designer who wants to know how to design something that will appeal to everyone: One person's acceptance is another one's rejection. Worse, what is appealing at one moment may not be at another. (Norman 2002)

The source of this complexity can be found in the three levels of processing. At the visceral level, people are pretty much the same all over the world. Yes, individuals vary, so although almost everyone is born with a fear of heights, this fear is so extreme in some people that they cannot function normally they have acrophobia. Yet others have only mild fear, and they can overcome it sufficiently to do rock climbing, circus acts, or other jobs that have them working high in the air.

The behavioral and reflective levels, however, are very sensitive to experiences, training, and education. Cultural views have huge impact here: what one culture finds appealing, another may not. Indeed, teenage culture seems to dislike things solely because adult culture likes them.

4.4. Artifacts and Emotional State Changes

Artifacts are the devices, both physical and mental, that reveal the problem solving and problem structuring strategies of users during task completion (Spillers 2003). Artifacts are instrumental in problem-solving, decision-making and sense-making. (Norman 1991) extended artifacts to include cognitive phenomenon, which he termed “cognitive artifacts”. Cognitive artifacts are created or elicited in order to aid successful task achievement. They may be used as triggers to preserve workflow integrity, as “task-switching” or “role-switching” aids to manage disturbances, oras mediators of social activity or rhythms (Spillers and Loewus- Deitch 2003).

Artifacts carry emotional clues for designers. Identifying the role that artifacts play during product interaction can lead to an understanding of the emotional requirements necessary for a design. For example, (Wensveen et al. 2002) designed an alarm clock that predicted mood and acted accordingly based on input from the user. Their work illustrates the importance of a tight coupling between the emotional level of interaction, the appearance and the actual use (interaction design).

(Hutchins 1995) defined cognitive artifacts as physical objects made by humans for the purpose of aiding, enhancing, or improving cognition. Likewise, affect serves a crucial function in interpretation, exploration and appraisal of a user interface. The more confusion a user feels with a product, the more likely they are to engage in problem solving behaviors in an attempt to reach a state of understanding. As users explore their concerns by appraising a product, they become either more successful or less successful with a user interface. When examining a new icon on a screen, a user may adopt a state of curiosity or annoyance in order to bridge expected notions of what the icon symbolizes and what it is really supposed to represent. The curiosity or annoyance provides an emotional state change that can either propel the user toward a feeling of satisfaction (success) or disappointment (failure).

Changes in emotional state may serve any of the following functions:

- Explore, manipulate or investigate the interface
- Produce a shift in concentration or attention
- Free up cognitive resources to focus on the task
- Alter the social arrangement or group dynamics where the product is being used

Just as a cognitive artifact is used as a vehicle to perform a task (Hutchins 1999), so to is emotion used as a variable in task completion. For the designer, emotions in this view are viewed as co-active aspects of the design, and not merely by-products of the design or interaction. In short, the significance of the emotion in the user interaction becomes of primary importance due to its sense-making properties.

4.4.1 Affective Artifacts as Cognitive Aids

The primary role of an artifact is to aid and extend cognitive abilities. Cognitive artifacts mediate emotional state changes, and help manage workload, error minimization and task accomplishment (Hutchins 1999, Norman 1991, Spillers 2003). "Affective artifacts" represent or elicit emotions and assist product interaction and user cognition during the product appraisal process (See figure 4.7.).

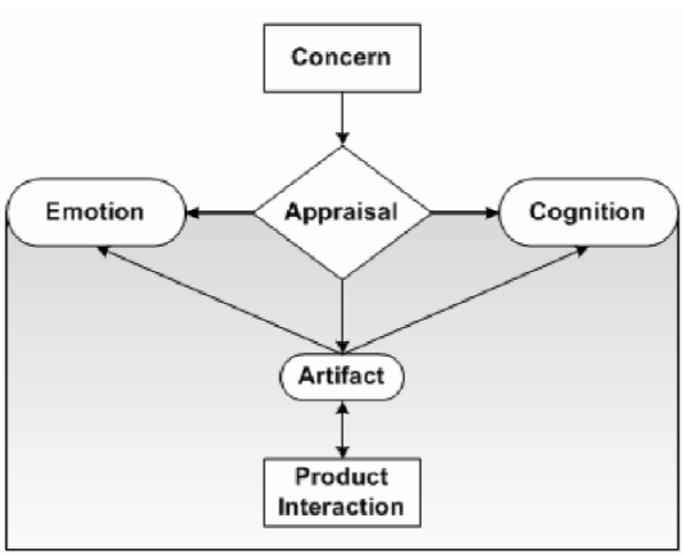

Figure 4.7. Artifacts that are created or accessed during product interaction take on affective properties as they interchange with emotions in order to aid cognition and task performance.

(Desmet 2002) emphasized the role that concerns play in how people relate to and appraise products. Concerns may also serve more specific task functions, such as acting as triggers to problem solving or to restarting interrupted tasks (Dix and Wilkinson 2003). Concerns that arise during product interaction, may serve the user in practical ways.

4.4.2. Emotional State Changes

Task environments are the backdrop where artifacts are created, shared and manipulated. According to (Kirsh 2000), users alter their physical environments to gain leverage over problem solving and to aid task completion. Emotions appear to provide a similar purpose in appraisal and performance. Hence, changes in emotional response before, during, and after product interaction are important to note, when identifying concern in the design of products.

4.4.2.1. Sense-Making Properties of Artifacts

Emotion is a critical element of artifact sense-making according to (Rafaeli and Vilnai-Yavetz 2003). Emotion, they argue, is central to how artifacts are interpreted. Shifts in emotion assist sense-making. Reliance on physical artifacts may also trigger and elicit cognitive artifacts (emotion) to extend sense-making abilities. For example, when planning an event without a calendar, a user may verbally re-cite the days of the week based on a mental reference of the current date. While this recall is occurring, the user may simultaneously recall events from the previous week, year or decade (triggered by a special date or time of year). The recall may elicit an emotion such as urgency, disappointment or excitement. The benefit of this affective state might be to add cognitive resources (artifacts) to the current situation in order to learn more from past events. Or it may assist in applying perspective to an anticipated situation or problem.

According to Rafaeli and Vilnai-Yavetz, sense-making of the artifact involves emotion in three ways:

- Instrumentality: Tasks the artifact helps accomplish.
- Aesthetics: Sensory reaction to the artifact.
- Symbolism: Association the artifact elicits.

Artifacts appear to both trigger and elicit emotional states. (Wertenbroch and Carmon 1997) found that “Consumers enable themselves to maintain the quality of their experiences over time by affecting the internal or external resources and constraints under which they make their choices". They refer to this as engaging in 'dynamic preference maintenance'. Emotion in product interaction seems to play a similar role. For example, users may delay gratification (or evaluation) with a product feature in order to feel fully satisfied that the overall product meets expectations and desires.

4.4.2.2. Perception of Pleasure

Emotions govern **the quality of interaction** with a product in the user's environment and relate directly to appraisal of the user experience. A framework for user experience can be presented where pleasure must satisfy two levels. The first level involves appearance (aesthetics) and user interface (usability).The second level extends to user personality (socio-cultural context), product meaning (time/historic context), environment (physical context), interaction (use context) and product novelty (market context).

According to (Keinonen 1998), emotions that accompany product usability inevitably lead to generalizations made about the product with regard to its perceived usefulness. Keinonen also found that expectations users have toward the expected usability of a product also differ greatly to actual measured usability.

4.5. Emotion in Product Sound Design

Most people agree that auditory sensations, sounds and music, can arouse profound and deep emotional reactions. Despite this, systematic studies of emotional reactions to auditory only recently have gained some interest. This seems surprising, since a primary goal of product sound design development is to elicit positive consumer or user reactions. Following this definition, product sound design is also about the emotion design. In this thesis we are concerned with when and how certain sounds elicit specific emotions. Moreover, a focal point of this thesis is the measurement and prediction of product emotions. We will try to highlight the importance of considering affect in psychoacoustics, product sound quality, and sound design by reviewing research relevant to affective reactions to everyday sounds. We will mention music only briefly. We will conclude by discussing implications for sound design and product testing. It is hoped that this review will stimulate future research and applications of emotive sound design and affective sound quality.

4.5.1. The Place of Emotion in Product Sound Design

Affective or emotional reactions are fundamental components of human responses to auditory stimuli. Everyday examples of affective reactions to auditory stimuli can easily be found: people may be annoyed by the sound of a car passing by, get tired by the constant fan noise in the office, enjoy the rumbling noise of a motorcycle in a street, be startled by the sudden noise of a door slamming. As a consequence, when verbally describing sounds, people consistently use affect-laden words such as pleasant, tiring, annoying, irritating, happy, and so forth (Namba et al. 1991).Thus emotional reactions to sound appear to be of importance for both evaluations and reactions.

There is unfortunately little consensus concerning the definition of the terms emotion, affect, mood and feeling in current emotion psychology. Often affect is used as a colloquial term for all above-mentioned terms. The current distinction between mood and emotion is somewhat more detailed. Emotions are often considered to be directed at a specific object, whereas moods are global in character without a specific cause or intentional object (Frijda 1994).For instance, (Clore et al. 1994) argued that "mood refers to feelings that need not be about anything, whereas emotion refers to how one feels in combination with what the feeling is about." .Emotion and affect is used interchangeably referring to the individual's reaction when exposed to a sound. We treat mood as a background feeling state, not caused by a specific events, stimulus or object.

Most classes of sounds such as auditory warnings, ear cones/auditory icons, product sounds, environmental sounds, computer and system sounds, and man-made sounds all have emotional connotations. These emotional connotations will influence the way the listener perceives the sound. Following this, a systematic approach to affective reactions to sounds will further increase our understanding and prediction of human responses. In order to understand the importance of affect for sound perception, we need to take the detour over current status of product sound quality.

4.5.2. Product Sound Quality: A Need for Emotional Significance

For a long time acoustic engineers have been accustomed to reduce the noise emitted by a product with the underlying idea that "less is better".Often such a position also holds that noise annoyance is linearly related to sound level. However, sound not only cause nuisance, but may also convey information about the current state of affairs, and provide important information regarding the environment of the receiver. Moreover, two products producing the same level in dBA may sound drastically different and, therefore, human perception of sound cannot be described by simple linear or weighted sound levels. To account for the fact that auditory events are multidimensional and not only related to loudness, the term "Sound Quality" was coined.. Later, sound quality has come to refer to "the adequacy of a sound in the context of a specific technical goal or task " (Blauert and Jekosch 1997).In the light of this, sound quality concerns optimization of the sound emitted by a source by taking into account properties the listener/user find suitable or desirable for such a sound.

Traditionally, optimization of product sound quality has been based on ear-oriented metrics and even though these metrics show reasonable correlation with subjective opinions, some subjective effects such as affective reactions cannot be predicted or accounted. Nevertheless, an affective reaction to sound stimuli is a fundamental component of perception of the auditory environment. Suggesting that affective reactions are a primary component of auditory perception, (Blauert and Jekosch 1997) formulated a model of product sound quality with focus on the listener/customer. This model considers factors such as input from other sensory modalities than hearing, cognitive functions such as experience and memory, emotional states and expectations, to reach a more complete understanding of sound quality.

What then is product sound quality? Currently the definition by (Blauert and Jekosch 1997) appears to be predominant in product sound quality research and development; "Product-sound quality is a descriptor of the adequacy of the sound attached to the product. It results from judgments upon the totality of auditory characteristics of the said sound – the judgments being performed with reference to the set of those desired features of the product which are apparent to the users in their actual cognitive, actional and emotional situation." (Blauert and Jekosch 1997).This definition holds that the acoustic waves emitted by a product and the auditory perception (jointly referred to as a auditory event) results in a sort of perceptual evaluation. The listener will evaluate the sound with reference to “a set of desired features”, and in relation to prevailing personal and situational characteristics. Following this definition sound quality is not an inherent property of the product but develops as the listener evaluates the sound according to his/her desires and expectations. Moreover, the frame of reference is not the only factor affecting the evaluation of sound quality, but also non-auditory cues such as visual and tactile input will influence the judged appropriateness of the sound. Taken together, perceived sound quality may be decomposed in three interrelated components, (1)physical (sound field), (2)psychoacoustic (auditory perception),and (3) psychological (auditory evaluation and reaction) (Genuit 1997). The first component, physical, concerns various ways of objectively describing and recording the sound emitted by a product. The second component, psychoacoustics, also concerns describing and colleting the sound from the product, but taking into account the characteristics of human hearing and auditory perception. Finally, the third component, psychological, deals with describing how the listener perceives and interprets the sound emitted by a product. (Guski 1997) suggested that a psychological account of product sound quality would entail, (a) suitability of the sound, or stimulus-response compatibility, (b) pleasantness of sounds and (c) identifiably of sounds or sound sources.

The current definitions of sound quality suggest that “good ” sound quality is characterized by auditory events perceived as pleasant (or at least not as unpleasant),which produces a pleasant impression of the sound, promote well-being, not interfering with activities, are easy to identify, and are compatible with the function, brand, and non-auditory cues of the product.” Bad” sound quality, on the other hand, is characterized by auditory events perceived as either unpleasant, and/or impair well-being; interfere with activities, are difficult to identify, and are incompatible with function, brand, and non-auditory cues of the product.

4.5.3. Cognition and Emotion in Sound Perception

Cognitive processes involved in the perception of product sound quality may be perceptual processes by which the sound is identified, that is, perceived as a discrete event in a stream of auditory events (Bregman 1990, McAdams 1993) or it may be that the sound is cognitively evaluated. Similarly, affective processes related to sound perception may be that an auditory event is perceived as threatening (Bradley and Lang 2000) or that it is perceived as unpleasant or makes the listener feel unpleasant. Sound quality involves both cognitive and affective processes from the first perception of an auditory event to the evaluation of it and the action following it (Blauert and Jekosch 1997).The cognitive and affective evaluations may be done with respect to the suitability of the sound in the context on non-auditory aspects of the product, previous experiences, memory and preference. Moreover, cognitive and affective processes are interlinked. (Namba 1994) argued that sound quality evaluation involves a two-stage process by which (a) a sound source is identified or recognized on the basis of timbre and level with respect to cognitive functions such as perceptual processes, memory, and expectations (cognitive)and (b)once the sound is (or is not)identified the sound is evaluated in terms of pleasantness-unpleasantness or the persons simply reacts to the stimuli (affective).A great portion of research in sound perception has been devoted to understanding cognitive processes of perceiving and identifying a sound (Bregman 1990, McAdams 1993, Gaver 1993).However in sound quality research most of the research has studied cognitive and affective evaluations of the sound rather then identification or categorization of sounds 2 (Ballas 1993). Research on human perception and evaluation of sound have traditionally sought to establish the underlying perceptual dimension that people use when evaluating (Ballas 1993, Gabrielsson and Sjögren 1979, Guski 1997, Osgood et al 1957) or reacting to sounds. A common way of establishing a lexicon for studying underlying perceptual dimensions is by the use of the semantic differential technique (Guski 1997).The semantic differential technique was developed by Osgood and colleagues (Osgood et al. 1957) and involves ratings of concepts or objects on 7- point bipolar scales. (Björk 1985) have applied this technique to evaluate sounds and sound reproduction. Typical dimensions are evaluation, potency and activity.

Unfortunately though, researchers in auditory perception have not been explicit in differentiating between cognitive evaluations and affective reactions. People can make evaluations of and/or reaction to sounds (Ballas 1993, Gabrielsson and Sjögren 1979, Guski 1997, Osgood et al 1957).

