Music that Works

An Epitome with contributions from Medicine, Neuroscience, Psychology and Health.

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Contributions of biology, neurophysiology, psychology, sociology, medicine and musicology

Chapter 1

Introduction: Music that works

Music therapy and quality research

The present volume it comprises contributions from the fields of biology, chemistry, mathematics, education, psychology, sociology and medicine and aims to create a basis for the discussion of current research findings on the effects of music as well as to encourage readers from differing backgrounds to include insights from neighbouring disciplines. The bridges being built between chronobiology and neuropsychology, between music therapy and neurology, be- tween public health studies and mirror neuron research as well as between musical education and research into emotions struck us as being potentially very valuable starting points towards a deeper understanding of more complex aspects of the psycho-physiological effects of music on listeners.

Music therapy and medicine

Perhaps it is a phenomenon peculiar that music therapy does not yet enjoy its rightful place in the medical therapeutical palette. For as can be seen from the contributions of Oliver Sacks and Conchetta Tomaino, which describe investigations carried out as early as the nineteen-nineties, the situation in the USA, to name only one example, is very different. Music therapy is implemented routinely in many clinics there. As may be expected of a generally recognised form of therapy, clinically applied music therapy must be proven to fulfil certain performance criteria, i.e. its efficacy must be susceptible to scientific verification. In the USA there appears to be avid competition in the fields of health care, music therapy and neuropsychology to furnish relevant data.

At least Austria can boast a Music Therapy Act, passed by the Austrian National Parliament in 2008. The new law provides a framework for regulating both training and implementation. However, the situation in Germany shows what efforts are needed to ensure that music-therapeutical approaches are in compliance with current medical standards, can be defined in terms of the so-called diagnosis related grouping (DRG) or be assigned an internationally recognised operations procedures key (OPK). The basis for such benchmark- ing is provided by the principles of evidence-based medicine (EbM), which requires proof of degrees of treatment quality both in outpatient and in hospital treatment according to clinical experience and independent research findings. To this end, investigations are assigned to various quality levels, ranging from Level IVb, which reflects the opinion of respected experts, to Level I, which involves meta-analysis of numerous randomised, controlled studies.

But there remains considerable room for further definition of the concrete potential and limitations of music therapy. For instance, a Cochrane meta-study involving xx studies on pain therapy with music makes clear that the essential 'medicament', namely the music itself, is only very rarely sufficiently well delineated as to allow reliable testimony as to its specific contribution to the healing process.

Research into the effects of music

Benchmarking and quality assurance remain important goals for those involved in music therapy – on the one hand on account of the new legal framework, but also because state supported and university level training in music therapy requires standards of research and teaching which can withstand international comparison.

It is not that the research community need fear comparison, it being the birthplace of a decisive impulse in respect of interdisciplinary studies concerning the brain and music: As early as 1973 – many years before the 'Decade of the Brain' in the USA – the physicist Juan G. Roederer presented a trailblazing paper entitled 'The Physical and Neurobiological Foundations of Music' as part of the Carinthian Summer Music Festival in Ossiach, Kärnten. In 2004, the American musicologist Diana Deutsch wrote about this period: " … A series of interdisciplinary workshops on the Physical and Neuropsychological Foundations of Music .. . was held in Ossiach, Austria [during the Carinthian Summer festivals], and it was at these workshops that many of us learned for the first time, and with great excitement, about studies on music that were being carried out in each other's fields. It became clear at these exhilarating workshops that an interdisciplinary study of music, with input from music theorists, composers, psychologists, linguists, neuro-scientists, computer scientists, and others, was not only viable but even necessary to advance the understanding of music". Afterwards Juan G. Roederer wrote his standard work on psychoacoustics and remained faithful to this field of study until, and indeed beyond, his retirement. We were very gratified to be able to welcome him as honoured speaker at the first congress.

Roederer's series of workshops continued until 1985, whereupon the baton was passed on to a research group led by Gerhard Harrer and W. J. Revers at the University of Salzburg. The group attracted the attention and support of the Austrian conductor Herbert von Karajan and with his cooperation it was able to conduct neuropsychological experiments in Salzburg. One hundred years after J. Doigel's pioneering investigations on the effects of music on bodily processes (*Über den Einfluss der Musik auf den Blutkreislauf*, 1880 – 'On the influence of music on the circulatory system', 1880), the researchers in Salzburg demonstrated the possibility of detecting the psycho-physiological resonance of music by measuring parameters obtained from the brain and the skin. Nearly thirty years ago this area of research – studies and theories on psychosomatic processes – yielded measurement data for the autonomous nervous system which today forms the basis for standard medical practice and, with the aid of a new generation of HRV measurement devices is likely to become available to the general public for self-therapy in the near future.

Since 1974, the neurologist Hellmuth Petsche from the University of Vienna has pursued the question as to how the effects of music on listeners can be detected by means of EEGs, more recently in cooperation with laboratories in Irvine, CA. With Gordon Shaw and Francis Rauscher he became a witness of the phenomenon which later, under the pseudonym 'Mozart Effect', was to have considerable influence on developments in the field of neuropsychology.

