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To Hear is to Feel

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"Because music makes you happy, it touches your heart." This was the answer given by a group of dancers in response to the question of why they willingly accepted the challenge of multiple rehearsals. At first glance, this is not an unusual answer. Until one considers that the dance troupe is comprised of both deaf and hearing impaired individuals. This was the answer Manuela-Carmen Prause received when she attended a performance of a professional American dance troupe during her research in the United States some years ago. (Prause, 2001, p.13) Deaf individuals are indeed interested in music, and associate both positive and negative emotions with their individual forms of music perception. Music touches people regardless of their ability to hear. What do we really know about music perception?

Music, as a perceived acoustic event, serves as the subject of study in numerous disciplines. Despite considerable effort to date, the process of hearing, listening and processing of sound by the brain has yet to be completely explained. The scientific study of acoustics began in Greece and China. Pythagoras of Samos (ca. 575-495 BC), who is attributed with the development of the first chromatic scale, is considered one of the first scientists in this field. History points not only to the classical origins, but also to the interdisciplinary nature of this field of study. As an auditory event, music is treated by the fields of medical audiology, anatomy, biochemistry, neurology, music pedagogy, linguistics, making instruments and psycho-acoustics, just to name a few. (cp. Hellbrück et Ellermeier, 2004) The studies of the functional mechanisms and influencing factors have increasingly come to serve as the foundation of music pedagogy and music therapy.

What do we hear, when we listen?

Sound is comprised of oscillations in air pressure. These pressure oscillations, resulting from a sound source, spread through the air and other materials in a wave-like fashion similar to the ripples on a lake when a stone is thrown in. If the oscillations are possessed of a more or less complex recurrent pattern, we recognize tones and sounds. Non-recurrent oscillations or events are perceived as noise.

Natural tones always contain complex oscillation patterns (Ill. 1) comprised of a base frequency (1.) and its integral multiples, the upper- and partial tones (2./3./4.).

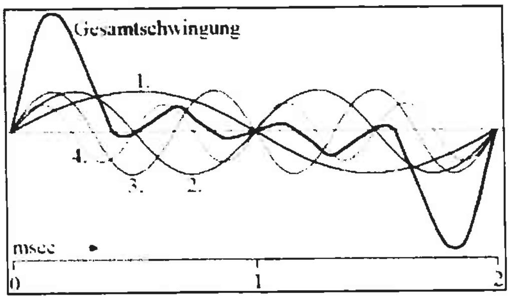

Illustration 1 from:
www.tonalemusik.de/bild/schwingung.gif
(Stand 10/2006)

Taken together, a characteristic frequency pattern (total harmonic oscillation) is established for any particular instrument. When two or more tones occur simultaneously, it results in interactions that influence the total sensory input – such as occlusion effects, beats and combinatorial tones that do not physically exist, but are generated in the mind. The ear and brain also interact in the processing of other musical parameters such as the melodic- and time structure. (cp. Krumhansl, 2000)

Sound Waves – The path to the brain

Following the reception of sound signals and / or music by the functional outer-, middle- and inner ear, the sound information passes through various switching stations on its way to the acoustic nerve. Each station is specialized for a specific task. The highest degree of specialization achieved in the evolutionary process is that for the processing of speech.

In the outer- and middle ear, sound waves are filtered and optimized for processing by the inner ear. The inner ear and cochlea are protected by the most durable bone in the human body, the petrous part of the temporal bone (pars petrosa ossis temporalis). The cochlea is an approximately 3.2 cm long tube that is snail shaped with two and half coils. The size of a pea, the cochlea is the only organ of the body that is fully developed in the prenatal stage (between the 4th and 5th month) and that does not continue to develop in later stages. (cp. Boenninghaus et Lenarz, 2004)

In the mid-part of the cochlea is the actual organ for hearing, the cortical organ, where air pressure oscillations are transformed into nerve impulses. Responsible for this transformation are various ion concentrations in the fluid filling the cochlea. These various ion concentrations are the equivalent of electrical voltage and serve as a "battery" for the electrical processes that take place in the hair cells. (cp. Hellbrück et Ellermeier, 2004) These processes have not yet been fully explained, but the principles governing the sound waves' transformation into nerve impulses are considered essentially correct.