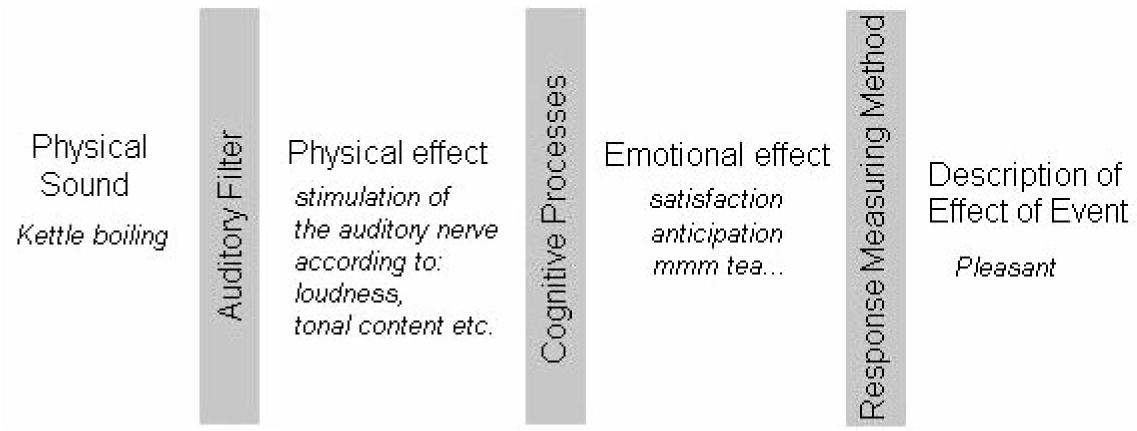

Figure 4.8. An emotion measurement process of a kettle's sound

Typical items in an experiment on auditory perception may be sharpness, pleasantness, and annoyance. It can be argued that the rated sharpness of a sound is an evaluation of the sound. A person uses his/her analytic ability to judge the perceptual property sharpness. Annoyance on the other hand, is a mainly affective reaction to a sound. The antecedent to annoyance could of course be cognitive/evaluative ("this sound is very sharp, therefore it is disturbing") and, conversely the state annoyance could be evaluated cognitively ("I am annoyed, probably because this sharp sound is really disturbing ").However, the core of annoyance is an affective reaction.

The pleasantness rating is more complex and it could be argued that for such items a confounding exists. Take the example "this sound is pleasant" and compare it with "this sound makes me feel pleasant".The former refers to a situation where the sound is the object, while the latter refers to a situation where the individual reaction to the sound is the object. The research discussed here focuses on the affective component of product sound quality and sound design; that is how individuals react and affectively evaluate sounds with different qualities. Affective reactions and affective evaluation of auditory information is little studied and, in large, neglected component of product sound quality development. This thesis addresses the importance of an "affective product sound quality" approach. Before reviewing research related to emotions and sound perception we need to consider some theories of emotion perception.

4.6. Theories of Emotional Perception and Processing

Education on emotion has either tended to think of emotional experience as either;

- Discrete feeling states or
- States that can be placed along dimensions of experience.

Both approaches have their merits and can be applied to understand human affective perception.

4.6.1. Specific/Discrete Emotion Approach

The specific or basic emotions approach postulates the existence of a limited number of fundamental emotions that can be found cross-culturally (Lazarus 1991).The use of the term "basic emotions" is still highly controversial as researchers do not agree neither in the number and subset of emotions that can be considered as basic (classifications range from two to nine), nor in what sense they are so. In general, basic emotions seem to be universally found across societies in humans, have particular manifestations associated with them (facial expressions, behavioral tendencies, physiological patterns),have adaptive, survival-related functions that evolved through their value in dealing with situations which are or were fundamental in life, can be seen as prototypical emotional states of a number of emotion families (e.g., rage and anger belong in the same family, anger being the more standard or prototypical case, while rage corresponds to a highly intense anger),and can be taken as building blocks out of which other, more complex emotions form.

4.6.2. Dimensional Approaches

Some researchers prefer to characterize emotions in terms of continuous dimensions, rather than as discrete categories. The two most commonly used dimensions are valence (positive/negative) and activation or arousal (calm/excited) (Russell 1980).

The idea of a dimensional representation of emotional experience is not new. (Wundt 1924) concluded from introspection of affective reactions to auditory rhythms, that three dimensions may account for all possible differences between affective states: pleasure-displeasure, strain-relaxation, and excitement-calmness. However, more recent evidence from judgments of similarity between emotion adjectives, judgments of facially expressed emotions, self-reported mood, and psycho physiological measurements suggest that two dimension account for the main variance in affect.

These views are not incompatible. In fact, basic emotions can be easily placed in an emotional space defined by these dimensions, although two dimensions alone are not enough to distinguish among all the basic emotions-intense fear and anger, for example, are both characterized by negative valence and high arousal. A third dimension, dominance or potency (powerfulness/powerlessness), is sometimes added. Thus, it appears as if the three affect dimensions overlap with (Osgood et al. 1957) semantic dimensions. Figure 4.9 shows a dimensional account (the affect circumplex) with specific emotions or affective states incorporated as combinations of the two axes.

4.7. Measurement of Emotional Reactions to Sound

Regardless of if one considers emotions as discrete states or as dimensions, the measurement of emotional responses are fundamentally similar. Typically, emotions can be measured by self-reports, by observation of various behaviors, and by recording of physiological responses.

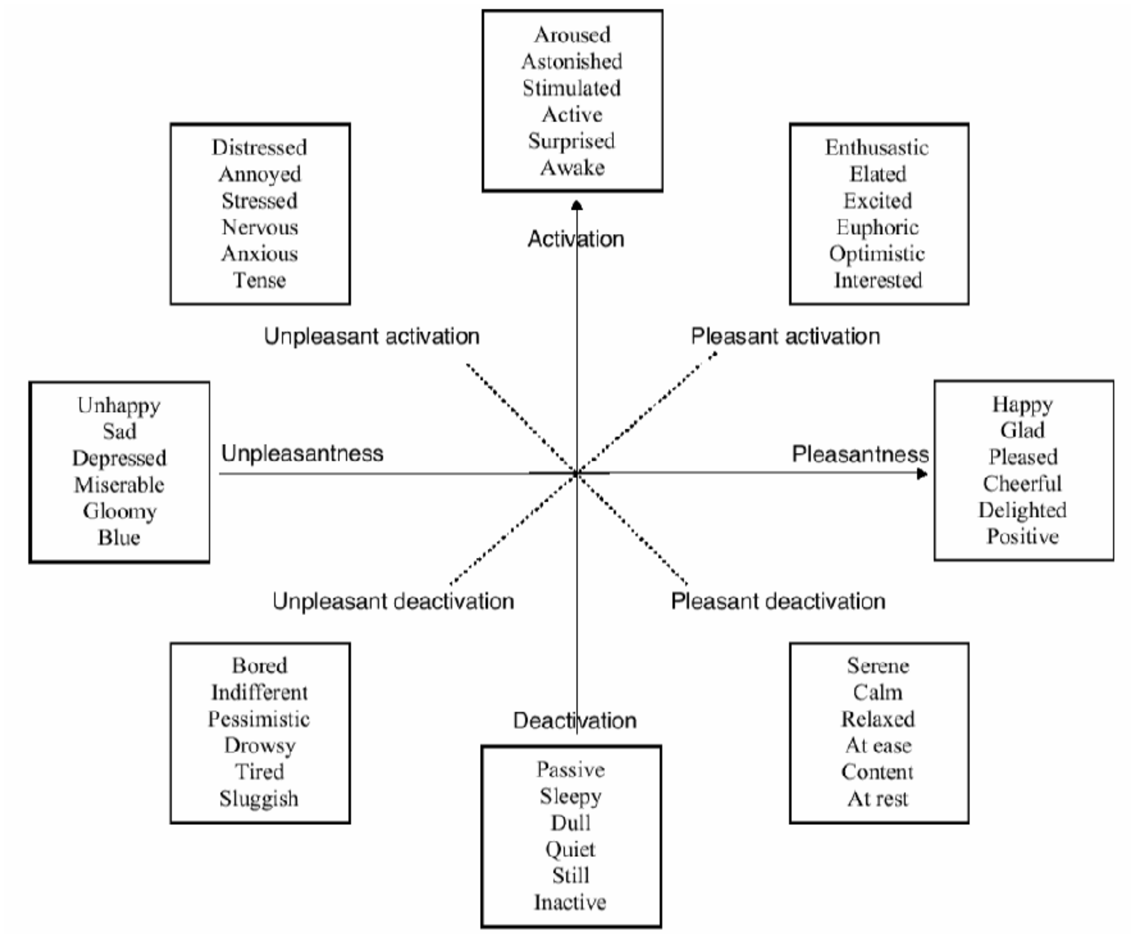

Figure 4.9. The affect circtcumplex

(Source: Västfjäll and Kleiner 2001)

4.7.1. Self-report

Self-report measures rely on that participants accurately can report their felt emotion. Although there are a large number of different instrument, there are similarities between them.

Below are a few examples of classes of self-report measures given.

Single-item measures are typically intended to measure global affective states (overall, how unpleasant do you feel?) or to measure specific emotions (how angry are you?).Other measures use graphical representation of, for instance, happy and sad faces (Bradley and Lang 2000).Such scales have the advantage of being understood by different populations in different cultures. Multiple-item measures instead consist of a list of emotion related adjectives that the participants are required to check.

Since it may be advantageous to continuously record participants ' affective experiences, a number of different "on-line" or real-time rating scales have been developed such using computer interfaces (Gulbol et al. 2002) or other devices.

4.7.2. Behavior

Various emotion-sensitive tasks may be used as the indication of the experienced emotion. There are a large number of performance measures that have been shown to be influenced by the currently experienced emotion. Below are a few of them reviewed.

(Clark 1983) argued that the time taken to count from 1 to 10 is a sensitive measure of changes in naturally occurring depressed mood. (Clark and Teasdale 1985) recorded participants' counting's and replayed through a polygraph to obtain a visual speech print from which duration of counting could be measured. They found that the negative emotion was associated with longer count times than was positive emotion. Similar results have been obtained in studies of vocal expression of emotions, where speech rate typically decreases in depression (Scherer 1986).

A number of investigators have used a number writing task in which participants are asked to write down numbers, in descending order from 100 and are given 1 min to do so. (Clark 1983) and (Kenealy 1988) found that this measure discriminated between negative and positive moods. (Clark 1983) has shown that incentives ratings are responsive to induced moods in that loss of incentive is a feature of negative affect. In an attempt to measure incentives, (Clark and Teasdale 1985) asked participants, given the chance at the moment of rating, how much they would like to engage in each of eight positive activities: "Right now, how much would you like to: 1)sit at home in your favorite couch reading a book, 2)have coffee with old friends, 3)go out shopping, 4)go to a party, 5)take a long, hot bath, 6)listen to your favorite record with your best friends, 7)take some physical exercise for yourself, and 8)go for a meal with some new and interesting people. Clark and Teasdale found that participants exposed to sad music gave lower incentive ratings than did participants exposed to happy music. Subjective probability estimates of future events have been shown to be responsive to induced moods; in than negative mood participants are more pessimistic than positive mood participants. Participants exposed to negative stimuli typically give lower estimates of the probability of future successes and lower estimates of the number of past successes than participants exposed to positive stimuli.

A procedure in which participants were asked to close their eyes and make an approximation of a specified distance by placing their hands those distances apart. Using this method, it was found that participants exposed to negative stimuli estimated a significantly smaller distance than did participants exposed to a positive stimulus. In sum, both psychomotor (i.e. writing speed) and psychological (i.e. incentives) mood-sensitive measures have been found to differentiate between negative, neutral and positive emotions.

4.7.3. Physiology

Many different physiological processes indicate emotional experiences. For instance, video recordings of the face can obtain measures of facially expressed emotions during emotional experience. Electro-myographical (EMG) measures of facial muscle contractions can also be used. This is typically measured by attaching electrodes in the facial region and measure muscle micro-movements. Activity in the corrugators muscle (eyebrow contraction) can be linked to unpleasant emotions whereas activity in the zygomatic (activated during smile) may be linked to pleasant emotions. Other measures of activity in the autonomic nervous system can be used to infer specific emotion the person is experiencing (Larsen and Fredrickson 1999).As already mentioned, vocal measures of experienced emotions can also be obtained (Scherer 1986). Below are results from studies using self-reports and physiological indicators of emotional reactions to sound further discussed.

4.8. Sound and Emotional Reactions

Previous research on emotional reactions to sound has predominantly studied different aspects of one single affective state; annoyance .Annoyance has been shown to correlate moderately with objective metrics such as equivalent dB(A)level for community noise, and with psychoacoustic metrics such as loudness, sharpness, roughness for specific sound sources (Guski 1997).

The notion of positive-negative responses to auditory stimuli is not new. Some early research by Wundt suggested that emotional reactions to sound could be mapped on a Pleasantness-unpleasantness (Lust-Unlust) dimension (Wundt 1924). Wundt argued that an affect curve (Figure 4.10.) could describe the course of emotional reaction as a function of stimulus intensity (above the absolute threshold).

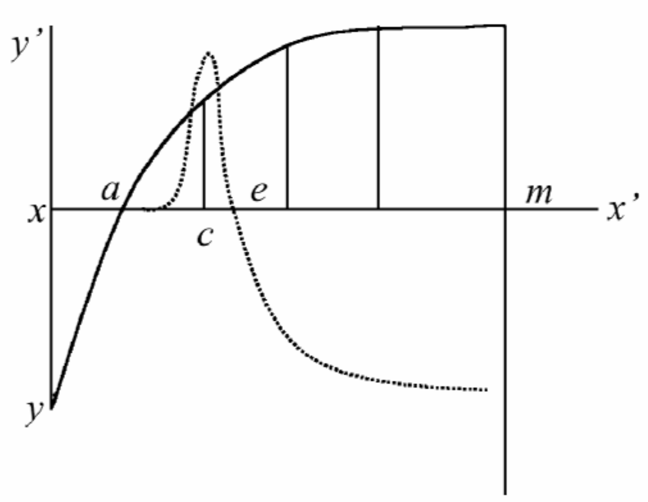

Figure 4.10. The Wundt-curve
(Source: Västfjäll and Kleiner 2001).

Figure 4.10. shows that the intensity of the emotional reaction increases with stimulus intensity. The dimension y-y' represent intensity of sensation, and the abscissa x-x 'the stimulus level. Point a is the absolute threshold, and m is the maximum stimulus height. The dotted curve is the affect curve (Gefühlskurve). Wundt suggested that the affect curve has an asymmetrical bell shape that grows until reaching maximal positive value c, and then decreases into a change from positive to negative emotional reaction (point e). In auditory research, the affect curve proposed by Wundt has been well validated (Todd 2001).For instance; pair comparison studies of tones similar in loudness have found that frequencies between 200 and 1000 Hz are most pleasant. It was understood that among tones varying in loudness (40-90 dB), 50 dB gives maximal hedonic responses. Below 60 dB low frequencies are more pleasant than high, whereas the reverse was found for intensities above 60 dB. On the basis of the Wundt-curve, "equal pleasantness contours" have been constructed for tones varying in intensity and frequency (Todd 2001).Even though these studies provide some insight into human

reactions to sounds they may have low ecological validity in that pure tones have been used. A number of experiments that studied emotional reactions to a wider range of auditory stimuli have found that more than one dimension is needed to describe human reactions. (Björk 1985) studied the perceived sound quality of various natural sounds. The point of departure for Björk's study was (Mehrabian and Russell 1974)'s theory for affective perception of environments. Mehrabian and Russell proposed that the affect eliciting qualities of an environment (such as an auditory environment) may be characterized by the two dimensions of pleasantness and arousal. (Björk 1985) factor analyzed 85 participants ' ratings of the affective quality of 15 natural sounds and found that the two first factors replicated Mehrabian and Russells pleasantness and arousal dimensions. In an ambitious research agenda, topics have systematically studied self-report and psycho physiological indicators of emotional reactions to sound. Their research program uses graphical scales assessing valence, activation and dominance (Mehrabian and Russell 1974).Over the last ten years, Lang and collaborators have focused on emotional reactions to pictures and even standardized a corpus of pictorial stimuli, the International Affective Picture System (IAPS).When people look at pictures with emotional content (e.g. snakes, children, war victims, flowers etc.),reliable patterns of somatic, visceral and central system change can be observed. Moreover, these physiological changes are highly correlated with self reported emotional reactions in terms of valence and activation. With the hypothesis that different modalities utilize the same emotional system (Panksepp 1995), (Bradley and Lang 2000) suggested that naturally acoustic stimuli should exhibit similar physiological responses and self-reports as pictorial stimuli. In support of this Bradley and Lang found that self reported reactions to 60 natural sounds were scattered in a two-dimensional space of pleasantness and arousal. Moreover the reactions were clustered along two axes, one stretching from low activation and neutral valence to unpleasant high activation, and the other one from low activation and neutral valence to pleasant high activation. Figure 4.11. is an adaptation of Bradley and Lang ´s results for both emotional sounds and pictures with stimuli scattered along the two axes. Earlier research on emotional pictures has consistently exhibited this pattern and this organization is consistent with a bi-motivational structure implying two systems of appetitive and defensive motivation (Lang 1995).The valence dimension primarily indicates which motivational system that is active, whereas the activation dimension indicated intensity or engagement with each of the systems (Lang et al. 1990).