Petsche was already using EEG readings for systematic research at a time when computers were not yet available to process the results and few people had an inkling of the hidden potential of such data. On being invited by the Herbert von Karajan Trust (founded in 1978) to take over the post of scientific director, he advanced to become a pioneering representative of Austrian investigative effort in the field of musical analysis using EEG data. It was he who discovered that listeners to music have more concentrated networks in various regions of the brain, as well as significant differences between musicians and non-musicians: Certain distinctive patterns found in the frequency range above 30 Hz amongst the members of the first group provide evidence for high levels of cognitive performance. The work of Stefan Koelsch and Peter Vuust on the way music is processed in the speech centre and on the semantics of music provides a further confirmation of the value of this kind of approach in the era of magnetic resonance tomography. With his EEG studies, Petsche was able to identify 'musicality in the brain', and using Howard Gardeners concept of different types of intelligence he was able to find evidence to suggest that musical intelligence probably has the greatest effect on the development of intelligence generally.

Further impulses came in 1995 through the congress on the psychology of music therapy at the University of Vienna, which was based on the work of Dr. Gerhard Tucek in the field of ethno-medicine, as well as Ingrid Haimböck's conscientious efforts as the Director of the Karajan Centre in Vienna until 2006. During this time she upheld the spirit of the Karajan Trust, promoting studies by G. Bernatzky from Salzburg, symposia led by Hellmuth Petsche in Vienna and a series of interdisciplinary lectures at the university level. Notable too is the work of K. Vanecek, a music psychologist at the University of Vienna, and the musical education symposium 'Musik als Chance', which was initiated by Jutta Unkart-Seifert in 1998 in Salzburg.

From 2001 onwards the young Mozarteum University in Salzburg embarked on its research programme on the effects of music.

The eras of Rector Revers and Prof. Harrer in Salzburg were long past – thus it was all the more gratifying that, in 2005, it was once again possible to hold a congress on Austrian research into the effects of music involving researchers both young and old.
Indirectly, however, this development also led to the finding of the I.M.A.R.R.A.A. in Vienna in 2003 (now located in Lower Austria) as well as a research programme for musical medicine at the Paracelsus Medical Private University in Salzburg which continues unabated up to the present.

Art and music therapy, catharsis and healing – psychosomatic perception?

I should like to add some reflections on the relationship between music as art and music as therapy, to perception, to research into the manner of our perception and to therapeutic aspects of art.
Nowadays the call for an adequate 'return of investment', unhappily adopted from the business world, is becoming more and more insistent. I was wondering what message is conveyed to the audience, their understanding of themselves, and for the society they lived in, by art which is presented in that way?

Could it be that art as a whole, with its century old debate on 'catharsis' or aesthetic education, will be reduced to a convoluted entertainment and educational operation for less than 7% of the population? An operation with a 200-year-old musical repertoire, with an 'aesthetisement' of auditoria which can no longer measure up to 'catharsis' as the highest aim of human culture and which cadges its own aesthetic essence from other media, oscillating between the cult of meaning and the investments in a market of art products – leaning more towards value treasure than the supply of imagery for human existence.

Perhaps a very European, romantic view reflects the historical accident that the continent houses an enormous number of such institutions enjoying public support and fulfilling the role as ambassadors of our cultural heritage and significance.

At the other end of the scale we find the mass media propagating today's digital, globalised, industrialised, confectioned art. The world's images, its street and strand music, its modern storytelling disgorge from televisions, cinemas, Googles, YouTubes and surge back and forth in the gathering swell of the 'social networks'.

As a field of study, 'Perception' is seen today in the international scientific community as covering all the various channels in which our senses enable us to become aware of the world around us. Essential to this discipline is the 'perception' that we perceive on two different, perhaps even dichotomous levels. On our journey of encounter and learning from infancy to old age we experience at first an 'initial state of being', which I should like to describe as the preverbal perception of our human existence via the sensory organs. We learn to trust these sensory impressions, we become more and more aware of them and thus we become acquainted with our world and develop the ability to distinguish between it and ourselves. Then, in a clearly subsequent step, we begin to name things and the relationships between them as well as to form an assessment of what we feel and experience in our interactions with them.

The combination of preverbal and postverbal awareness also constitutes a 'state of being', but of another order of magnitude: An 'image' of the first order, but one in resonance with our senses. At first, children find it hard to make the right connections between the words, the things and the processes. But with practice they begin to tell stories, stories which provide the basis for new relationships. Language gives us access to this 'game', which nevertheless always remains connected with sensory perception via the body and with our spectrum of feelings.
From this moment we lead a double life: What we see and feel constitutes one of our 'states of being', and

what we say about it, or indeed what we say about what we say, the other. Simple though this may sound, anthropological developmental research has shown how complex and differentiated these psycho-physiological capacities are. And it seems to me to be axiomatic that this 'second state of being' is precisely that which defines our true human existence and virtuosity.