The hearing organ is constantly in close communication with the processing centers in the brain. Not only do nerve impulses pass from the cortical organ to the central nervous system (afferent/approaching nerve fibers), but also from the central nervous system to the cortical organ. Through efferent (carrying out) nerve fibers, attention can be focused on certain frequency ranges in the cortical organ and the ability to distinguish between individual frequencies ranges can be sharpened when analyzing sound. (cp. Altenmüller, 2002)

On their way from the inner ear to the auditory cortex (the region in the brain that is primarily responsible for processing sound), the electrical impulses pass through various switching stations. The signal is filtered, patterns are recognized and the direction from which a sound emanates is calculated. In one of these switching stations – the thalamus – sound information is either sent on for further processing or suppressed. This so-called 'gating-effect' enables selective attention, e.g. listening to one instrument during an orchestral performance.

The afferent aural tract ends at the primary auditory cortex, where the tone pitch information is processed. The primary auditory cortex is surrounded by auditory association-fields that process additional musical parameters such as timbre, rhythm or polyphony. Bordering on these large cortical regions is the Wernicke Area which plays a decisive role in language recognition. (cp. Altenmüller, 2002)

On the way from the acoustic nerve to the brain, the sound signals are not sequentially analyzed and processed, rather in a parallel manner. The information is then compared with available patterns and checked for familiarity and musical meaning.

The limbic system, and thus emotional reactions, is always active during the analysis and memorization of music. This results through the recognition of symmetries, regularities and surprise effects, e.g. a sudden change in familiar musical patterns. The listener's experience is decisive: "To me, musicality is the ability to retain, recognize and produce sound patterns and to associate them with emotions and with other aspects of experience. It certainly isn´t something that resides in the ear. It resides in the brain" (Robbins & Robbins, 1980, p. 22; cp. Carter, 1999)

Hearing is not the same as listening. Hearing is the purely physiological process of sound recognition, whereas listening is the processing of the sound signals that requires the participation of the brain.

Where exactly music is processed in the brain has been detailed with increasing accuracy in research reports from recent years. Starting in the 1970s indications were found that music is uniquely represented in the brain depending on the music specialization of the individual. It is different for a professional musician than for a layman, and different for a trumpet player than a cellist. (cp. Spitzer, 2004)

In contrast to the analysis of a single tone, when processing complex music with its numerous parameters, numerous areas of the brain are activated. "There is no musical centre in the brain. (...) recent studies on the representation of music in the brain show that virtually the entire brain participates."(Spitzer, 2004, p. 212)

In opposition to earlier assumptions, today it is certain that the brain changes throughout the life of an individual. The central nervous system constantly adapts in accordance with the life experience of the organism to which it belongs. This adaptation process is termed 'neuroplasticity'. Listening to and understanding music is now understood as an exceedingly complex activity that requires not only special hearing skills, but also cognitive performance.

Multiple Sensory Perceptions
The ability to experience music with multiple senses was recognized in practical applications when working with deaf and listening impaired children at the end of the 19th century. Whereas the deaf and blind Helen Keller describes that her music perception was primarily achieved by laying her hand on a musical instrument, Eugen Sutermeister – deaf since childhood – describes his music perception as resonant vibrations throughout his body. (cp. Katz et Révész, 1926)

Van Uden later termed these reception modi as 'Contact Sense' (direct contact to the sound source) and 'Resonance Sense' (transmission of vibrations through the air) and presented them as alternative paths of music perception for the hearing impaired. Other authors include indirect vibration sensation, i.e. direct contact with vibrating objects such as balloons or tympanums. (cp. van Uden, 1982; Plath, 1991; Prause, 2001)