Bradley and Lang further found that, for psycho physiological indices, facial (corrugator) EMG activity and startle reflexes were significantly higher for unpleasant sounds as compared to pleasant. For acoustical correlates only equivalent sound level was recorded where it was found that valence ratings was very weakly related to sound level (r =.07) and activation ratings was moderately related (r =.38).However, these correlations only accounted for 14% of the variance why the emotional reactions are due to other aspects of the stimuli. Taken together, Bradley and Lang concluded that emotional processing of acoustic stimuli highly resembles processing of emotional pictures. Following this it appears that affective processing and reactivity is not modality specific, but affective structures and systems may be shared by both visual and auditory processing.

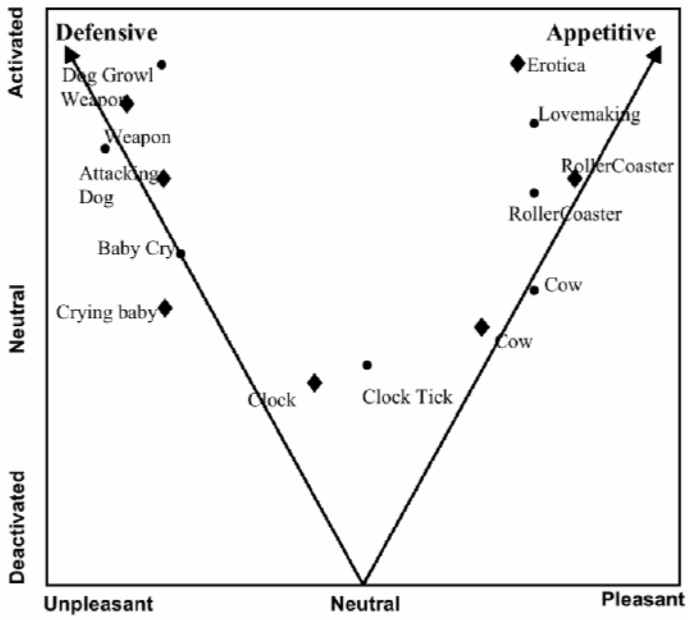

Figure 4.11. Ratings of pictures (squares) and sounds (circles) varying in pleasantness and activation

(Source: Bradley &Lang 2000)

4.8.1. Physical Correlates of Emotional Reactions to Some Everyday Sounds

In the domain of product sound design, (Västfjäll et al. 2002) studied emotional reactions to sounds recorded in the interior of commercial aircraft. The main aims were to a) identify dimensions underlying affective reactions and b)to find psychoacoustic and objective correlated to emotional reactions to the sounds. In two experiments 60 participants rated their affective reactions from listening to 20 interior aircraft sounds. In the first experiment participants rated their emotional reactions on each of 24 unipolar items. Principal component analysis across participants and sounds showed that the items pleased, happy, harmonious, depressed, bad mood, sad, optimistic, cheerful mood, enthusiastic, calm, relaxed, serene, nervous, stressed, and bored loaded on a valence dimension .The adjectives peppy, energetic, active, faint, tense, dull, quiet, tired and passive loaded on an activation dimension. The two dimensions accounted for 83 per cent of the variance. In the second experiment, participants made ratings on 12 bipolar scales that conformed to the results of the first experiment. In the third experiment, another 20 undergraduates rated the cognitive/perceptual dimensions of the same sounds. Standard level measures such as A,B,C,D-weighted sound level and loudness as well as more specialized measures such as sharpness, roughness (amplitude- and frequency modulation between 1 and 20 Hz: (Aures 1985), fluctuation strength (amplitude and frequency modulation between 15 and 300 Hz and tonal vs. noise spectra components (Bienvienue et al. 1991). The results suggested that the affective dimensions of valence and activation discriminate between affective reactions to the sounds. Moreover, the affective reactions were only weakly related to conventional sound quality with the exception that valence reactions (positive/negative reactions) were related to loudness. In the third Experiment it was shown that affective reactions to interior aircraft sound was related to perceptual and cognitive ratings. Valence was highly correlated with loudness (-.81)and the naturalness vs. artificiality of the reproduced sound (.74).Activation was related to sharpness (.58),fluctuations strength (-50) and prominence ratio (-.64).However, the perceptual ratings in turn were not related to the objective metrics (with the exception of loudness).These results thus suggested that existing objective metrics is only capturing parts of human sound perception, largely excluding important affective and cognitive evaluations. Following up these results (Västfjäll et al. 2002) performed experimental synthesis by systematically vary either the level of fundamental tone (around 100 Hz) and harmonics or the noise spectral envelope in steps of 3dB (from -12 to 12 dB)as compared to reference sound. As expected, valence ratings increased with increased loudness and audibility of tones, whereas activation increased with increasing noise spectra level.

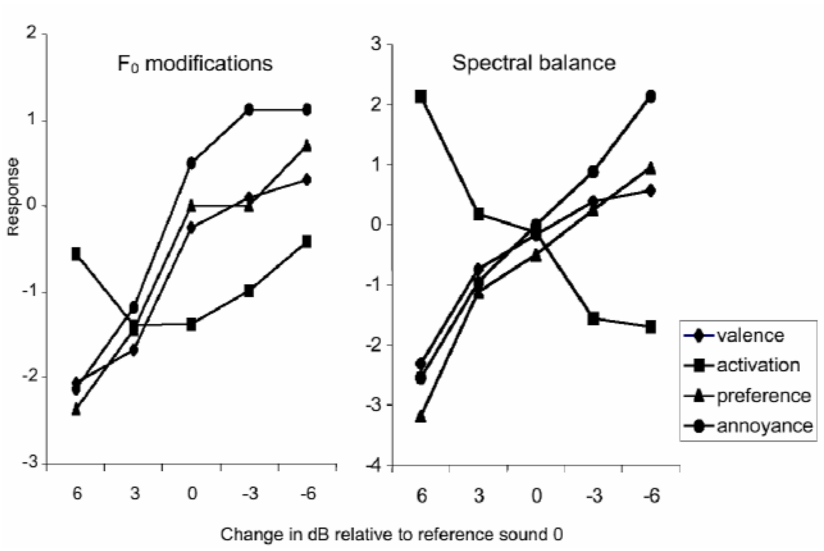

Figure 4.12. Mean ratings of valence, activation, preference, and annoyance for fundamental frequency and spectral balance modifications.

(Source: Västfjäll et al. 2002)

Independent of this research, (Bisping 1995, Bisping 1997) proposed that affective evaluations are fundamental to the perception of (interior car sound quality. Analogous to the affective reaction dimensions pleasantness and arousal, (Bisping 1997) suggested that pleasantness and powerfulness of sound form a two-dimensional perceptual space for evaluation of car interior sound quality. In three studies using both German and US samples, (Bisping 1995) found that ratings of quiet, annoying, desirable, booming, pleasant, rough, noisy, and friendly items loaded meaningfully on a factor interpreted as pleasantness, whereas the items racy, fresh, powerful, dynamic, fast, and exciting loaded on a factor related to powerfulness. This two-dimensional space was found to discriminate well between different types of interior car sounds. (Bisping 1997) reported that the sounds of luxury cars were positioned in the powerful/pleasant quadrant, while mainly sounds from sporty cars were scattered in the powerful/unpleasant quadrant. The ratings of interior sound from standard middle-sized cars were mainly found in the powerless/pleasant quadrant, whereas the powerless/unpleasant quadrant contained the sound from trucks and small cars. Bisping reported that the low frequency level envelope associated with the different engine orders were related to ratings of unpleasantness-pleasantness and weakness-powerfulness. Unpleasantness increased with the height of the envelope whereas power was associated with steep rise times or increase of the envelope. In additional experiments (Bisping 1995, Bisping 1997) experimentally manipulated the height of the envelope by increasing in steps of 3 dB from 0 to 12 dB. Magnitude estimation ratings showed that power increased linearly with increasing level, whereas pleasantness remained unaffected from 0 up to 6 dB, but from 9 to 12 db significantly decreased. Bisping's studies mainly concerned evaluations of the emotional character of the sound. It is however likely those emotional reactions to sound are similar to emotional evaluations. The ratings of emotional reactions to various single, static, or time-varying sound sources correlated highly with pleasantness and power ratings.

In summary, emotional perception of both single and multiple sound sources appears to be related to primary emotions dimensions recovered also in other areas such as picture processing, facial expression, and self-report ratings.

4.9. Other Determinants of Emotional Reactions to Auditory Stimuli

4.9.1. Mood and Individual Differences

Current research on noise perception has shown that affective reactions to auditory events are resulting both from noise characteristics and personality traits such as sensitivity to noise. Surprisingly, most of this research has neglected pre-existing affective states that the listener may experience before and while hearing the sound. Research in the domain of social, emotion and personality psychology suggests that pre-existing mood states influences most judgmental processes and moreover that affective influences on judgment frequently occur (Forgas 1995).Similarly, in auditory research it has been proposed that pre-existing cognitive processes and emotional states may influence the following evaluation of an auditory event (Blauert and Jekosch 1997).

It is easy to imagine that if a person is already annoyed or irritated the annoyance of a sound may be greater than if the person would feel calm and relaxed. Research in social judgment has convincingly shown that happy people tend to make more positive evaluations of objects, products and people than neutral or sad participants. Conversely, sad participants make a more negative evaluation than do neutral or positive participants (Forgas 1995).Findings of mood-congruent judgment may be assumed to also apply also to noise perception, so that people negative mood state make more negative judgments of the noise than do positive participants.

To test if mood influence annoyance reactions to an everyday sound, we used mood inductions (recall of personal experiences and reading of self-referent material) to elicit mild annoyance or a neutral affective state. Following the mood induction participants heard a sound and rated how annoyed they were by the noise.

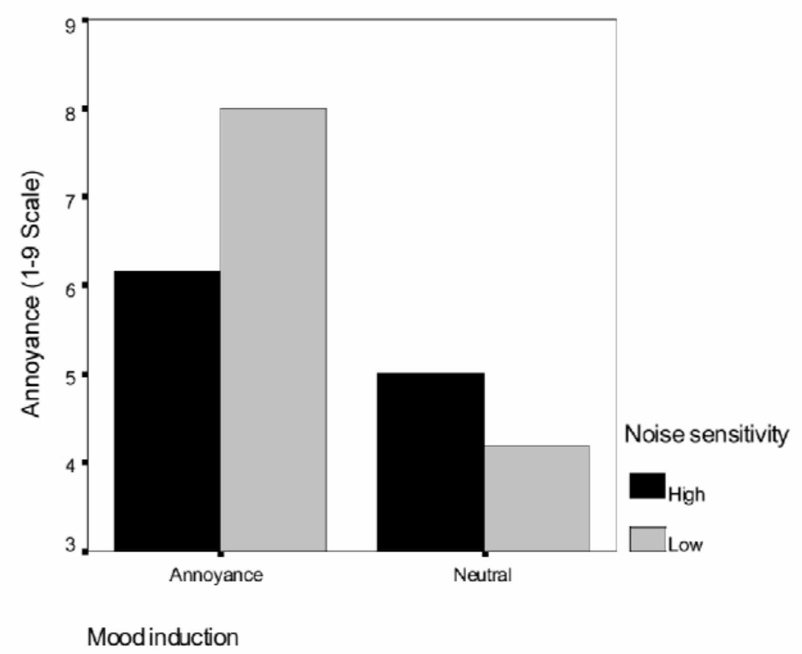

Figure 4.13. Mean annoyance ratings following mood induction. Ratings for each mood condition are divided in high and low noise sensitivity.

(Source: Västfjäll and Kleiner 2001)

The results indicated an overall effect of current mood on both annoyance and preference ratings. Overall, participants who already were annoyed (annoyance condition) rated themselves as more annoyed than did participants who were in a neutral affective state. Similarly, participants in the annoyance condition overall disliked the sounds more than participants in the neutral condition. These results thus suggest that current mood influences affective reactions as evaluations of auditory stimuli and is consistent with the mood-congruent judgment effect (Forgas 1995).However; the present results also indicated that current mood had different influences depending on individual sensitivity to noise.

Participants in the annoyance condition that reported being sensitive to noise also judged themselves as less annoyed than did participants low in noise sensitivity. For the neutral condition the reverse was true. Similarly, participants low in noise sensitivity receiving the annoyance mood induction disliked the sound more than did participants sensitive to noise. Again the reverse was found for the neutral condition. The counter-intuitive findings for the annoyance condition may reflect that the participants that are not noise sensitive generally may temporarily have a lowered threshold when their current mood is negative (annoyed). The difference between high and low noise sensitivity in the annoyance condition may also be accounted for by the fact that participants temporarily (annoyed low noise sensitivity participants)but not generally (as for high noise sensitivity individuals)give a higher weight to their current mood. Individuals generally sensitive to noise may use their knowledge and predispositions ("I 'm sensitive to noise in general") when judging and reacting to the noise. However, individuals with low noise sensitivity do not hold these dispositions and must therefore use something else as a frame of reference: their current mood ("right now, I 'm annoyed").

4.9.2. Situation Appraisal, Cognition, and Meaning

It has been shown that emotions are elicited and differentiated on the basis of dimensions or criteria in a person 's evaluation of the personal significance and meaning of an object or situation (Scherer 1999).Such appraisal criteria or dimensions include pleasantness (how pleasant is the sound?),novelty or attentional activity (how new is the sound?),goal significance (how relevant is the sound?),outcome uncertainty or unexpectedness (how well is the sound understood?),urgency or effort (how much mental effort is required?),control potential or situational control (can the sound be controlled?),coping potential or agency (who is responsible for the noise?),and value relevance or legitimacy (is it fair that I am being exposed to this sound?) (Frijda 1994, Scherer 1999, Smith and Ellsworth 1985, Västfjäll et al. 2002).It is (Västfjäll et al. 2002) tested if environmental sounds (Paris soundscapes) that were perceived as equally pleasant could be discriminated on basis of a number of auditory appraisal criteria. Participants were asked to describe their reactions in terms of how pleasant the soundscape was, how attention demanding it was, how much control they experienced, if they felt safe and could predict the sound, how much mental effort that was required, and if they wanted to get away from the situation (action tendencies).