Through this peculiarly anthropological feature of perception – the interplay between the first and the second states of being – our species experiences the mixed blessing of experiencing, simultaneously, Being and Awareness, the Deed and the Word, Passion and Knowledge, Unity and Separation.

For using the symbols which characterise the second state of being – sounds and words, images and representations – we are able to create new worlds; we have in our words and sensory perception the tools which we need to become syntactical-semantical sculptors.

We may be sitting in a bus on the way to another day's work – but still we can see, feel, smell and hear the dawn, the town and the raucous market scenes which we are extracting line by line from the novel which we are reading. If the author has done his job well enough, then those scenes exist more truly in our experience than the ones which are, in gray actuality, flashing past the windows of the bus.

Insofar as the sensory impressions, with attendant bodily reactions, are themselves present in these symbols, their use and our awareness of this affects our state of being quite directly. Language, a sound, an image, a movement – the symbols of Art – evoke reactions in us which neurobiologists can now demonstrate with their representations of the activity of specific brain regions. The observation is not itself new, but has merely become susceptible to scientific proof, and it contains within it the concept of catharsis and of aesthetic effect. And their direct counterparts can now be found in the human psycho-physiological blueprint.

We may even assume that in the course of our evolution we have extended our capacities for perception – as exemplified by the mirror neurons – and can use our psychology to build a kind of amplifier, increasing the effect of the symbols which we ourselves have invented. How else can it be possible for us to see into the past, into the future and become one with faraway people and places all within the confines of a room in which darkness chases light, shadows and sound ply our senses with input originating from a fellow human's brain and pen.

Art – the symbolic language for our senses – harmonises and at the same time lives the dichotomy of our states of being. We use our sensory organs to assimilate artistic symbols as they are presented on a stage or on a rostrum – by an actor's body, for instance. The body is real, and we appreciate it's actions as such, whilst at the same time applying to it another layer of meaning, another identity. In what we are pleased to regard as reality, the actor's body is confined, with ours, within a narrow space called a theatre. Nevertheless, he strides across foreign lands, speaking words and doing deeds which strike home deep within us as we look at him and listen, communicating to us the worlds of feeling, compelling us to resonate with him. This is why we call a play a play, for a playhouse is where the second state of being is at play, playing games which society licences by giving them the name of Art.

To this end every culture has developed its own structure and semantics of symbols, so that those who belong to it can be addressed at the level of their first state of being. And therefore every minute gesture made by an actor, every daub of paint on a canvas, every aspect of a sculpture, the space created by a dancer and every note of music have their echoes within our bodies, in reactions of the brain stem, the autonomous nervous system, in muscle activity and in hormonal surges.

This interplay between the first and the second states of being, and especially our capacity to accommodate and cope with the psycho-somatic process of perception, represents the food on which Art subsists. By extension, it is equally the means by which therapies involving art can take effect. For both make use of the symbols of being. Art itself is mainly concerned with new ways of combining and representing symbols, perhaps even with the creation of new ones, whereas art therapy uses them to mobilise our power to communicate with their substance, the true 'first state of being'. Precisely this is the system which sometimes loses its equilibrium and expresses this with symptoms which we call disease. In life-long training we have learned to address the first state of being via the second, so that the therapy consists in using the symbols of the second state of being to allow regenerative processes to take effect in the first state, to restore the balance on which our existence depends.

Therefore it is evident that everything which is art can, in principle, be used for therapeutic purposes. However, the symbols to be implemented at any given time and the therapeutic aims to be reached vary from case to case.

At this point the need for a discourse between Art and Science becomes paramount. The decisions as to what kind of art are to be put to the service of art therapy must be guided by reflection on the human capacity for consciousness and perception of consciousness. In pure art there are no boundaries, no framework – 'anything goes'. Art therapy, on the other hand, has a clearly defined task, even duty, to address a less-than-whole state of being and show how it may regain its natural, healthy condition. It can only achieve this through a thorough knowledge of that initial state of being, i.e. of the psycho-physiological framework present in our bodies, of the causalities and structures governing all functions. In a therapeutic context it is not merely legitimate, but necessary, to investigate these functions on a solid scientific basis in order to understand their nature as fully as possible. There are many ways of attempting this, but all should be governed by the desire to obtain a comprehensive grasp of what is involved.

As the Arts are very ancient, they do not share the enthusiasm of the natural sciences to formulate a causal principle on the basis of every discovery made. Their methods are legion, and as phenomenological as they are causal. We are learning more and more how body and mind work together – for instance in the study of psychosomatic phenomena. And therapies which use, in part, the imagination to achieve certain physical effects (such as showing films of arctic waters to patients with third degree burns, which effectively lowers their body temperatures) provide a great incentive to pursue the question as to how they work and how such effects may be increased.

In this respect the symbolic language of art provides a reliable bridge to the effects, for it operates entirely with the sensory organs and without the metaphysical – remaining always within the realm of the physical – but with the advantage that this can be interpreted both biologically and phenomenologically. Thus it is not necessary to launch another 'body-and- soul' discussion when demonstrating the effects of music in the brain, in the heart rate, in the circulation system, in glandular functions and in muscle tension. Attention can, and must, be focussed on the psychosomatic aspects.