The physical foundation of these reception possibilities is the ability of the skin to register pressure, tangency and vibration, which are collectively termed as the sense of 'touch'. This ability applies to the surface area as well as the internal part of the body (surface sensibility and deep sensibility). As an example, the Pacinian corpuscle is specialized for the registration of vibrations (Illustration 2).
Pacinian corpuscles are formed like onionskins and react to vibrations by conveying them as impulse frequencies to the nerve fibres. Such sensory cells can be found in the ligaments, muscles and joints and play an important role in the perception of resonant vibrations. (cp. Leonhardt, 1990; Silbernagel et Despopoulos, 1988)

The percussionist Evelyn Glennie enjoyed perfect hearing before she lost most of her sense of hearing altogether as a child. At this time, she sat down with her music instructor and worked with great intensity on tone pitch recognition and argues that higher frequencies could be sensed as vibrations if our ears didn't "suppress" this sensation "If we can all feel low frequency vibrations why can't we feel higher vibrations? It is my belief that we can, it's just that as the frequency gets higher and our ears become more efficient they drown out the more subtle sense of 'feeling' the vibrations." (Glennie, 2005)

But not only the lower end of the sound field, the deep frequency sounds, but also the upper end, the high frequency sounds that can range into ultrasound, influence the evaluation of a sound's quality. This ability is not reserved for normal hearing individuals. New studies have shown that the hearing impaired enjoy a heightened sensibility for ultrasound. "In conclusion, earlier studies that show that ultrasound is meaningful for music perception could be confirmed. Detailed conclusions support the theory that ultrasound is not processed over the typical hearing channels, but rather through as-of-yet unknown

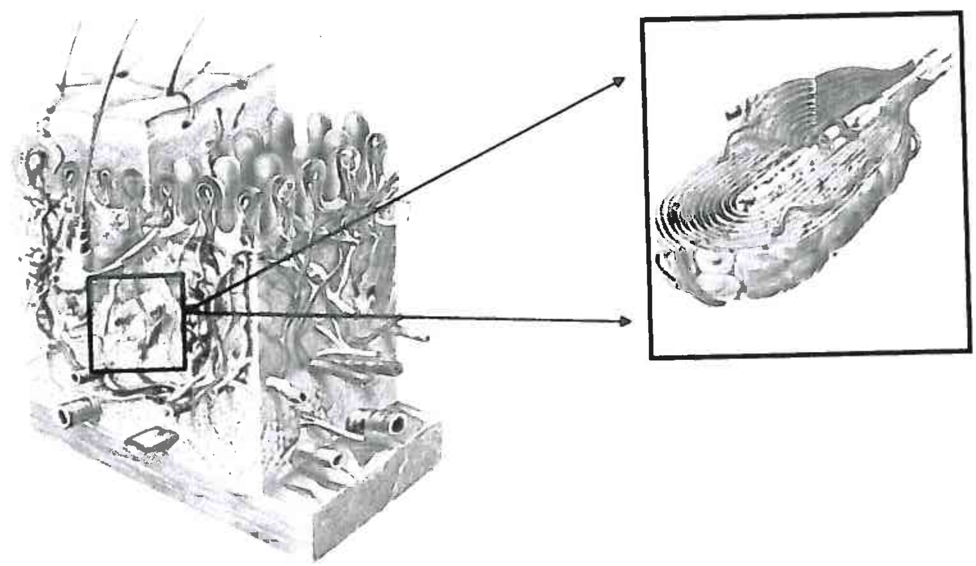

Illustration 2 from: LEONHARDT 1990, S. 343, Schematic representation of the layers of the skin with „pacinian corpuscle“

mechanisms of perception." (Stelzhammer-Reichhardt et Salmon, 2008)