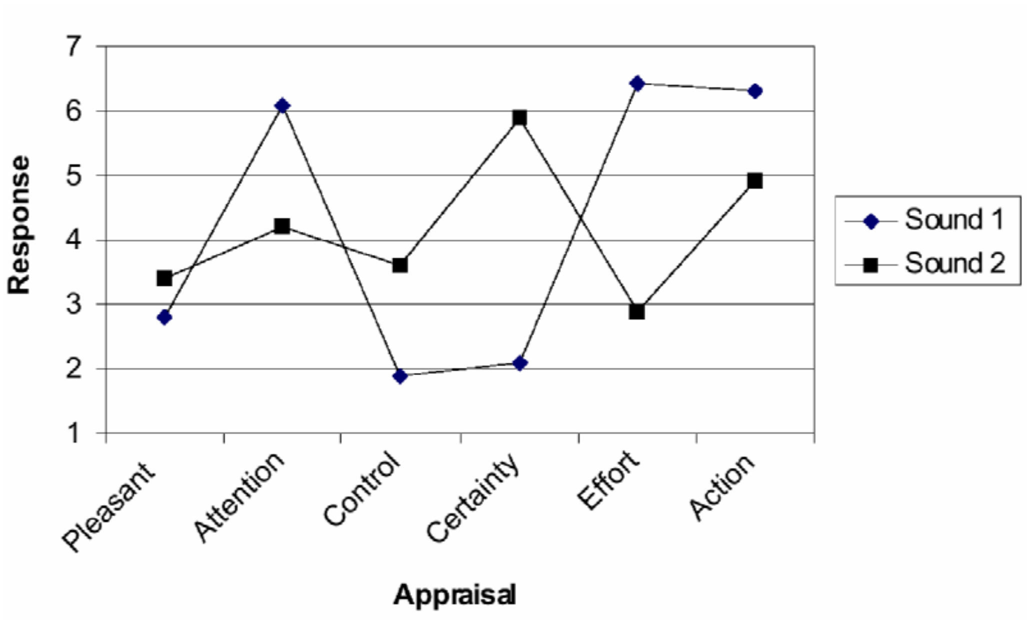

Figure 4.14. Appraisal ratings for two soundscapes.

(Source: Västfjäll et al. 2002)

Figure 4.14. shows ratings of appraisal judgments for two soundscapes perceived as equally pleasant. As may be seen, soundscape 1 was perceived as more attention demanding, less controllable, more uncertain, as requiring more mental effort and elicited more tendencies to move away from the environment, than did soundscape 2. These data suggest that factors related to subjective interpretation and meaning modulate the overall sound experience.

Consequently, It has been seen that different product sounds cause different emotions. Therefore it is likely that users will raise their expectations and demands concerning the "affective intelligence" of future product. In line with the notion that product sounds actually provide the user with information rather than just being a nuisance factor, future product sounds could be used to enhance the products' image. As it is going to be understood in further chapters, new concepts in branding have been developed with respect to those emotional affects of artifacts such as color, texture, sound etc.

CHAPTER 5

EMOTIONALLY SIGNIFICANT BRANDS
HOW?

“People spend Money when and where they feel good” – Walt Disney

5.1. Definition of Branding

A brand is something that encapsulates the key features of the products-Its image, sound, price and usage- in an easily recognizable and interesting form. And so goes the contemporary definition. Rather than huge advertisements and image or brand awareness, branding boils down to how a product makes a customer feel and that is where emotional branding comes in and that is where the competitive edge also comes in.

5.1.1. Introduction to Emotional Branding

From the many ways in which products and services are useful to us, a considerable share is either psychological or social. It is pursued that psychological and social goals and use products and services to achieve intrapersonal and interpersonal ends. Moods are controlled by wearing tough-looking sunglasses, by listening to nostalgic music, or by watching a comedy. People destine themselves to become 'feminine and motherly', or 'fame fatal', or 'career women' and purchase products and services that fit the image.

People hardly ever satisfy their needs with bare reality and live an 'enriched' reality, both subjective and shared. For example, fantasies help alleviate emotional distress (like loneliness and longing), motivate and arouse enthusiasm; or enable to experience or to revive emotions, which are unavailable in reality among other usages. People have fantasies of adventure, of omnipotence, of irresistible sex appeal as well as other fantasies of grand achievements and tremendous successes that in all probability shall never be realized. **Products and services support our enriched reality.** For most practical purposes, instruments designed for the achievement of psychological and social ends are not essentially different from means designed to create a desired experience, or from instruments to a physical effect. In all instances, people are trying to do something. In order to create emotionally significant brands, a deep understanding of our goals-beliefs-emotions system must be gained. (WEB_3)

The brand's symbolizations serve as a trigger to the feeling of anticipation towards the benefit that we attribute to the specific product or service. The brand Apple is the specific anticipation of original and exquisite design that enables to make an identity statement; that people have come to feel towards it.

If the anticipated outcome of consuming using or owning the particular product or receiving the service, is beneficial in a personally significant way, and there are no doubts to cloud the prevision of the benefit. Customers want it even more if the benefit is unique and if it is not accompanied by any drawbacks. (Perceived damage resulting from the price or the calories, for instance), which might impair users enjoyment.

From this standpoint, a designer can claim ownership of a brand only if his target consumers attribute to his product and/or service the ability of consistently delivering (exclusively, if possible) a certain desired experience or a beneficial result.

The following "Ten Commandments of Emotional Branding" illustrate the difference between traditional concepts of brand awareness and the emotional dimension a brand needs to express to become preferred.

5.1.1.1. From Consumers to People

Consumers buy, people live. In communication circles the consumer is often approached as the "'enemy” whom we must attack. It's us (meaning manufacturers, retailers, and their communications agencies) against them. Terminology like "breaking down their defenses, decoding their language, and strategizing to win the battle" is still commonly used. To create desire in customers in a positive manner without harassing or talking down to them .This can be achieved by using a win-win, partner-ship approach based on a relationship of mutual respect. After all, the consumer is best source of information. (Gobé 2001)

5.1.1.2. From Product to Experience

Products fulfill needs, experiences fulfill desires. Buying just for need is driven by price and convenience.

A product or shopping experience, such as REI stores' rock climbing walls or the Discovery Channel stores' myriad of "sound zones" has added value and will remain in the consumer's emotional memory as a connection made on a level far beyond need. For established products to attract and retain consumer interest, it is critical that innovative retailing, advertising, and new product launches capture their imagination. The lines are drawn every day between newness and tradition, between what is expected and the excitement of change. Curiosity in minds and sense of adventure often wins out over the known. However, a product can be old and new at the same time, if it continues to have emotional relevance for consumers. (Gobé 2001)

5.1.1.3. From Honesty to Trust

Honesty is expected. Trust is engaging and intimate. It needs to be earned. Honesty is required to be in business today. The federal authorities, consumer groups, and the people in general have an increasingly rigorous standard for products and will rate very quickly what needs to be on the shelf and what doesn't. Trust is something else altogether. It is one of the most important values of a brand and it requires real effort from corporations. It is what you would expect from a friend. One of the most powerful moves toward building consumer trust was retailers' implementation of the "no questions asked" return policy some years ago.

This strategy brings total comfort to customers and gives them the upper hand in their choices. A very smart decision indeed. Sincere efforts to know and contribute to the brand's community like those of Wal-Mart and FUBU are also great examples of building trust.

5.1.1.4. From Quality to Preference

Quality for the right price is a given today. Preference creates the sale. Quality is a necessary offering if you want to stay in business; it is expected and had better be delivered. Preference toward a brand is the real connection to success. Levi's is a quality brand, but it has currently lost its preferential status.

Victoria's Secret, a brand that has achieved an enviable and highly charged emotional connection with consumers today, is revolutionizing a new category and redefining the hosiery and beauty businesses-there is no stopping a brand when it is preferred.

5.1.1.5. From Notoriety to Aspiration

Being known does not mean that you are also loved. Notoriety is what gets you known. Conveying something that is in keeping with the customer's aspirations could be an innovative matter. Awareness is obviously not the only criterion to successful branding. Beyond awareness, it should be thought out what does AT&T really mean on an emotional level to consumers and is there really a difference for people between the well-known brands Exxon Mobil and Texaco. Nike is still a very notorious brand with great visibility, but is it as inspirational as it used to be.

5.1.1.6. From Identity to Personality

Identity is recognition. Personality is about character and charisma! Identity is descriptive. It is recognition.

Personality is about character and charisma. Brand identities are unique and express a point of difference vis-à-vis the competitive landscape. But this is only the first step. Brand personalities, on the other hand, are special. They have a charismatic character that provokes an emotional response. American Airlines has a strong identity, but Virgin Airlines has personality. (Gobé 2001)

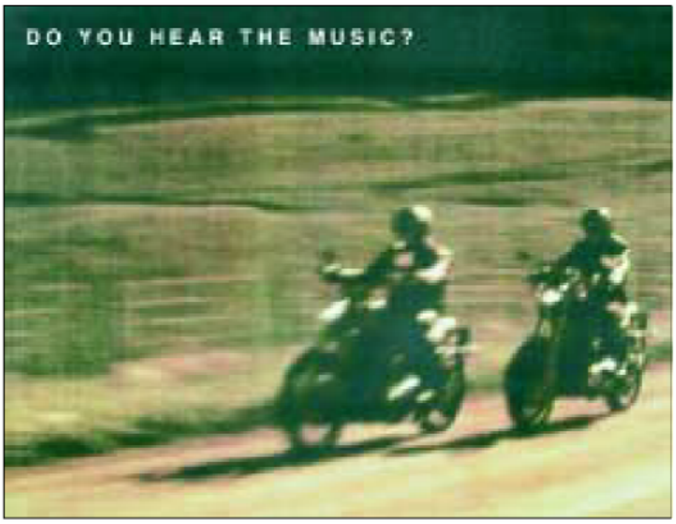

Figure 5.1. Harley Davidson motorbike's engine sound is its personality.

(Source: http://www.sandv.com/downloads/0303lyon.pdf)

5.1.1.7. From Function to Feel

The functionality of a product is about practical or superficial qualities. Sensorial design is about experiences. Functionality can become trite if its appearance and usage are not also designed for the senses.

Many marketers design for maximum function or visibility and not for the real experience of the consume.

Design is about human solutions, based on innovation that presents a new set of **sensory experiences**. Just like image, form, **sound,** even taste. Creating product identification by stressing product benefits is only relevant if product innovations are memorable and exciting to consumers. Absolut Vodka, the Apple iMac, and Gillette razors are brands that are focused on presenting fresh shapes and sensory experiences consumers appreciate.

5.1.1.8. From Ubiquity to Presence

Ubiquity is seen. Emotional presence is felt. Brand presence can have quite an impact on the consumer. It can forge a sound and permanent connection with people, especially if it is strategized as a lifestyle program.

There is hardly a stadium, a player uniform, a concert hall, or an urban space of size (billboards, bus stops, walls, and even the inside of bathroom doors) around the world that has not been used to promote a brand. And then, of course, there are the T-shirts, caps, mugs, and so on. But it has to be determined how effective they are. Most brand-presence strategies are based on the concept of quantity, not quality. The fear that a competitor might occupy the physical territory becomes the motivator, instead of a focus on inventive ways of making a real, lasting connection. Joe Boxer's wacky underwear vending machines which call out to passersby "Hey, do you need some new underwear?" and tell jokes is an inventive way of standing out and making a connection.

5.1.1.9. From Communication to Dialogue

Communication is telling. Dialogue is sharing. Communication, as conducted by main companies, is primarily about information-arid information is generally a one-way proposition. Take it and like it-hopefully. The bulk of most budgets are still spent on advertising efforts that approach consumers with the BI bomber-approach:

A massive, all-encompassing blanket advance at the target audience. Not only can advertising deliver more personal, targeted messages, but other-media, such as digital communications, PB, brand presence, and promotions can also stretch much further to really speak to consumers where they "live." Real dialogue implies a two-way street, a conversation with the consumer. Progress in digital media is now allowing; this evolution to take place, and finally will help foster a rewarding partnership between people and corporations.

5.1.1.10. From Service to Relationship

Service is selling. Relationship is acknowledgment. Who does not feel special when someone in a store or restaurant welcomes you by your own name! Service involves a basic level of efficiency in a commercial exchange. It is what allows or prevents a sale from taking place. But relationship means that the brand representatives really seek to understand and appreciate who their customers are. It is what you feel when you walk into a Quicksilver store and find that the music, the decor, and the salespeople all speak the same language; the customer's. It is the new expectation. Howard Shultz, CKO of Starbucks, speaks about romancing the consumer: "If we greet customers, exchange a few extra words with them and then custom-make a drink exactly to their taste, they will be eager to come back." (Gobé 2001)

5.2. Sounds Like Good Marketing

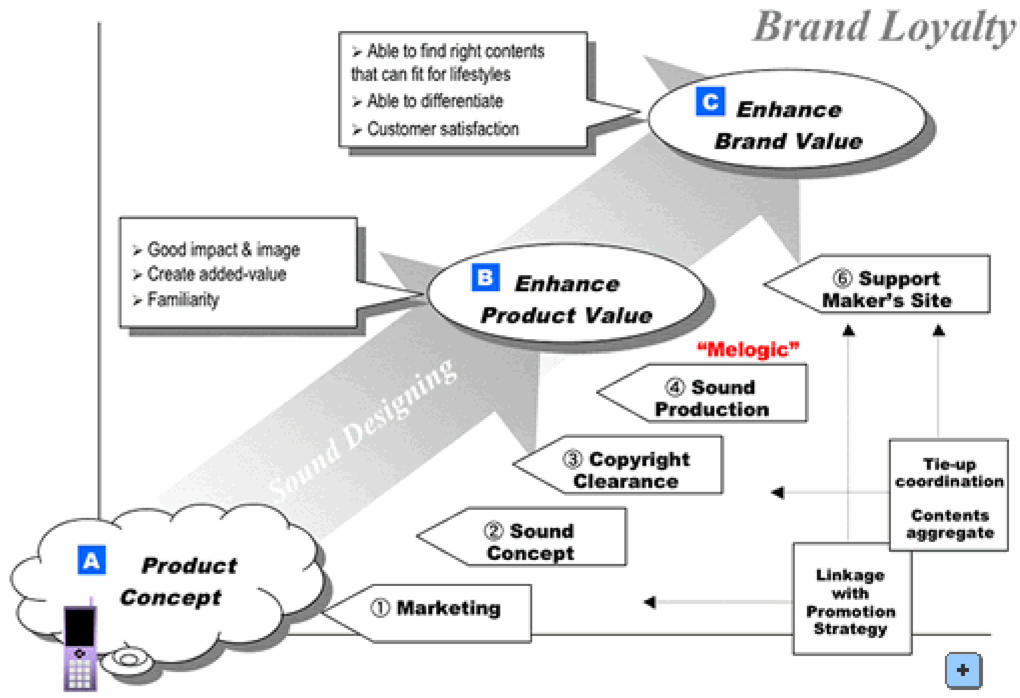

Figure 5.2 The elements of product concept foundation through electronic devices.

Generally, when consumers are exposed to products and their advertisements, they don't perceive a personal "need" for the product, nor do they intend to buy it. Because so many individuals are not actively seeking information about products, stimulating emotion and affect is a better way to distinguish a product and draw interest. Music is a particularly effective approach because it circumvents the rational mind and petitions directly to the emotional mind in which desire-driven shoppers revel.

Gerald Gorn demonstrates this in his study The Effects of Music in Advertising on Choice Behavior. (WEB_1)

The effects and benefits of sonic branding are highly evident in the computer technology company Intel. Their 'Intel Inside' sonic logo was introduced to create brand awareness for their 1994 Pentium Processor. Since then it has evolved into their premier marketing vehicle, used in television, radio, on-line and in-store advertising campaigns.

The success of the logo is due to several reasons. Firstly, it allows for unmistakable branding - confirming the identity of the brand in the consumer's mind every time it is heard. Secondly, it can be perceived almost subconsciously. This allows the advertiser to deliver the branded message without requiring the attention of the listener. And thirdly, it is recalled easily. Because it is musically evocative, sound operates continually at an emotional level. Repeated continually, a sonic logo can gradually alter brand perception in the minds of consumers - without them even realizing this.

Figure 5.3. Intel sonic logo impacts pleasure sense and carries its identity.

(Source: Intel Inc.)

By playing music while previewing products, Gorn found that subjects overwhelmingly (80 percent) chose products accompanied by the music they liked. Interestingly, subjects attributed their product preference to the qualities of the product (in this case, pen color) rather than the music after documenting and observing this effect, Gorn concluded that "an audience may be largely comprised of uninvolved potential consumers rather than cognitively active problem-solvers. Reaching them through emotionally arousing background features |such as music) may make the difference between their choosing and not choosing a brand. There are very real examples of the power of sound and music, such as a musical optic promotion created for Southern Comfort that increased sales.