The motivation behind the use of music for therapeutic purposes has, in the past, been of a varied nature – sometimes philosophical, sometimes political, sometimes individual. The touchstone for its validity, however, is always to be found in its ability to use the symbolic language of sounds, melodies and rhythms to address the true 'first state of being'. It has the need of science as a means to study perception and the results of perception with the same unerring accuracy with which Wolfgang Amadeus Mozart, the musical artist, was able to foresee the effects which his arias would have on his audiences. Here science and art can usefully enter into communication, for it seems almost as though musical education and musical practice still have a long way to go before they achieve a consciousness of these capabilities. What a magnificent potential for healing – and how ignorantly the centres of musical learning reflect on the questions surrounding the nature music and its effects on its listeners. 'Aesthetics'? – a dusty old word used in the 18th and 19th centuries; 'catharsis'? – is just another term that crops up in lectures on Greek tragedy. And yet our current knowledge about perception engenders a great new challenge, opening up new avenues of enquiry into the nature of music, listening and resonance. We now know enough about the biology, anthropology and history of music to allow far more reliable discussion of its effects and forms than was possible in the past – but the need to do so has yet to make itself evident on a large scale.

Stress and sources of stress form essential elements of our lives – indeed, life itself appears to be a matter of maintaining a state of unstable equilibrium between too much and too little stress. Thus 160 years after respected

scientists warned of the fatal consequences of travelling at speeds above 25 kph in the new horseless carriages, we now have a whole new range of playthings with which to test our ability to cope with stress: practically every gadget in the home, at work and on holiday has a clock to tell us how late it is and a source of radiation to keep our bodies vibrating.
The health statistics of the WHO rate stress as one of the major 'civilisation diseases', the consequences of which are very far-reaching. Be that as it may, the statistics alone tell us little about the conditions which oblige people to face up to all the stress in their lives.

Is it possible to implement music in a concert hall as a form of stress to be relished? Certainly: Wolfgang Amadeus Mozart had to face the criticism that he wrote 'too many notes', in other words, his listeners suffered from reception stress. And Geörgy Ligeti clearly aimed to generate stress through sounds. By way of comparison: In the course of the century which has elapsed between the first performance of Igor Strawinsky's 'Le Sacre du Printemps' in Paris, the scandal and stress at first experienced by audiences has undergone a metamorphosis to an ecstatically pleasurable musical experience.

The contrast between the lengths to which Heavy Metal musicians and fans are prepared to go in the search for more effective ways of raising adrenaline levels and the range of relaxatives from 'easy listening' to 'chill-out' shows the degree to which popular music is produced for the direct purpose of creating psycho-physiological effect. Art generates, so to speak, the capacity to perceive its symbolic language, i.e. to understand and to empathise.

Any form of art therapy must therefore inevitably be concerned with the process of perception in order to find out whether, and if so how, a given symbol of the first state of being (language, music, image, drama) influences its recipient.

This task has been addressed by each epoch in its own way. Today we command in the areas of neuropsychology, immunobiology and informatics very precise instruments and models with which we can observe and represent the phenomena involved.

Once again – science and art have much to say to each other, they have the potential to broaden each other's horizons. Art can profit from a more exact knowledge of the mechanism of reception, resulting, I suspect, in a more subtle relationship to the observer or listener. It can play more inventively with the latter's ability to interact, and more: As a mirror to human existence art can show its creators and recipients in ever greater clarity who they are and how they behave and live. Science, in contrast, can learn from the phenomenology of symbolic language. Just as designers of aircraft do well to observe the techniques which Nature has developed to enable animals to fly, it is probably more useful to investigate artistic perception in order to understand the interface between the brain and the computer than to resort to a model emerging directly from computer technology. In respect of the subject under discussion here – artistically based therapy – the dialogue surrounding the model of consciousness called Art can create degrees of freedom on both sides: Science, in this case the science of medicine, can achieve a structured, holistic understanding of the disease in question by retracing the paths which have led us to become capable of artistic creation. Art, on the other hand, no longer needs to be afraid of serving the cause of healing and therapy, for it recognises the common roots to itself in the figure of human consciousness and on that basis it can at once remain true to its artistic self whilst at the same time exercising a freer and stronger cathartic- therapeutic influence.

Thus we find the path back to the public significance of art: School is not only for children, but also carries on through life as a 'school of consciousness' for all who take pleasure in the creation of new 'states of being', who are curious to experience more of themselves and their nature, to explore, to throw themselves into the experience of reality. Art is a game of consciousness, gladly in the light of scientific knowledge of the structure of consciousness, and not merely as an archive of old and new narrations: This is where new perspectives for a liberated contention with experience emerge. This is no longer a moral institution – indeed *un*moral is rather the correct epithet – but as part of a conscious process it remains nevertheless an ethical one. We do not look at the stage or rostrum and see a mirror of society, but instead we see an image of consciousness. To use Art in this manner makes a gigantic difference. Further, it frees up the means which are gathered there and makes them available for much needed social development.