The importance of visual impressions when listening to music has long been recognized, but is also rarely discussed. The observation of deaf individuals such as the musician Sutermeister mentioned above, called attention to the relatedness of this aspect of study at a relatively early point in time. "The eye helps a great deal in my perception of music. By watching the movements of the conductor and the performers, especially the pianist, the kind and manner of the music is explained better and more quickly, enabling me to prepare for what is coming, than when I don't observe the proceedings." (Katz et Révész, 1926, p. 302)

The research group surrounding Altenmüller investigated this and other important aspects of processing music: When we play an instrument, we perceive music through sensors motor activity information as a series of hand positions. With sufficient practice we can experience inner music through the mere observation of notes such as can be found in a written score. In each of these modalities we can remember and represent music. (Altenmüller, 2002)

The simultaneous cortical processing of sense impressions and the synthesis of information from the various senses is termed as "cross-modal interaction". In every day life the brain processes information from the various senses simultaneously in order to accurately evaluate its environment. Earlier however, it was assumed that the brain processed the various levels of sensory information separately and individually, and then subsequently integrated the resultant information bundles with one another; new information however shows that there is an active integration of numerous basal brain areas. (cp. Kayser et.al., 2005; Vines et.al., 2006)

Hearing outside the norm

The sensitive components of the ear can suffer from a limited function starting at birth, or can be damaged throughout an individual's lifetime. Hearing impairment can occur in various regions of both the inner and outer ear, and can occur on one or both sides. (cp. Hellbrück und Ellermeier, 2004)

When hearing is impaired in general, or in a limited frequency range, an increased sensibility to sound can occur, especially when caused by excessive sound or old age. The difficulty thereby is that higher volume is necessary to compensate for hearing loss, but loud tones are more quickly perceived as discomforting. The volume range that enables positive sound perception is limited to a considerable degree.

The absences and disruptions are rarely equally spread across the frequency spectrum. Most of the afflicted have a distorted or fragmentary ability to hear. For individuals with a hearing impairment that occurred later in life this is particularly frustrating, especially when listening to music, as this results in the distorted tones being recognized as "wrong" in comparison to their memories of how it used to sound. This is due to the analysis and comparison that the brain undertakes as described above when processing sounds. If hearing suddenly provides a changed, distorted signal, this results in irritation or even discomfort, as does an incorrectly tuned guitar. For individuals with hearing impaired from birth on, this is less problematic, as the impressions they receive from sound perception are considered "correct" by the brain.

The technical possibilities to compensate for hearing loss have improved considerably in the last ten to 15 years. This is partially due to the advancement in hearing aids with the assistance of computer technology, and partially due to the development of the cochlear implant (CI). This consists of a

receiver and stimulator that are implanted in the cranial bone behind the external ear. A microphone picks up sounds from the environment that are then converted into electrical sound signals. These are transmitted to the internal device in the cochlea and then on to the auditory nerve.

Both methods of hearing compensation are however still tailored to the perception of speech. The unique rules of music cannot always be adequately accounted for (even with technology), meaning that hearing aids are not always helpful for music listeners.

The phase directly following the fitting of a hearing aid is particularly important. Before the hearing aid is integrated, depending on the previous history of the patient, a shorter or longer period of time occurred with considerably impaired hearing ability. Especially the utilization of a cochlear implant results in a radical change in the entire hearing spectrum, whereby hearing has to be learned again, so to speak. But also the use of a conventional hearing aid requires a period of adjustment and hearing training. Even years later, the experience of listening can continue to change. Listening is a life long experience with constant change. (cp. Wickel et Hartogh, 2006)

Research work and case studies show that deaf and hearing impaired individuals can find

alternative approaches to music. (cp. Salmon, 2008) These examples enable us to better understand our own approach to listening and music; they also support views in music pedagogy and music therapy that make use of multi-sensory approaches to music as an educational and therapeutical medium – because to hear is to feel.

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