The Canal Jeans Co. in Manhattan (US) successfully puts this idea into practice. It has hired DJs to spin hip and trendy record mixes while customers shop. These DJs are elevated on the store floor, near the entrance, so that customers pass by them as they shop. This provides the edgy and exciting feeling of a club for the young shoppers

(WEB_2). The in-store music a! Abercrombie & Fitch also does this, although in a less theatrical manner. Abercrombie carefully selects music that appeals lo its shoppers. Because its clientele is relatively particular in its tastes. Abercrombie & Fitch has the advantage of being able lo tailor its music lo their particular preferences. The sound is last and lively, brimming with youthful energy. This is consistent with the personality of Abercrombie & Fitch's aggressive, attitude-laden brand. Hence, the music not only stimulates customers, but also enables them to identify with the store. This is continued on the Abercrombie & Fitch Web site where these songs and many others are available as "A&F-Approved Tunes"

This brings us lo a second valuable application of sound-identification Particularly with Generation X and Generation Y shopper's, music is a device used for constructing an identity. By associating a brand with a particular genre of music, a firm can contribute lo the distinction of its identity, which is vital for attracting consumers. A growing number of retailers such as Gap, Toys "R" Us, and Eddie Bauer are investing in customized music programs with AEI Music Network, a company that crafts music collections specifically tailored to a company's brand image from its library of over seven million songs. American Eagle Outfitters includes music reviews within the catalogs that it mails to customers, as well as profiles of select musicians. The selections range from rock to hip-hop, assuring that most visitors will find something suited lo their own taste. Staples of hip youth culture, such as the Beastie shoppers, are featured, as well as little-known emerging acts, thereby catering lo shoppers' current pleasures but also providing means lo develop new interests via the inside filter of their favorite brand. All music featured in the catalog is also available for purchase on the American Eagle Web site. For those shoppers who discover a new favorite band in the catalog, the band, as well as its image and sound, are permanently associated with AF. Such thorough and personalized service enables AE to transcend remedial product-oriented marketing, and reach into the much more sophisticated and satisfying realm of supplementing and enabling entire lifestyles for its clients. (Gobé 2001)

The Discovery Channel has intelligently incorporated sound into its stores in such a way as to tailor an engaging and personalized encounter as well as enhance its own brand identity with consistency. For example, certain sections within the stores are demarcated not by partitions, but rather amorphous sound zones. Customers drift from one section of the store to the next, and the product changes are accompanied by corresponding changes in sound and music. This makes the experience of wandering through the stores into a fun adventure. Shoppers don't know what kind of sounds or music will surprise them next, which encourages them to explore the entire store as opposed to one area of interest. This exciting sound experience as well as tons of interactive devices, also entertains the kids, keeping the little ones occupied while mom and dad shop and explore. Kids and adults have a better shopping experience. The Santa Monica store has an attraction for children, which features representations of various animals that emit the corresponding sounds, as well as weight scales that indicate your weight on different planets in the solar system.

The media in the Discovery Channel stores is designed to be a function of the space; some areas have sound, some none, and some areas have sounds, music, and video all together, depending on what works best. All the music and sounds are available for sale, which adds to the pleasure of the trip since a part of the fun can be brought home, and this will contribute to the recall of the store and overall brand experience at a later date.

The Museum of Modern Art (MoMA) in New York City is another innovator in the use of sound and technology for creating stimulating, personalized service. For a $4.50 rental fee, visitors to the museum can rent Acoustiguide, a digital player and headset that provides a personal tour of the museum. Works and genres throughout the museum are labeled by numbers that correspond to tracks on the Acoustiguide. Visitors can pick and choose among these tracks, tailoring their own, personal tour. With this technology, MoMA (and certain other museums) are providing service that price considerations previously precluded from being available to the masses.

In addition MoMA has turned the Acoustiguide into an independent marketing device. In MoMA's exhibition ModernStarts (fall 1999-spring 2000). the Acoustiguide tour was set to music from the late nineteenth and early twentieth reunifies, which it encompassed. Other tracks were freestanding, only there to embellish the viewing experience. And, as the Acoustiguide informed listeners. The songs on the digital tour were sold as ModernStaris. a S14.98 CD compilation in the museum gill shop. In this way, MoMA has created, in its digitally recorded tour, individualized service, enjoyable atmosphere, and a vehicle for (subtly) advertising one of its product offerings. Incentive for attending the museum, learning about art history, and buying museum merchandise are cleverly wrapped up in one considerate, economical service.

Mega stores should consider emulating the MOMA Acoustiguide with headsets of their own. The potential of such devices is immense. Headsets could offer shoppers musically oriented guided tours or simply be a way of relaxing and "tuning the world out" while they shop to the music of their choice. The research on sound, as well as its applications in branding, is so extensive that to provide a comprehensive illustration of its potential uses is impossible. Research has shown us that music most definitely affects the speed of shopping, the amount of lime spent in the store, the amount of lime people will spend waiting for things, and the amount of money people will spend. But in terms of the type of music, it is necessary to experiment. As a general rule, quieterclassical music calms; one store, Asada, even found that when classical music was played, people spent 20 percent more. (Huron and Gardner 1985)

Although it's difficult to distinguish instinctual perceptions from cultural ones, scientific research has confirmed the broad generalized responses that music can cause, and the connections between particular sounds and music and certain emotional states.

Table 5.1. Different sounds on subjects who reported the following connotations.

Tempo	Slow	sadness, boredom, disgust
	Fast	activity, surprise, happiness, pleasantness, potency, fear, anger
Pitch level	Low	boredom, pleasantness, sadness
	High	surprise, potency, anger, fear, activity
Amplitude	Small	disgust, anger, fear, boredom
Modulation	Large	happiness, pleasantness, activity, surprise

In another study, subjects reported the following states associated with these particular songs:

Table 5.2. Subjects who heard Mendelssohn's "Song without Words" were more likely to be helpful immediately after than those who heard the other songs or no music at all.

SONG	CONDITION REPORTED BY SUBJECTS
Mendelssohn's "Song without Words"	Peaceful feelings
Duke Ellington's "One O'clock Jump”	Joyful feelings
John Coltrane's "Meditations"	Irritated Feelings

5.3. Music through Branding

Music plays a special role in our emotional lives. The responses to rhythm and rhyme, melody and tune are so basic, so constant across all societies and cultures that they must be part of our evolutionary heritage, with many of the responses pre-wired at the visceral level. Rhythm follows the natural beats of the body, with fast rhythms suitable for tapping or marching, slower rhythms for walking, or swaying. Dance, too, is universal. Slow tempos and minor keys are sad. Fast, melodic music that is danceable, with harmonious sounds and relatively constant ranges of pitch and loudness, is happy. Fear is expressed with rapid tempos, dissonance, and abrupt changes in loudness and pitch. The whole brain is involved-perception, action, cognition, and emotion: visceral, behavioral, and reflective. Some aspects of music are common to all people; some vary greatly from culture to culture. Although the neuroscience and psychology of music are widely studied, they are still little understood. We do know that the affective states produced through music are universal, similar across all cultures. The term "music," of course, covers many activities -composing, performing, listening, singing, and dancing. Some activities, such as performing, dancing, and singing, is clearly behavioral. Some, such as composing and listening, are clearly visceral and reflective. The musical experience can range from the one extreme where it is a deep, fully engrossing experience where the mind is fully immersed to the other extreme, where the music is played in the background and not consciously attended to. But even in the latter case, the automatic, visceral processing levels almost definitely register the melodic and rhythmic structure of the music, subtly, subconsciously, changing the affective state of the listener. (Hinton et al. 1994)

Music impacts all three levels of processing. The initial pleasure of the rhythm, tunes, and sounds is visceral, the enjoyment of playing and mastering the parts behavioral, and the pleasure of analyzing the intertwined, repeated, inverted, transformed melodic lines reflective. To the listener, the behavioral side is vicarious. The reflective appeal can come several ways. At one extreme, there is the deep appreciation of the structure of the piece, perhaps of the reference it makes to other pieces of music. This is the level of music appreciation exercised by the critic, the connoisseur, or the scholar. At the other extreme the musical structure and lyrics might be designed to delight, surprise, or shock.

Finally, music has an important behavioral component, either because the person is actively engaged in playing the music or equally actively singing or dancing. But someone who is just listening can also be behaviorally engaged by humming, tapping, or mentally following-and predicting-the piece. Some researchers believe that music is as much a motor activity as a perceptual one, even when simply listening. Moreover, the behavioral level could be involved vicariously, much as it is for the reader of a book or the viewer of a film. (Boorstin 1990)

Rhythm is built into human biology. There are numerous rhythmic patterns in the body, but the ones of particular interest are those that are relevant to the tempos of music: that is, from a few events per second to a few seconds per event. This is the range of body functions such as the beating of the heart and breathing. Perhaps more important, it is also the range of the natural frequencies of body movement, whether walking, throwing, or talking. It is easy to tap the limbs within this range of rates, hard to do it faster or slower. Much as the tempo of a clock is determined by the length of its pendulum, the body can adjust its natural tempo by tensing or relaxing muscles to adjust the effective length of the moving limbs, matching their natural rhythmic frequency to that of the music. It is therefore no accident that in playing music, the entire body keeps the rhythm. All cultures have evolved musical scales, and although they differ, they all follow similar frameworks. The properties of octaves and of consonant and dissonant chords derive in part from physics, in part from the mechanical properties of the inner ear. Expectations play a central role in creating affective states, as a musical sequence satisfies or violates the expectations built up by its rhythm and tonal sequence.

Minor keys have different emotional impact than major keys, universally signifying sadness or melancholy. The combination of key structure, choice of chords, rhythm, and tune, and the continual buildup of tension and instability create powerful affective influences upon us. Sometimes these influences are subconscious, as when music plays in the background during a film, but deliberately scored to invoke specific affective states. Sometimes these are conscious and deliberate, as when we devote our full conscious attention to the music, letting ourselves be carried vicariously by the impact, behaviorally by the rhythm, and reflectively as the mind builds upon the affective state to create true emotions.

We use music to fill the void when pursuing otherwise mindless activities, while stuck on a long, tiring trip, walking a long distance, exercising, or simply killing time. Once upon a time, music was not portable. Before the invention of the phonograph, music could be heard only when there were musicians. Today we carry our music players with us and we can listen twenty-four hours a day if we wish. Airlines realize music is so essential that they provide a choice of styles and hours of selections at every seat.

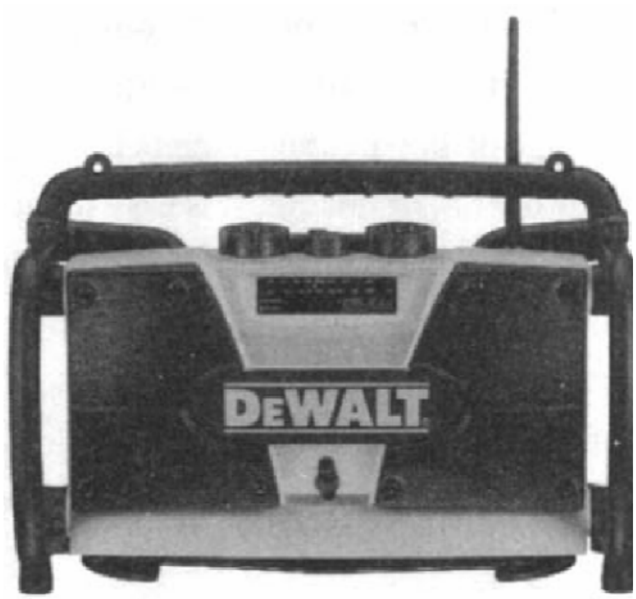

Figure 5.4. Music everywhere.While drilling holes or recharging batteries, while taking photographs, on your cell phone. While driving a car, jogging, flying in an airplane, or just plain listening to music. Figure shows the DEWALT battery charger for portable tools, with built-in radio (Image a courtesy of DeWALT Industrial Tool Co. Image b courtesy of Fujifilm USA. Note: This model is no longer available.)

(Source: Norman 2003)

Figure 5.5. Voice recorder with digital mp3 player

(Source: Iriver Inc.)

Automobiles come equipped with radios and music players. And portable devices proliferate apparently endlessly, being either small and portable or combined with any other device the manufacturer thinks you might have with you: watches, jewelry, cell phones, cameras, and even work tools (Figure 5.4. & 5.5.). Whenever I have had construction work done on a home, I noted that, first, the workers brought in their music players, which they set up in some central location with a super-loud output; and then they would bring in their tools, equipment, and supplies. DEWALT, a manufacturer of cordless tools for construction workers, noticed the phenomenon and responded cleverly by building a radio into a battery charger, thus combining two essentials into one easy-to-carry box. The proliferation of music speaks to the essential role it plays in our emotional lives. Rhyme, rhythm, and melody are fundamental to our emotions. Music also has its sensuous, sexual overtones, and for all these reasons, many political and religious groups have attempted to ban or regulate music and dance. Music acts as a subtle, subconscious enhancer of our emotional state throughout the day. This is why it is ever-present, why it is so often played in the background in stores, offices, and homes. Each location gets a different style of music: Peppy, rousing beats would not be appropriate for most office work (or funeral homes). Sad, weepy music would not be conducive to efficient manufacturing. (Hinton et al. 1994) The problem with music, however, is that it can also annoy-if it is too loud, if it intrudes, or if the mood it conveys conflicts with the listener's desires or mood. Background music is fine, as long as it stays in the background. Whenever it intrudes upon our thoughts, it ceases to be an enhancement and becomes an impediment, distracting, and irritating. Music must be used with delicacy. It can harm as much as help. But if music can be annoying, what about the intrusive nature of todays beeping, buzzing, and ringing electronic equipment this is noise pollution gone rampant. If music is a source of positive affect, electronic sounds are a source of negative affect. In the beginning was the beep. Engineers wanted to signal that some operation had been done, so, being engineers, they played a short tone. The result is that all of our equipment beeps at us. Annoying, universal beeps. Alas, all this beeping has given sound a bad name. Still sound, when used properly, is both emotionally satisfying and informationally rich. Natural sounds are the best conveyers of meaning: a child laughing, an angry voice, the solid "clunk" when a well-made car door closes. (Coates 2003) The unsatisfying tinny sound when an ill-constructed door closes. The "kerplunk" when a stone falls into the water. But so much of our electronic equipment now bleats forth unthinking, unmusical sounds that the result is a cacophony of irksome beeps or otherwise unsettling sounds, sometimes useful, but mostly emotionally upsetting, jarring, and annoying. When working in the kitchen, the pleasurable activities of cutting and chopping, breading and sautéing, are continually disrupted by the dinging and beeping of timers, keypads, and other ill-conceived devices. It is possible to produce pleasant tones instead of irritating beeps. The kettle in figure 5.6 produces a graceful chord when the water boils. The designers of the Segway, a two-wheeled personal transporter, "were so obsessed with the details on the Segway HT that they designed the meshes in the gearbox to produce sounds exactly two musical octaves apart-when the Segway HT moves, it makes music, not noise." Some products have managed to embed playfulness as well as information into their sounds. Thus, Handspring Treo, a combined cellular telephone and personal digital assistant, has a pleasant three-note ascending melody when turned on, descending when turned off. This provides useful confirmation that the operation is being performed, but also a cheery little reminder that this pleasant device is obediently serving me. Cell phone designers were perhaps the first to recognize that they could improve upon the grating artificial sounds of their devices. Some phones now produce rich, deep musical tones, allowing pleasant tunes to replace jarring rings. Moreover, the owner can select the

Figure 5.6. Richard Sapper's kettle with singing whistle, produced by Alessi. Considerable effort was given to the sound produced by the whistling spout: a chord of "e" and "b," or, as described by Alberto Alessi, "inspired by the sound of the steamers and barges that ply the Rhine."