That such development is overdue can be seen in the many irresponsible forms of the so- called 'knowledge' concerning consciousness which abound today. Not only do such forms abound in esoteric circles, but also where neurobiology and psychology are trivialised to pander to man's craving for orientation. Art, however, commands that such potential can be employed in many areas, including medicine in the form of artistically based therapies, in the investigation of the relationship between consciousness and the body and in drafting a concept for healing and recovery.

To some extent this is already taking place, concealed in an explosion of therapeutic methods throughout the world. But the way across the bridge of consciousness and our 'modulation of the first and second states of being' – i.e. the combination of science and art has only been found by a few to date. Much will have been achieved if this volume and the congresses on which it is based can provide a contribution and motivation towards the furtherance of this aim.

Chapter 2

Sonification: listen to brain activity

Physiology as a musical problem

The body with its diseases can be experienced in a new way by listening. In the natural sciences we are used to getting into contact with natural phenomena via visual perception. But there is no *a priori* reason that this has to be like that necessarily. Scientific explanation, modeling and forming of a theory, is supposed to be independent from the modality of the individual perception. There is no reason to assume that a congenitally blind person cannot be as good a scientist as a deaf person. However, there is no guarantee that an exclusively visual and an exclusively auditory perception of phenomena will lead to the same models and theories. On the contrary, it is probable that the evaluation of perceptions by the visual and the auditory sense stresses different aspects and thereby will lead, for example, to complementary conclusions, particularly when complex phenomena are involved. Should this thought turn out to be correct, it would provide an important motivation to test how the modality of listening can be exploited systematically in the natural sciences and in medicine.

The present contribution deals with the problem that arises first in this endeavor, namely the fact that in the case of human physiology many processes, among them the electric activity of neurons in the brain, do not generate any sound. So how can we listen to processes that cannot be heard?

Prior to dealing with this question and its (at least partial) solution we take one step back: before any phenomena can be discovered by listening – listening itself has to be learned. The emphasis is, of course, on the scientific way of listening, listening as a tool in the natural sciences. It turns out that the history of listening in the natural sciences is rather a narrative of regression: a story of decline and expulsion. In today's school systems, what is the only subject that seriously teaches (non-linguistic) listening? It is music.

But music, its contents and intentions are diametrically opposed to the contents and intentions of the natural sciences. What is taught in music lessons (intonation, intervals, harmony, harmonic evolution) may not be the best tools to understand even simple natural phenomena. And in popular talk, widely used and popular metaphors like "the harmony of emotions", "the interplay of hormones", or "a symphony in the brain" often turn out to be word plays which do not survive a serious scrutiny and as such they are of little use or not useful at all. This was not always the case, however.

Listening in medicine

Medicine as a scientific discipline, as we know it today, in one period of its history was much more advanced than we are today in the art of scientific listening. If one would like to name, in a simplified view, a year to mark the beginning of modern medicine, it might be (in the opinion of some) the year of the first use of the stethoscope. In 1816, René Théophile Hyacinthe Laënnec (1781-1826) started to use the stethoscope as a tool to arrive at a diagnosis in his clinical work at the Necker Hospital in Paris. His "Treatise in the diseases of the lung and the heart" which appeared in 1819 comprises in detailed description the acoustic signals that he perceived in many patients by means of the stethoscope and assigns to them specific pathologies, malfunctions of physiology and anatomy. It is the first time in history that someone explicitly describes acoustic features and parameters as signs representing pathologic phenomena in medical diagnosis. In the subtitle of an essay that appeared in 1821, Laennec calls this method the "diagnosis that builds on a new principle by means of an acoustic instrument". Listening, drawing conclusions, and communicating results in a metalanguage of sounds (Sterne 2003) became a practice in medicine.

Laennecs optimism concerning the new method of mediate auscultation (listening to the body by means of the stethoscope) was damped in the course of the nineteenth century (Sterne 2003). It is not possible by acoustic analysis alone to arrive at an unambiguous diagnosis of a given disease and to differentiate it from other diseases: a single acoustic feature may belong to two different pathologies, and a single pathology may possess different acoustic features in two patients. Nevertheless, mediate auscultation became the hallmark of the investigation of human physiology *in vivo* and was soon applied throughout Europe. At the turn of the century, with the discovery of X-ray radiation a new approach of looking into the human body began. This approach was successful and took over in medical practice. Today, almost all data are being displayed visually with imaging techniques. At the same time, the importance of listening declined almost continuously.

At the low point of this decline, in the 1990s of the twentieth century (when a standard textbook of human physiology with more than one thousand pages, the one by Guyton and Hall, dedicated no more than three short paragraphs to the topic of heart sounds) a new discipline officially came to life. Gregory Kramer, then a scientist at the Santa Fe Institute in New Mexico, who is also a musician and meditation teacher, organized a conference which would become the starting point for a renaissance of listening in the sciences.