(Source: Alessi Web Site)

allowing each individual caller to be associated with a unique sound. This is especially valuable with frequent callers and friends. "I always think of my friend when I hear this tune, so I made it play whenever he calls me," said one cell phone user, describing how he chose "ring tones" appropriate to the person who was calling: joyful pleasant tunes to joyful pleasant people; emotionally significant tunes for those who have shared experiences; sad or angry sounds to sad or angry people. But even were we to replace the grating electronic tones with more pleasant musical sounds, the auditory dimension still has its drawbacks. On the one hand, there is no question that sound-both musical and otherwise-is a potent vehicle for expression, providing delight, emotional overtones, and even memory aids. On the other hand, sound propagates through space, reaching anyone within range equally, whether or not that person is interested in the activity: The musical ring that is so satisfying to a telephone's owner is a disturbing interruption to others within earshot. Eyelids allow us to shut out light; alas, we have no ear lids. When in public spaces-the streets of a city, in a public transit system, or even in the home-sounds intrude. The telephone is, of course, one of the worst offenders. As people speak loudly to make sure they are heard by their correspondent, they also cause themselves to be heard by everyone within range. Telephones, of course, are not the only intrusions. Radios and television sets, and the beeps and bongs of our equipment. More and more equipment comes equipped with noisy fans. Thus, the fans of heating and air-conditioning equipment can drown out conversation, and the fans of office equipment and home appliances add to the tensions of the day. When we are out of doors, we are bombarded by the sounds of passing aircraft, the horns and engine sounds of motor traffic, the warning back-up horns of trucks, the loud music players of others, emergency sirens, and the ever-present, shrill sounds of the cellular telephone ring, often mimicking a full musical performance. In public spaces, we are far too frequently interrupted by public announcements, starting with the completely unnecessary but annoying "Attention, Attention," followed by an announcement only of interest to a single person. There is no excuse for this proliferation of sounds. Many cell phones have the option to set their rings to a private vibration, felt by the desired recipient but no others. Necessary sounds could be made melodious and pleasant, following the lead of the Sapper kettle in figure 5.6 or the Segway. Cooling and ventilation fans could be designed to be quiet as well as efficient by reducing their speed and increasing their blade size. The principles of noise reduction are well known, even if seldom followed. Whereas musical sounds at appropriate times and places are emotional enhancers, noise is a vast source of emotional stress. (Cooper 1999) Unwanted, unpleasant sounds produce anxiety, elicit negative emotional states, and thereby reduce the effectiveness of all of us. Noise pollution is as negative to people's emotional lives as other forms of pollution are to the environment.

Sound can be playful, informative, fun, and emotionally inspiring. It can delight and inform. But it must be designed as carefully as any other aspect of design. Today, little thought is given to this side of design, and so the result is that the sounds of everyday things annoy many while pleasing few.

CHAPTER 6

CONCLUSION

It is obvious that the design of a product should reflect the desired image of a product. Solid, fast, youth attractive, high quality, feminine, masculine…. all these attributes can be reflected and enhanced through sound design. On the other hand, poor sound design can be confusing and damaging to the image. When designing products it is required to control the "aural impact" of the product and in this process it is equally important to shape and even create the sounds which the product will generate.

Emotions govern the quality of interaction with a product in the user's environment and relate directly to appraisal of the user experience. Users generate emotion as a way to minimize errors, interpret functionality, or obtain relief from the complexity of a task. As manipulating emotions, sound acts as a cognitive artifact in task achievement and can be a good reference point to how other artifacts are interpreted and how pleasure is perceived. Sound has a valuable role in sense making and impacts how users interpret explore and appraise a user interface. Artifacts that embody affective properties can be viewed as affective artifacts and therefore captured as valuable design criteria.

Measurable emotional responses with products are apparent where attitudes, values, goals and expectations are coupled with usability and pleasure-ability. In this view, sound is seen as an integral component of the design and an important driver of cognitive processing and task performance. User expectations are coupled with the emotional state that accompanies or codifies interaction expectations and the emotional signature is reflected in how users perceive pleasure with the product.

A properly designed product sound is an effective form of communication providing information about the quality, function, and condition of a product. The optimization of product sound is a multidimensional process with physical, psychoacoustic, and psychological aspects. Product sound design tools are being used more and more to solve sound-related design problems and to develop products that yield a higher level of customer satisfaction. At the same time, product sound is emerging as an important marketing factor, as is the case with the famous Harley

Davidson motorcycle sound, for example. The Product Sound Wheel is a useful aid in keeping product specifications as close as possible to the desired values throughout the iterative process of product sound design.

This thesis reviewed research showing that emotions may influence sound perception in many different ways. The intention of this review was to provide some background to assessment of emotion and the role of emotions in sound perception and sound design. The review focused on perception of everyday sound, but many of the principles discussed here are likely to apply to virtually any form of sound perception.
Whether a product sound is attractive is not determined by the sound alone and its relation to the function, but also by what the user is accustomed to, what the competitors' products do, and not least important, what the surroundings are willing to accept. So, when discussing perceived product quality we must accept that it is a multidimensional discipline.

Also, it seems possible to separate emotional reactions to sound from more cognition-based evaluations. Thus, it should be possible to reliably predict user or listener responses to various product sounds. In sound design, criteria for intended emotions could be established and advice on sound design could be derived from these criteria.

It seems possible to predict user responses with a fair amount of accuracy; another conclusion evident from the present review is that emotions are dependent on individual characteristics and situational influences. In this respect, theory and research on both sound quality and affective sound design is in its infancy the need for considering affect in product sound design is great. As may be noted from recent publications such as affective computing and emotional branding, emotions are becoming an integral part of our everyday interaction with products. Therefore it is likely that users will raise their expectations and demands concerning the "affective intelligence" of future product.

Sound quality is sometimes referred to as whether the quality of the sound befits the function of the product. But there is more to sound quality than simply making a kettle sound like a kettle. It is about what you want that product sound to portray: do you want it to give the impression of being powerful, robust, well made etc. Sound quality isn't always just about making the product acceptable, it can also be about changing the impression of customers in a favorable way. Product Sound Design engineering isn't always about avoiding annoyance and bad impressions.

Methods to evaluate Sound Quality have to consider the product specific requirements and the background of human perception. They thus have to go beyond the pure acoustical signal and have to consider other sensory quantities and non-sensorial moderating factors. These moderating factors have to be identified first in each evaluation. The application example has shown that the rating of subjects can significantly depend on the non-acoustical and even non-sensory factors, so that they have to be considered and controlled or documented in each evaluation.

Additionally, the use of sound in brand design can be seen as an important means of communicating brand values. As a readily marketable commodity, however, it is also something that can be controlled and exploited for commercial interests. As a result, it often loses the original conviction of the message it was intended to convey, becoming a means of making profit rather than the potent barer of a particular ideology. Through sonic branding, the use of sound to influence perception becomes less of an emotionally valuable experience and touches on the more sinister practice of coercion.

It is seen that there are different ways of using sound and music: sound logos, original tunes, original music CD packages, live performances in shops and via web sites; due to its special qualities, product sound and music has the capability to create new images, atmosphere and product ethos. These are some of the results that can be expected:

- The performer can intentionally portray the product's image and ethos; without using any words a message and product placement can be conveyed.
- By selecting music with a particular mood, or of a certain genre, it becomes possible to effectively target groups that are sensitive to a specific style.
- Since the impression customers receive of music includes something personal, customers will unconsciously accept the propositions that are being made.
- It's possible to shape the whole customer experience of a product or service in accordance with the ethos that you want to project.

To get customers interested in a product, it's essential that they feel a sense of personal identification with the product; to put it another way, we could say that customers want to be offered a new sense of their individuality. The link that can be created between a product and customer lifestyle using sounds and music makes the relationship between branding and a sense of individuality even stronger.

As more and more designers become aware of the particular potency and power of sound, they must also become aware of the responsibility they hold in harnessing that power. Through sound, the design profession can communicate with consumers in a way that was neglected through the prevalence of functionalism or aestheticism. Designers need to take advantage of our society's willingness to embrace this value and create products and environments worthy of user's attention.

BIBLIOGRAPHY

American Standards Association 1960. *USA Standard Acoustical Terminology* (American Standards Association, New York) pp.32- 52

Attneave, F. and Olsen, R.K. 1971. "Pitch as a medium: A new approach to psychophysical scaling". *American Journal of Psychology*. Vol. 84, pp. 147-166

Aures, W. 1985. "Der sensorische Wohlklang als Funktion psychoakustischer mpfindungsgrößen". *Acta Acustica*, Vol. 58, pp. 282-293.

Ballas, J. A. 1993. "Common factors in the identification of an assortment of brief everyday sounds". *Journal of Experimental Psychology: Human Perception and Performance*, Vol. 19, pp. 250-267.

Balzano, G. J. 1984. "Absolute pitch and pure tone identification". *Journal of Acoustical Society of America.* Vol. 75, pp. 623-625

Bernsen, J. 1999. *Sound in Design*. (Danish Design Center, Copenhagen.), p. 4

Bisping, R. 1995. "Emotional effect of car interior sounds: Pleasantness and power and their relation to acoustic key features". *SAE thesis 951284*, pp.1203-1209.

Bisping, R. 1997 "Car interior sound quality: Experimental analysis by synthesis". *Acta Acustica*. Vol. 83, 813-818.

Björk, E. A. 1985. "The perceived quality of natural sounds". *Acta Acustica.* Vol. 57, pp. 185-188.

Blauert, J. and Jekosch, U. 1997. "Sound Quality Evaluation - A Multi-Layered Problem". *ACUSTICA - Acta Acustica*. Vol. 83 No.5, pp. 747-753.

Blauert, J., Lehnert, H., Sahrhage, J., Strauss, H. 2000. "An Interactive Virtual-Environment Generator for Psychoacoustic Research". *Acustica united with Acta Acustica*. Vol. 86, pp. 94-102

Blauert, J. and Jekosch, U. 1996. *Sound Quality evaluation - a multilayered problem*. (EEA-Tutorium, Antwerpen), pp. 20-33

Blythe, M. A., Overbeeke, K., Monk, A. R., Wright, P. C. 2003. "Funology: From usability to enjoyment". *Kluwer Academic Publishers*. Vol.26 p.50

Bodden, M., Heinrichs, R. 1998. "Evaluation of interior vehicle noise using an efficient psychoacoustic method". Proc. of the Euronoise 98, Munich, Vol.2 pp. 631-642.

Boorstin, J. 1990. *The Hollywood eye: What makes movies work*. (Cornelia& Michael Bessie Books, New York), p. 62 (online)

Bradley, M. M. and Lang, P. J. 2000. "Affective reactions to acoustic stimuli". *Journal of Psychophysiology*. Vol. 37, pp. 204-215.

Bregman, A. S. and Campbell, J. 1971. "Primary auditory stream segregation and perception of order in rapid sequences of tone". *Journal of Exp. Psychology*. Vol. 89, pp. 244-249

Bregman, A.S. and Pinker, S. 1978. "Auditory streaming and the building of timbre". *Canadian Journal of Psychology*. Vol. 32, pp. 19-31

Bregman, A. S. 1990. *Auditory scene analysis*. (MIT Press, Cambridge.) pp. 38-43

Brink, G. van den 1982. "On the relativity of pitch". *Journal of Perception.* Vol.11, pp. 721-731

Carmon, Z. and Wertenbroch, K. 1997. "Introduction to the Special Issue on the Dynamics of Consumer Preferences". *Marketing Letters.* Vol. 8, pp. 55-56

Cattell, J.M. 1886. "The inertia of the eye and brain". *Brain.* Vol. 8, pp. 295-312

Christensen, T. 1987. "18th-century science and the corps sonore: The scientific background to Rameau's principle of harmony". *Journal of Music Theory*. Vol. 31, pp. 22-50

Clark, D. M. 1983. "On the induction of depressed mood in the laboratory: Evaluation and comparison of the Velten and musical procedures". *Advances in Behaviour Research and Therapy*, Vol. 5, pp. 27-49.

Clark, D. M., and Teasdale, J. D. 1985. "Constraints on the effect of mood on memory". *Journal of Personality and Social Psychology.* Vol. 48, pp. 1595-1608.

Clarkson, M.G., Clifton, R.K. 1985. "Infant pitch perception: Evidence for responding to pitch categories and the missing fundamental". *Journal of Acoustical Society of America*. Vol. 77, pp. 1521-1528

Clifton, T. 1983. *Music as Heard: A Study in Applied Phenomenology*. (Yale University Press,New Haven, CT) p.120

Clore, G. L., Schwarz, N., Conway, M. 1994."Affective causes and consequences of social information processing". in *Handbook of Social Cognition*, edited by R. S. Wyers and T. K. Srull , 2nd ed., pp-323-417.

Coates, D. 2003. *Watches tell more than time: Product design, information, and the quest for elegance*. (McGraw-Hill, New York.) pp. 88-90

Cohen, E.A. 1984. "Some effects of inharmonic partials on interval perception". *Music Perception*. Vol.1, pp. 323-349

Cooper, A. 1999. *The inmates are running the asylum: Why high-tech products drive us crazy and how to restore the sanity*. (Prentice Hall, Indianapolis) p. 46.

Crowder, R.G. and Morton, J. 1969. “Precategorical acoustic storage (P. A. S.)”. *Journal of Percept. Psychophys*. Vol. 5, pp. 365-373

Crowder, R.G. 1970. “The role of one's own voice in immediate memory”. *Journal of Cognitive Psychology*. Vol. 1, pp. 157-178

Dalglish, W. 1978. “The origin of the hocket”. *Journal of American Musicol. Soc*. Vol. 31, pp. 3-20

Damasio, A.R. 1999. *The feeling of what happens: Body and emotion in the making of consciousness*. (Harcourt Brace, New York) pp. 15-23.

Daniel, P. and Weber, R. 1997. “Psychoacoustical roughness: Implementation of an optimized model”. *Acta Acustica*, Vol. 83, pp. 113-123.

Demany, L. 1982. “Auditory stream segregation in infancy”. *Infant Behav. Dev.* Vol. 5, pp. 261-276

Desmet, P.M.A. 2002. *Designing Emotions Doctoral Dissertation* (TU Delft, Netherlands), pp. 44-56

Dewar, K.M., Cuddy, L.L., Mewhort, D. J. K. 1977. “Recognition memory for single tones with and without context”. *Journal of Exp. Psychol.: Human Learning and Memory.* Vol. 3, pp. 60-67

Dix, A. and D. Ramduny Ellis, J. Wilkinson 2003. ”Trigger Analysis - Understanding Broken Tasks". in *The Handbook of Task Analysis for Human-Computer Interaction*, edited by D. Diaper & N. Stanton, (Lawrence Erlbaum Associates, New Jersey), pp. 33-41

Dowling, W.J. 1973. “The perception of interleaved melodies”. *Journal of Cognitive Psychol.* Vol. 5, pp. 332-337

Dowling, W.J., Lung, K., Herbold, S. 1987. “Aiming attention in pitch and time in the perception of interleaved melodies”. *Percept. Psychophys*. Vol. 41, pp. 642-656

Eimas, P.D., Siqueland, E.R., Jusczyk, P., Vigoroto, J.M. 1971. “Speech perception in infants”. *Science* Vol. 71, pp. 303-306

Ellis, C.J. 1985. *Aboriginal Musk, Education for Living* (University of Queensland Press, St. Lucia, Queensland) , p. 126

Elmasian, R. and Birnbaum, M.H. 1984. “A harmonious note on pitch: Scales of pitch derived from subtractive model of comparison agree with the musical scale”. *Percept. Psychophys*. Vol. 36, pp. 531-537

Eriksen, C. W. and Johnson, H. J. 1964. “Storage and decay characteristics of non-attended auditory stimuli”. *Journal of Exp. Psychol.* Vol. 68, pp. 28-36

Erickson, R. 1982. “New Music and Psychology” in *The Psychology of Music*, edited by D.Deutsch (Academic, New York), pp. 69-75

Evans, E.F. 1975. “The sharpening of cochlear frequency selectivity in the normal and abnormal cochlea”. *Audiology.* Vol. 14, pp. 419-442

Fastl, H., 1997. “The Psychoacoustics of Sound-Quality Evaluation”. *ACUSTICA - acta acustica.* Vol. 83, No.5, pp. 754-764.