Sonification

At the center of the small workshop that united 32 equally minded researchers was the technique of *sonification*. Sonification denotes in a general way the representation of data by sounds and noises; it is established today as a scientific discipline in analogy to visualization. Historically, there were various methods to produce sounds from recordings in an analogous way, among them the alarms and the Geiger counter. However, by far the most important technique since that workshop is the digital sound synthesis.

This young discipline was mainly developed in the context of modern music and in the entertainment industry. In the 1980s it began to spread in movie making and advertisement. All of a sudden it then appeared to also provide the appropriate tools for the sound rendering from scientific data. Thus, there was a good deal of enthusiasm when the group of scientists, programmers and musicians joined in 1992 in Santa Fe to discuss the possibilities and problems of this idea.

The possibilities of digital sound synthesis are infinite. But this does not mean that it is simple, or effective in each case. It was not very clear what exactly its value for sonification could be. The proceedings of the Santa Fe workshop thus start with a defining and orienting essay by Kramer (Kramer 1994). In this essay he discusses the possible significance of sound to
science and writes "The function of an auditory display (AD) is to help a user to monitor and comprehend whatever it is that the sound output represents.
If the display medium is non-speech sounds the AD will exploit evolutionarily acquired environmental adaptions, including cognitive and preattentive cues." (p. 1). As the main fields of application for sonification Kramer proposes: first, data exploration, the searching for any kind of interesting patterns in huge data bases that might be missed by visual scanning and second, data mining, the searching of high-dimensional data for predefined patterns. These two modes of searching correspond to two modes of auditory attention: receptive listening, where one is open for interesting events in the environment without expecting anything

in particular (exploration); and aural searching, where one explicitly pays attention to sound properties that give cues about a certain source (mining). It is interesting to note that the receptive mode is essentially a "default" setting of our perception. The second mode, the searching with templates in mind, can then be deliberately added if required. The most prominent task of the new discipline of sonification is thus to deal with the methods to transform data (digital sequences of numbers) into sounds. This transformation is designed to avoid distortion or masking of the information contained in the data and to make this information available for the listening scientist.

This way, sonification becomes a complex, multidisciplinary task. In the first place is the technical skill to realise the sound synthesis digitally. Apart from this it requires expert knowledge about the data, and it has to take care that the information can be correctly perceived by the listener. In order to accomplish the latter, knowledge in cognitive psychology includes related disciplines like music perception and speech recognition. In particular, music perception raises the demands for sound synthesis because in music we are accustomed to assign special importance to the emotional character of the sound whereas it is the main goal of sonification to address analytic, scientific listening, where the emotional character is supposed to be excluded as far as possible.

After the constituting conference in 1992 the scientific interest group ICAD was formed, the International Community for Auditory Displays. This group initially met every two years and since 1996 yearly organizes a conference where the latest advancements of sonification and related scientific studies are presented and discussed. There, such different topics as auditory commands for mobile phones, listening to "electrosmog" and auditory games for children are presented and join studies in the applications of listening in medicine.

Electric brain activity

The human brain works by using electric signals. Biochemical processes create electric potentials in nerve cells, and chemical substances, the so-called neurotransmitters, carry the information contained in the electric signals from cell to cell. On the level of larger communities of nerve cells and on the level of the brain it is the spatio-temporal organisation of the electric signals that best represents the macroscopic aspects of activity of the brain. The recording of these signals on that level is therefore suitable to assess the brain's physiology and disorders thereof.

The first publication about the recording of electric activity of the human brain is from 1929. German psychiatrist Hans Berger had for various years studied people wounded during the first world war, patients, and his own children in a laboratory in Jena and had arrived at the conclusion that certain electric potentials measured from the scalp mostly reflected the activity of nerve cells and that these signals can be separated from the effects of muscle contractions and blood flow. The resulting recording technique, the EEG or electroencephalogram (in the original German publication "Elektroenkephalogramm"), initially evolved slowly but rapidly since the
second world war and quickly became the most important routine investigation in neurology.

The principle of the measurement is simple: electrodes are directly placed on the scalp and connected to a differential amplifier. The difference between the signals of two electrodes is then recorded as electric potential. In general between 19 and 64 electrodes are fixed and the potentials are recorded at rates between 100 and 500 measurements per second over periods between a few minutes and a couple of days. The resulting data, called the EEG, are mostly evaluated by visual inspection.

The three most prominent criteria to judge an EEG are its rhythmicity, the intensity of the rhythms, and their location.

Rhythmicity: the main feature of the EEG is not the potential in absolute terms but its temporal structure or rhythmicity. In clinical neurology a rhythm is supposed to be a non- random repetition of a certain wave form that distinguishes itself clearly from the background. Depending on the context, either the presence or the absence of a given rhythm can be at the center of interest. Figure 1 shows a resting EEG recorded with five electrodes from a subject in stress-free position with eyes closed. Time series 4 and 5 show a characteristic rhythm with an average frequency of 10 oscillations per second.