Fastl, H. and Hesse, A. 1984. “Frequency discrimination for pure tones at short durations”. *Acustica.* Vol. 56, pp. 41-47

Fletcher, H. and Munson, W.A. 1933. “Loudness, its definition, measurement and calculation” *Journal of Acoustical Society of America*. Vol. 5, pp. 88-102

Fletcher, H. 1934. “Loudness, pitch and timbre of musical tones and their relations to the intensity, the frequency and the overtone structure”. *Journal of Acoustical Society of America.* Vol. 6, pp. 59-69

Fog, C.L. 1998. *Optimal Product Sound: Design and Construction Guidelines for Developing Products with Desirable Sound Characteristics and Minimal Noise.* Report SPM 144 (in Danish), (DELTA Acoustics & Vibration, Copenhagen), p.13

Fog, C.L. 1999. “Use of Product Sound Optimization Tools”, 6th International Conference on Sound & Vibration, Copenhagen, DELTA Acoustics & Vibration, Vol. 5, pp. 16-23

Fog C.L. and Pedersen T.H. 1998. *Introduction to Product Sound Quality, Nordic Acoustical Meeting*, Stockholm, Notes., pp. 12-19

Fog C.L. and Pedersen T.H. 1999. “Tools for Product optimization”, *Delta Acoustics & Vibration*, Vol. 6, pp. 126-133

Forgas, J. A. 1995. “The affect infusion model (AIM)”. *Psychological Bulletin*, Vol. 119, pp. 23-47.

Fredrickson, B. L. 1998. “What good are positive emotions?” *Review of General Psychology*, Vol. 29, pp. 300-319.

Frijda, N. H. 1994. “Emotions are functional, most of the time”. in The Nature of Emotion, edited by P. Ekman & R. J. Davidson (Oxford University Press, New York), pp. 112-122.

Gabrielsson, A. and Sjögren, H. 1979. “Perceived sound quality of sound reproducing systems”. *Journal of the Acoustical Society of America*. Vol. 65, pp. 1019-1033.

Galliver, D. 1969. “Favolare in armonia - A speculation into aspects of 17th century singing”. *Journal of Misc. Musicol.* Vol. 4, pp. 129-146

Garner, W.R. 1970. “Good patterns have few alternatives”. *Journ. of Am. Sci.* Vol. 58, pp. 34-42

Gaver, W. W. 1993. “How do we hear in the world? Explorations in ecological acoustics”. *Ecological Psychology.* Vol. 5, pp. 285-313

Genuit, K. 1997. “Background and practical examples of sound design”. *Acta Acustica.* Vol. 83, pp. 805-812.

Gibson, J. J. 1966. *The Senses Considered as Perceptual Systems*, (Houghton Mifflin, Boston) pp. 76-88

Gibson, J.J. 1979. *The Ecological Approach to Visual Perception*, (Houghton Mifflin, Boston) pp. 45-66

Glucksberg, S., Cowen, G. N., Jr. 1970. “Memory for nonattended auditory material”. *Cognitive Psychol.* Vol. 1, pp. 149-156

Gobé, M. 2001. *Emotional Branding: The new paradigm for connecting brands to people*. (Allworth Press, New York), pp. 28-32

Goleman, D. 1995. *Emotional intelligence*. (Bantam Books, New York), pp. 59-86

Green, D.M. and Swets, J.A. 1974. *Signal Detection Theory any Psychophysics.* (Krieger, New York), pp. 23-55

Gulbol, M.A., Västfjäll, D., Kleiner, M & Gärling, T. 2002. ”Affective reactions to- and evaluations of interior and exterior vehicle auditory quality”. *Journal of Sound and Vibration*, Vol. 255, pp. 501-518.

Guski, R. 1997. “Psychological methods for evaluating sound quality and assessing acoustic information”. *Acta Acustica*, Vol. 83, pp. 765-774.

Hall, D.E. and Hess, J.T. 1984. “Perception of musical interval tuning”. *Music Percept.* Vol. 2, pp. 166-195

Heinbach, W. 1986. “Untersuchung einer gehOrbezogenen Spektralanalyse mittels Resynthese“. *Fortschr. Akustik - DAGA*. Vol.22, pp. 453-456

Hesse, A. 1987. “Ein Funktionsschema der SpektraltonhShe von Sinustonen“. *Acustica* Vol. 63, pp. 1-16

Heyde, E. M. 1987. “Was ist absolutes Hdren? Eine musikpsychologische Untersuchung“ Reviewed by T.H. Stoffer: Neue Zeitung fiir Musik (Profil,Munich) 148/6, p.56

Hinton, L., Nichols, J., Ohala, J. J. 1994. *Sound symbolism*. (Cambridge University Press,Cambridge) pp. 112-134

Hofstadter, D. R. 1980. *Gödel, Escher, Bach: An Eternal Golden Braid* (Penguin, New York) pp. 66-86

Houtgast, T. 1976. “Subharmonic pitches of a pure tone at low S/N ratio”. *J. Acoust. Soc. Am.* Vol. 60, pp. 405-409

Houtsma, A. J. M. 1979. “Musical pitch of two-tone complexes and predictions by modern pitch theories”. *J. Acoust. Soc. Am.* Vol. 66, pp. 87-99

Houtsma, A. J. M. and Rossing, T. D. 1987. “Effects of signal envelope on the pitch of short complex tones”. *J. Acoust. Soc Am.* Vol. 81, pp. 439-444

Huron, D., and Gardner M.P. 1985. "Mood States and Consumer Behavior: A Critical Review" *Journal of Consumer Research*. Vol.12 pp. 256-263

Hutchins, E. 1995 *Cognition in the Wild.* (MIT Press, Cambridge), pp.106-114

Hutchins, E. 1999 "Cognitive Artifacts". in *the MIT Encyclopedia of the Cognitive Sciences*, edited by Robert Wilson and Frank Keil. (MIT Press, Cambridge), p.127.

Isen, A. M. 1993. “Positive affect and decision making” in *Handbook of emotions* edited by M. Lewis & J. M. Haviland (Guilford, New York), pp. 261-277.

Jordan, D. S. and Shepard, R.N. 1987. “Tonal schemas: Evidence obtained by probing distorted musical scales”. *Percept. Psychophys.* Vol. 41, pp. 489-504

Jordan, P. W. 2000. *Designing pleasurable products: An introduction to the new human factors* (Taylor & Francis, London), pp.79-94.

Keinonen, T. 1998. “One-dimensional usability - Influence of usability on consumers' product preference”. University of Art and Design Helsinki, UIAH: A21.

Kenealy, P. 1988. “Validation of a music mood induction procedure: Some preliminary findings”. *Cognition and Emotion.* Vol. 2, pp. 41-48

Kirsh, D. 2000. “A Few Thoughts on Cognitive Overload” *Intellectica*. Vol. 10, p.50

Krumhansl, C. L. 2002. “Music: A link between cognition and emotion”. *Current Directions in Psychological Science*, Vol.11 pp. 2, 45-50

Kubovy, M. 1981. “Concurrent-Pitch Segregation and the Theory of Indispensible Attributes”, in *Perceptual Organization*, edited by M. Kubovy, J. R. Pomeranz (Erlbaum, Hillsdale, NJ), pp. 66-70

Kuhn, T. S. 1962. *The Structure of Scientific Revolutions* (Chicago University Press, Chicago), pp. 135-144

Lang, P. J., Bradley, M. M., Cuthbert, B. N. 1990. “Emotion, attention, and the startle reflex”. *Psychological Review*, Vol. 97, pp. 377-395.

Lang, P. J. 1995. “The emotion probe: Studies of motivation and attention”. *American Psychologist*, Vol. 50, pp. 372-385.

Larsen, R. J. and Fredrickson B. L. 1999. “Measurement issues in emotion research” in *Well-being: The foundation of hedonic psychology*, edited by D.Kahneman, E. Diener, & N. Schwarz, (Russell Sage Foundation, New York), pp. 40-60.

Lazarus, R. S. 1991. *Emotion and adaptation.* (Oxford University Press, New York), pp. 26-31

Lilly, J.C. 1974. *The Human Biocomputer*. (Abacus, London),p. 88

Lockhead, G.R. and Byrd, R. 1981. “Practically perfect pitch”. *J. Acoust. Soc. Am.* Vol. 70, pp. 387-389

Madsen, C.K. and Geringer, J.M. 1981. “Discrimination between tone quality and intonation in unaccompanied flute/oboe duets”. *Journal of Res. Music Educ.* Vol. 29, pp. 305-313

Massaro, D. W. 1978. “A bidimensional model of pitch in the recognition of melodies”. *Percept. Psychophys*. Vol. 24, pp. 551-565

McAdams, S. 1984. “The Auditory Image: A Metaphor for Musical and Psychological Research on Auditory Organization”, in *Cognitive Processes in the Perception of Art*, edited by W. R. Crozier, A. J. Chapman (Elsevier, Amsterdam), pp. 63-87

McAdams, S. and Saariaho, K. 1985. “Qualities and functions of musical timbre”, Proc. 1985 Int. Computer Music Conf., edited by B. Truax, Computer Music Association, San Francisco. pp. 23-35

McAdams, S. 1993. “Recognition of sound sources and events”. in *Thinking in Sound: The Cognitive Psychology of Human Audition*, edited by S. McAdams & E. Bigand (Oxford University Press: Oxford), pp. 146-198.

Mehrabian, A. and Russell, J. A. 1974. *An approach to environmental psychology*. (MIT Press, Cambridge, MA), pp. 29-33.

Meyer, J. 1979. “Zur TonhOhenempfindung bei musikalischen Kungen in Abhangigkek vom Grad der Gehorschulung“. *Acustica* Vol. 42, pp. 189-204

Mitnick, K. D. and Simon, W. L. 2002. *The art of deception: Controlling the human element of security*. (Wiley, Indianapolis), p. 106

Moore, B. C. J. 1982. *An Introduction to the Psychology of Hearing.* (Academic, London), p.59

Moore, B. C. J., Peters, R. W., Glasberg, B. R. 1985. “Thresholds for the detection of inharmonicity in complex tones”. *J. Acoust. Soc. Am.* Vol. 77, pp. 1861-1867

Moran, H. and Pratt, C.C. 1926. “Variability of judgments of musical intervals”. *J. Exp. Psychol.* Vol. 9, pp. 492-500

Namba, S. 1994. “Noise-quantity and quality”. *In Proceedings of Inter-noise.* Vol. 94, pp. 171-218

Namba, S., Kuwano, S., Hashimoto, T., Berglund, B., Da Rui, Z., Schick, A., Hoege, H., Florentine, M. 1991. “Verbal expression of emotional impression of sound: A cross-cultural study”. *Journal of the Acoustical Society of Japan* (E), pp. 19-29.

Neisser, U. 1967. *Cognitive Psychology*. (Meredith, New York), pp. 136-144

Norman, D. 1991. “Cognitive artifacts”. in *Designing interaction: Psychology at the human-computer interface*, edited by John M. Carroll (Cambridge University Press, Cambridge) pp.17-38.

Norman, D. A. 2002. *The design of everyday things*. (Basic Books, New York), pp. 156-170

Norman, D. A. 2003. *Emotional Design: Why We Love (Or Hate) Everyday Things*. (Basic Books, New York), pp. 21-33, 115-123.

Ohm, G.S. 1843. “Ober die Definition des Tones, nebst daran geknilpfter Theorie der Sirene und ahnlicher tonbildender Vorrichtungen“. *Ann. der Phys. Chem.* Vol. 59, pp.513-565

Olsen, R.K. and Hanson, V. 1977. “Interference effects in tone memory”. *Memory Cognition*. Vol. 5, pp. 32-40

Ortony, A., Clore, G. L., Collins A. 1988. *The cognitive structure of emotions*. (Cambridge University Press, Cambridge), pp. 78-88

Osgood, C. E., Suci, G, J., Tannenbaum, P. 1957. *The measurement of meaning*. (University of Illinois Press, Urbana) p. 109.

Paanksepp, J. 1995. “The emotional sources of “chills” induced by music”. *Music Perception*. Vol. 13, pp. 171-207.

Papanek, V. J. and Hennessey. J. 1977. *How things don't work.* (Pantheon Books, New York), p.44.

Pearce, A. 1994. *Design of Artifacts from a Cognitive Engineering Perspective*. (Online, Atlanta: USA), pp. 80-89

Pedersen T.H. and Fog C.L. 1998. “Optimisation of Perceived Product Quality”, Euro-Noise Proc. 98, München, J. Acoust. Soc. Am., Vol. 76, pp. 1688-1693

Picard, R. 1997. *Affective computing*, (MIT Press, Cambridge, MA), pp.66-89

Pipping, H. 1895. “Zur Lehre von den Vocalklangen“ *Z. Biol.* Vol. 13, pp. 524-583

Popper, K.R, and Eccles, J.C. 1977. *The Self and Its Brain*, (Springer, Berlin, Heidelberg), pp. 159-186

Rafaeli, A. and Vilnai-Yavetz I. 2003. *Emotion as a Connection of Physical Artifacts and Organizations.* (Online, Tel Aviv), pp. 110-125.

Rasch, R.A. 1985. “Perception of melodic and harmonic intonation of two-part musical fragments”. *Music Percept.* Vol. 2, pp. 441-458

Rasch, R.A. and Plomp, R. 1982. “The Perception of Musical Tones” in *The Psychology of Music*, edited by D. Deutsch (Academic New York), pp. 49-76

Read, H. E. 1953. *Art and industry, the principles of industrial design*. (Faber and Faber, London), pp. 99-108

Risset, J.C. 1978. “Musical Acoustics”, in *Handbook of Perception*, Vol. 4, p.60

Roederer, J.G. 1987. “Why Do We Love Music? A Search for the Survival Value of Music”, in *Music in Medicine*, edited by R. Spintge, R. Droh (Springer, Berlin, Heidelberg), pp. 74-85

Rogers, G. L. 1987. “Four cases of pitch-specific chromesthesia in trained musicians with absolute pitch”. *Psychol. Music* Vol.15, pp. 198-207

Rose, J.E., Brugge, J.F., Anderson, D. J., Hind, J.E. 1967. “Phase-locked response to low-frequency tones in single auditory nerve fibers of the squirrel monkey”. *J. Neurophysical.* Vol. 30, pp. 769-793

Russell, J. A. 1980. “The circumplex model of affect”.*Journal of Personality and Social Psychology.* Vol. 39, pp. 1161-1178.

Saldanha, E. and Corso, J. 1964. “Timbre cues and the identification of musical instruments”. *J. Acoust. Soc. Am.* Vol. 36, p. 2021

Scherer, K. R. 1986. “Vocal affect expression: A review and a model for future research”. *Psychological Bulletin.* Vol. 99, pp. 143-165.

Scherer, K. R. 1999. “Appraisal theory”, in *Handbook of cognition and emotion*, edited by T. Dalgleish & M. Power (Wiley, Chichester), pp. 637-663.

Schouten, J.F. 1940. “The residue, a new component in subjective sound analysis”. *Proc,K. Ned. Akad. Wet*. Vol. 43, pp. 356-365

Shepard, R. N. 1982. “Geometrical approximations to the structure of musical pitch”. *Psychol. Rev.* Vol.89, pp. 305-333

Siegel, J.A. and Siegel, W. 1977a. “Absolute identification of notes and intervals by musicians”. *Percept. Psychophys.* Vol. 21, pp. 143-152

Siegel, J.A. and Siegel, W. 1977b. “Categorical perception of tonal intervals: Musicians can't tell sharp from flat”. *Percept. Psychophys.* Vol. 21, pp. 399-407

Simmons, F.B., Edley, J.M., Lummins, R.C., Guttman, N., Frishkopf, L.S., Harmon, L. D.,Zwicker, E. 1965. “Auditory nerve: Electrical stimulation in man”. *Science* Vol. 148, pp. 104-106

Sloboda, J.A. 1985. *The Musical Mind: The Cognitive Psychology of Music*. (Clarendon, Oxford), pp. 84-87

Sloboda, J.A. 1976. “The effect of item position on the likelyhood of identification by inference in prose reading and music reading”. *Can. J. Psychol.* Vol.30, pp. 228-237

Smith, C. A. and Ellsworth, P. C. 1985. “Patterns of cognitive appraisal in emotion”. *Journal of Personality and Social Psychology*, Vol. 48, pp. 813-838.