Intensity: the amplitude or intensity of a signal is clearly an obvious feature of interest (compare for example curves 3 and 4 shown in Fig. 1) but it is also difficult to interpret. First, what enters is the amount of neural activity. Put simply, the more the neurons are active the larger the amplitude of a rhythm becomes on the surface. Second, the coordination of the activity of many nerve cells plays a role: the more coordinated or synchronized an activity is, the stronger the amplitude on the surface. But the amplitude also depends on many other factors. The most important of those other factors are the depth under the surface in which a coordinated activity takes place; and the velocity with which the processes are repeated.

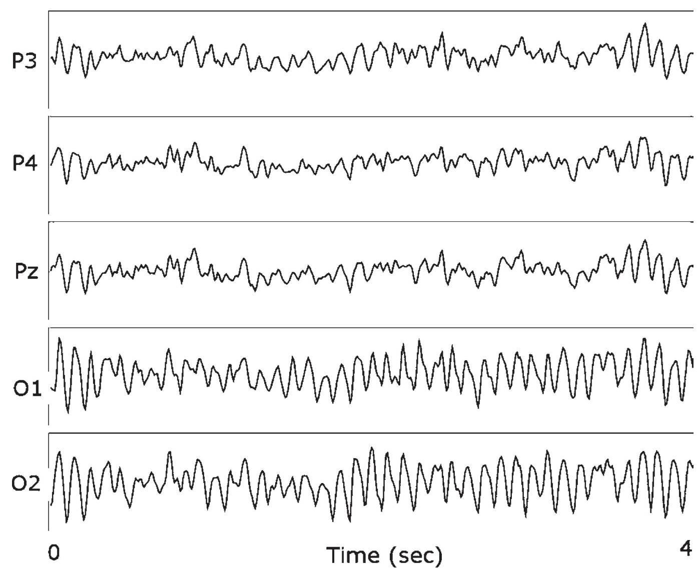

Fig. 1: Potentials of five EEG-Electrodes as a function of time. Healthy subject.

The deeper in the brain a process is, the larger is the distance between source and sensor and the weaker the signal on the surface becomes. And the quicker a rhythm, the weaker is the am- plitude due to the filter characteristic of the medium between the nerve cells and the electrode.

Localization: every electric process in the brain occupies a certain space. It can therefore be recorded from more than one electrode. However, the amplitude of a signal decreases with the square of its distance and as a consequence a given rhythm is captured, mainly by the electrodes that are closest nearby. Consequently, the number and position of the electrodes that measure the same rhythm indicates the location and extension of the brain region where it is produced. In Fig. 1 it is to be seen that the rhythm with about 10 oscillations per second is mainly sensed by electrodes in the rear of the head (time series 4 and 5), whereas other electrodes in the vicinity (time series 1 through 3) display less or nothing of this rhythm. From this one can conclude that principally posterior regions of the brain are involved in its generation.

Listening to brain rhythms

Audification

The idea to listen to brain rhythms and not only to represent them visually surely was considered by many who worked with the human EEG. As it is a traditional custom in neurophysiology to monitor the electrical activity of individual neurons by connecting the electrodes to a speaker, it is a small step to try something similar with the EEG signals. The possibility to listen to brain activity appears to even have been a feature of some commercial EEG machines some thirty or forty years ago; however, it is not being implemented commonly today. A problem was that prior to the distribution of digital sound synthesis, only the raw signals were to be heard in many attempts. With raw signals it is the wave form of the EEG that causes the speaker membrane to vibrate and this has some disadvantages. First, EEG signals hardly contain any components that are faster than 30 Hz. As the human ear is designed to perceive air wave frequencies that are above this value, almost nothing can be heard in this way. The signal has to be supplied in an accelerated form for EEG rhythms to shift to the perceptible range. Second, it turns out that EEG signals mostly are not much more than filtered noise and therefore even without appropriate acceleration not much more than a filtered noise can be heard from the speakers.

For example, Sound 1 is such an accelerated signal sent to the speaker. A continuous noise can be heard which is occasionally interrupted by a clicking noise. The clicking stems from muscle artefacts, potentials which are inevitably recorded from the scalp electrodes. Towards the end of the sound a short buzzing can be perceived. This buzzing stems from the modified rhythm during an epileptic seizure. Even thought the buzzing is distinguished from the other parts of the signal by virtue of its volume and its different spectral characteristic, it nevertheless is not characteristic enough to perceive the attack as a salient well-structured auditory object. However, this is exactly what would be required to do justice to the variety and complexity of pathologic brain rhythms. At this point digital sound synthesis is the more flexible and superior method, opening the way for more complex sonifications.

Sonification of body rhythms

A couple of specific strategies to digitally create sounds from human EEG were proposed by Hermann and colleagues (2002). Both features that depend on the spectral details of the signal and features that depend on relationships between signals are employed. The authors stress that the human sense of listening is aware of qualities that are also important when listening to music: timbre, harmonic relationships and temporal ordering. Only some of the proposed techniques were applied in the context of specific EEG questions so far

(Meinicke et al. 2004). No application of the methods to pathologic rhythms was undertaken.

Since 2003 the authors of the present essay have developed a variety of approaches of sonification, especially in the area of epilepsy research (Baier and Hermann 2004, Baier et al. 2006, Hermann et al. 2006).