Spillers, F. 2003. “Task Analysis Through Cognitive Archeology”. in *The Handbook of Task Analysis for HCI*, edited by D. Diaper and N. Stanton (Laurence Erlbaum Associates), p.3

Spillers, F. and Daniel L.D. 2003. “Temporal attributes of shared artifacts in collaborative task environments” *in Proceedings of HCI2003: Workshop on the Temporal Aspects of Tasks*. (Bath: Online, United Kingdom). p.7.

Stevens, S. S., Volkmann, J., Newmann, E. G. 1937. “A scale for the measurement of psychological magnitude pitch”. *J. Acoust. Soc. Am.* Vol. 8, pp. 185-190

Stevens, S.S. and Volkmann, J. 1940. “The relation of pitch to frequency”. *Am. J. Psychol. Vol.* 53, pp. 329-353

Stoll, G. 1982. “Spectral-pitch pattern: A Concept Representing the Tonal Features of Sounds”, in *Music, Mind and Brain: The Neuropsychology of Music*, edited by M. Clynes (Plenum, NewYork), pp. 158-166

Stoll, G. 1985. “Pitch shifts of pure and complex tones induced by masking noise”. *J. Acoust. Soc. Am.* Vol.77, pp. 188-192

Stone H. and Sidel J.L. 1993. *Sensory Evaluation Practices*, (Academic Press, San Diego) pp. 113-148

Terhardt, E. 1974a. “Pitch, consonance and harmony” *J. Acoust. Soc Am.* Vol. 55, pp. 1061-1069

Terhardt, E. 1979a. “Calculating virtual pitch”. *Hearing Res.* Vol. 1, pp. 155-182

Terhardt, E. 1979b. “Conceptual aspects of musical tones”. *Humanities Assoc Rev.* Vol. 30, pp. 45-57

Terhardt, E. 1983. “Musikwahrnehmung und elementare Horempfindungen“ (with English tranlation). *Audiol. Acoust.* Vol. 22, pp. 53-56, 86-96

Terhardt, E. 1985. “Fourier transformation of time signals: Conceptual revision”. *Acustica* Vol. 57, pp. 242-256

Terhardt, E. and Grubert, A. 1987. “Factors affecting pitch judgments as a function of spectral composition”. *Percept. Psychophys*. Vol. 42, pp. 511-514

Terhardt, E. and Seewann, M. 1983. “Aural key identification and its relationship to absolute pitch”. *Music Percept.* Vol. 1, pp. 63-83

Terhardt, E., Stoll, G., Seewann, M. 1982b. “Algorithm for extraction of pitch and pitch salience from complex tonal signals”. *J. Acoust. Soc. Am.* Vol. 71, pp. 679-688

Thomson, W. 1983. “Functional ambiguity in musical structures”. *Music Percept.* Vol.1, pp. 3-27

Todd, N. 2001. “Evidence for a behavioral significance of saccular acoustic sensitivity in humans”. *Journal of the Acoustical Society of America*, Vol. 110, pp. 380-390.

Tolkien, J. R. R. 1954a. *The fellowship of the ring: being the first part of The lord of the rings*. (George Allen and Unwin, London), Vol. pt. 1, pp.169-201

Tolkien, J. R. R. 1954b. *The two towers: being the second part of The lord of the rings* (G. Allen & Unwin, London), Vol. pt. 2, pp. 159-187

Trehub, S.E. 1987. “Infants' perception of musical patterns”. *Percept. Psychophys*. Vol. 41,pp. 635-641

Ueda, K. and Ohgushi, K. 1987. “Perceptual components of pitch: Spatial representation using a multidimensional scaling technique”. *J. Acoust. Soc. Am* Vol. 82, pp. 1193-1200

Västfjäll, D., Kleiner, M. 2001. “Emotion in Product Sound Design” Proceedings of Journées Design Sonore, Paris, (20-21 March 2002). pp.1-17

Västfjäll, D., Kleiner, M., Gärling, T. 2002. ”Subjective reactions to tonal and noise components in interior aircraft sound”. *Journal of the Acoustical Society of America*. Vol. 56, pp. 889-912

Vos, J. 1982. “The perception of pure and mistuned musical fifths and major thirds: Thresholds for discrimination, beats and identification”. *Percept. Psychophysics*. Vol. 32, pp. 297-313

WEB_1, Gerald J. G. “The Effects Of Music On Advertising And Choice Behavior”. 26/08/2004. http://www.freeessays.cc/db/45/sqt127.shtml

WEB_2, Canal jeans Website “DJs spin hip and trendy record mixes while customers shop”. 16/03/2005. http://www.canaljean.com/

WEB_3, Herman D. Herman Strategic Consultants “A new understanding of brands and branding”.25/04/2004. http://www.danherman.com/PDF%20files/A%20new%20understanding%20of%20brands%20and%20branding.pdf

WEB_4, What is sound. 08/09/2004. http://www.tek-ltd.com/school2.htm.

WEB_5, Understanding how we hear. 12/12/2004. http://www.ehealthmd.com/library/innitus/TIN_how.html

WEB_6, Sound Waves. 15/01/2005. http://teachhealthk-2.uthscsa.edu/pa/pa06/0606B.htm

Wedin, L., Goude, B. 1972. “Dimensional analysis of the perception of timbre”. *Scand. J. Psychol.* Vol. 13, pp. 228-240

Wegel, R. L. and Lane, C. E. 1924. “The auditory masking of one sound by another and its probable relation to the dynamics of the inner ear”. *Phys. Rev.* Vol. 23, pp. 266-285

Wensveen, S., Overbeeke K., Djajadiningrat, T. 2002. *Push Me, Shove Me and I Show You How You Feel: Recognizing mood from emotionally rich interaction*. (ACM Press, New York), pp. 5-6

Wertenbroch, K. Carmon, Z. 1997. “Dynamic Preference Maintenance”. *Marketing Letters*, Vol. 8 No.1, pp. 145-152.

Wertheimer, M. 1923. “Principles of Perceptual Organization” in *Readings in Perception*, edited by D.C. Beardslee, M. Wertheimer (London: Routledge & Kegan Paul), pp. 145-153

Wessel, D. 1979. “Timbre space as a musical control structure”. *Comput . Music J.* Vol. 3, pp. 45-52

Wright, J.K. 1986. “Auditory Object Perception: Counterpoint in a New Context” *Masters dissertation*, (McGill University, Montreal), pp. 88-92

Wundt, W. 1924. *An introduction to psychology*. (Allen & Unwin, London), pp.88-103

Zenatti, A. 1985. “The role of perceptual-discrimination ability in tests of memory for melody,harmony and rhythm”. *Music Percept.* Vol. 2, pp. 397-404

Zwicker, E. 1970. “Masking and psychological excitation as consequences of the ear's frequency analysis”, in *Frequency Analysis and Periodicity Detection in Hearing*, edited by R. Plomp, G. F. Smoorenburg (Sitjthoff, Leiden), pp.177-193

APPENDIX A

VOCABULARY

Acceptability: State of a product or sound favorably received by a given individual or population, in terms of its attributes or its judged conformity with standard(s) or stated requirement(s).

Accuracy and Signifance: The statistical computations of mean standard deviations and confidence intervals of the results may give information of the accuracy of the results. The influence of working conditions and stability of the sound sources may be estimated by measurements or estimated by experience. Consideration should be given before any generalization of test results to how representative the tests and the result are of the situation or product under investigation.

Acoustics: The objective study of the physical behavior of received sound.

Acoustical life-cycle: (in an acoustical space)

- Direct waves - Reach the listener without bouncing off any surface.
- Early reflections Bounces off 1 surface gives subjective information on room size.
- Reverberation. (reverb) Latter reflections of, densely spaced reflections created by random, multiple, blended replications of a sound. Reverb fills out loudness.

a) Big Reverb & Long Decay - Concert Hall, Castle, Large Church.

b) Big Reverb & Short Decay - Tiled Bathroom (singing in the shower)

c) Little Reverb & Medium Decay - Living Room, Conference Room

d) Little Reverb & Short Decay - Inside a Car.

e) No Reverb - Out side in a open space or in a anechoic chamber.

Acoustical phase: refers to the time relationship between two or more sound waves at a given point in their cycles. Phase can be either constructive or destructive Binaural - As human with two ears we use the intensity difference and the arrival time difference to give us location and dimension.

Acoustical Space: Where the sound takes place (large room, small room, cave, cathedral, bathroom, car, plane, dumpster etc...) Things that affect acoustical space:

shape, dimensions, surfaces, objects, temperature, humidity, isolation of sound inside and outside the space.

Ambiance: All the sounds contained in a given acoustical environment (space).

Audio Spectrum: Low freq. is 300 Hz and below, Midrange freq. is from 300Hz to 3,500 Hz, and High freq. is 3,500 Hz and above.

Auditory attributes: Acoustic characteristics of a sound rendered by a perceptual analysis.

Components of sound: Include; pitch volume, timbre, tempo, rhythm, duration, attack and decay.

Compressor: A signal processor with an output level that decreases as input level increases. Four basic settings include the threshold, the compression ratio, the attack time and the release time. How all four settings interact is crucial in making a compressor work.

Consumer: Normally a person who uses a product (user). It may also be a person who decides on the purchase of products (manager, buyer).

Delay: Is a time manipulation that changes how sound is heard by the brain. Delay has many special effects.

- Flanging 2 to 20 millisecond
- Doubling 20 to 40 millisecond.
- Choursing 15 to 35 millisecond re-circulated
- Echo greater than 40 millisecond
- Infinite repeat.

Distortion: Any change to the original wave form of the sound.

Dynamic range: The range of volumes from the loudest to the quietest over a given length of time.

Equal loudness principle: Midrange frequencies are perceived with more intensity than that of bass and treble frequencies. Most home stereos have bass and treble controls because of human insensitivity in these frequency ranges. If you have three pure tones at a fixed loudness the 1st at 50Hz, the 2nd at 1,000 Hz and the 3rd at 5,000 Hz the tone at 1,000 Hz will sound louder to your ear.

Equalization (EQ): Altering the frequency amplitude response of a sound source or a sound system.

Frequency: Refers to the number of cycles per second (CPS) = Hertz (Hz) at which the sound is vibrating. The audio range for human hearing is between 20Hz to 20,000 Hz. 1,000 Hz = 1 kHz (kilohertz)

Frequency response: How well does a device respond or reproduce all the frequencies that exist in the sound.

Listening: is perceiving sound with careful attention, analyzing its quality, understanding its nuance and examining your reaction in mood and feeling. It is not playing your favorite CD while washing dishes or talking on the phone.

Masking: The covering of a weaker sound when they exist at different frequencies simultaneously. High frequency is easier to mask than low frequency. The masking effect is greatest when the frequencies are close together. The effect is less the further the frequencies are apart.

Metric: Metrics or measures for the sound are the result of a physical measurement. The metrics may be any relevant traditional noise measures, may be psycho-acoustically related measures (see Section 4.3), other measures (e.g. the sound pressure level within a specified frequency range, rise time and level difference of impulsive sounds), or any combinations of these.

Midrange: A 5th, 6th & 7th octave (320 Hz - 2,560 Hz) for many sounds the fundamental or primary freq. or the 1st harmonic falls in the 5th octave. The 6th octave gives the sound a horn like quality. The 7th octave gives sound a tinny quality.

Noise: Anything other than the signal that is desired. It could be electrical hum and buzz, ambient noise Etc. Noise can be transient or steady state.

Noise annoyance: Noise-induced annoyance is a person's adverse reaction to noise. The annoyance caused by noise is a complex relationship between the noise and other physical variables as well as personal, psychosocial, socio-economic and other on-physical variables. Noise annoyance may e.g. be measured by socio-acoustic surveys among people who have been exposed to the noise in a certain context (home environment or workplace) for a period of time (months).

Pitch: Refers to the highness (treble) or lowness (bass) of a sound. This is dependent on the frequencies contained in the sound wave.

Pure Tone: a single freq. devoid of harmonics and overtones. Engineers use pure tone to set calibration of equipment for optimal signal transfer, recording and unity gain. Ex. 1,000Hz. at zero Vu.

Preference: Expression of the emotional state or reaction of an assessor which leads him/her to prefer a specific product (or sound) to other products (or sounds) of the same type or function.

Product: For the purpose of this guideline a product is defined as the item under investigation. The term product is to be understood in a broad sense, the product might be a household article, a car, a train, a plane, a room, a factory ... Even events (as e.g. traffic) may be defined as a product for the purpose of this guideline.

Psychoacoustics: is the subjective effect sound has on those who hear it.

Rhythm: Refers to the sonic time pattern, it can be simple, complex, constant ore changing.

Sound Design: Represents the overall artistic styling of the sonic fabric in an audio production.

Sound Wave: Is mechanical energy, physical vibration of molecules transmitting energy from one place to another. It can carry information and convey emotion. Sound provides cognitive information related to mental processes of knowledge, reasoning, memory, judgment and perception, it also contains affecting information related to emotion, feeling and mood. It is wave form.

Signal: A sound source represented by an electrical, magnetic, or digital form which is analogous to the sound wave.

Signal/Noise Ratio: How much signal is generated for each dB of noise, Ex. 85dB signal to 1 dB of noise.

Soundscape: Created by mixing different sound elements together forming a sense of time, place, motion, location, atmosphere and a point of view for the listener.

Subsonic: Are sounds with frequency below human hearing.

The Sound Envelope: Has three different parts Attack, Internal Dynamics and Decay. Attack is how a sound starts up. Internal Dynamics refers to initial decay & sustain and decay or the time it takes for a sound to fade away.

Test jury: A group of persons (users/ buyers/neighbors) who participate in affective (or preference) listening tests.

Perceived product quality: Perceived product quality is a collection of features that confer the product's ability to satisfy stated or implied needs. This is evaluated on the basis of the totality of perceived features and characteristics of the product, with reference to the expectations and implied needs that are apparent in the users' cognitive and emotional situations.

Timbre: is the tone color of a sound. That is why a trumpet and the human voice both making the same note sound different. Timbre is a multidimensional and consists of the entire sonic pattern created by the fundamental and the harmonics.

Treble: 9th & 10th octaves (5,120 Hz to 20,000Hz) Ads sharpness and crispness to sound. Tape hiss is in this frequency range also electronic noise in equipment can be heard in this range.

Ultrasonic: Are Sounds with frequency above human hearing.

Volume: Refers to the amplitude of the sound wave, perceived as loudness. It is measured as sound pressure level (SPL) = decibels (dB). Apparent loudness can range from very faint to loud to deafening.

Velocity of sound: Besides having amplitude and frequency sound has a component of speed. It travels at 1,130 ft/sec (sea level at 70 degrees F.) and 4,800 ft./sec. in water, 11,700 ft./sec in wood. 18,000 ft./sec in steel.

Wavelength: Equals the velocity divided by the frequency.

Freq. (Hz)	Wavelength (feet)	Wavelength (inches)
20	56.5	
31.5	35.8	
63	17.9	
125	9	
250	4.5	
440	2.5	
500	2.2	
880	1.2	
1000	1.1	
2000		6.7
4000		3.3
6000		2.2
8000		1.6
10000		1.3
12000		1.1
16000		0.07

Low Freq. waves are very long and non-directional. High Freq. waves are very short and very directional. Varying a sounds Freq. affects perceive loudness. Varying a sounds Amplitude affects perception of pitch.