The immediate association which the word "rhythm" stirs outside of the EEG context is the one to music. Rhythm is a central order parameter for music and is mostly perceived aurally.

In the human body many processes are organized rhythmically but with the exception of the heart beat and breathing they do not produce significant mechanical vibration and cannot be listened to. It is therefore an obvious question whether these "silent" rhythms can be made audible, in order to find out what the result sounds like.

While continuous sounds can be perceived if their frequency is in the range between 30 and 16,000 Hz, rhythm is perceived if a sound event repeats itself with a frequency between approximately 0.5 and 20 Hz. Sound synthesis of physiological rhythms that lie outside has to be transformed into this range. A number of examples to listen to (among them sonifications of cardiac arrhythmias, episodic hormone release, and cellular signaling) can be found on the CD that comes with the book "Rhythm" (Baier 2001).

If one studies the literature of pathologic EEG rhythms it turns out that a large part of them lies just in the range of 0.5 to 20 Hz. It means that in this case a transformation of the speed with which they are reproduced is not required and that the sonification can even be implemented online. EEG rhythms can be made audible as such during the recording (Hinterberger and Baier 2005). We will return to this point later. First, however, let us discuss how to produce the sounds technically and which features they display.

Brain rhythms made audible

A simple method to render sounds from rhythmic sequences in digitally recorded signals is the event-based sonification. This technique was first used in Baier (2001) for the auditory display of an epileptic seizure, and was systematically developed by Baier and Hermann and described in detail in a scientific context (Baier et al. 2007a). The main idea is simple: a characteristic feature of the rhythm is selected from a visual display of the data, for example, a local maximum of the amplitude. These maxima are defined as events. Then the digital recording is continuously scanned for local maxima and whenever the event is detected a short tone or sound is triggered. If no maximum is found (for instance in continuously rising curves) there will be nothing to hear. If three maxima per second are found, three sounds per second will be heard. The main advantage of this procedure is that pronounced rhythmic events in the time series will be perceived as such.

The second sonification example, Sound 2, was created from the background EEG activity of a healthy subject. Time series numbers 4 and 5 from Fig. 1 were employed for this purpose. Maxima were determined in both channels, each maximum was assigned a predefined short tone. For the two channels, two distinct fundamental frequencies were chosen in order to facilitate their separate perception while listening to both. In addition, in the sound example they are spatially separated by their stereo position in the left and right speakers, respectively. The level of the tone is determined by the actual amplitude of the signal. The larger the difference in potential between present maximum and the previous minimum the louder the tone.

The recording was made at original data speed, i.e. the sound is in real-time.

When listening to the recording, the most prominent feature of the sonification is its rhythm. With about 10 beats per second it is fast, and it is maintained throughout the segment. The chosen segment is representative for the resting state of the subject with eyes closed.

Therefore, in these two channels the comparatively regular rhythm dominates the subject's brain activity. In other channels of the same subject this is not the case. For instance, with time series 1 through 3 of Fig. 1 an overall irregular fundamental rhythm is produced where fast, medium, and slow intervals between beats vary. Also, the distribution of intensities of individual tones is more variable with the same sound synthesis algorithm.

If you listen to Sound 2 a second time, try to pay attention to the relationship between the two rhythms. Obviously they are not independent. As the distances between maxima in the two time series are similar but not identical the beats should always diverge quickly from an occasional accidental synchrony if the two generating processes were independent. What can be heard, in contrast, is that the beats coincide rather frequently. This leads us to conclude that there exists a strong correlation between the underlying electric activities of the corresponding brain regions.

Epileptic rhythms

Epilepsy is an umbrella term for a series of pathologic phenomena accompanied by recurring seizures or fits. As a rule, the seizures are manifested in altered rhythms of the electric brain activity. The EEG therefore is an important tool for their characterization and differentiation. On the neural level there is an excessive synchronization of electric discharges during a seizure. Depending on the type of epilepsy, however, the neural activity can result in rather different EEG patterns with different signal intensities and with varying spatial extensions. In the same patient, fits can be stereotypically similar or variable. In addition, in children the shape of seizures may vary with the developmental stage. Taken together, this means that epileptic seizures are mostly easy to recognize as such but not always easy to characterize in terms of their detailed dynamics.

We therefore propose to complement their common visual representation with auditory components in order to better perceive and differenciate their perception. Two examples may serve to (auditorily) illustrate this point.

The first example is a sonification of the so-called generalized or absence seizure. In childhood this type of epilepsy is comparatively frequent and our case is from a segment where the attack occurred spontaneously during the recording of the EEG.

For Sound 3 two EEG channels were sonified simultaneously. The seizure activity is recognizable by way of its increased intensities of beats and pronounced periodicity without problems. Salient is a punctuated rhythm which consists of a repeating sequence of a fast and a slow inter-beat interval. This perceptibly marks the beginning and the end of the attack. As is typical for absence seizures, these changes occur almost instantaneously in all recorded channels. The underlying physiologic activity therefore is a spatially extended process.

For Sound 4 an epileptic seizure with focal origin was sonified. In that case 20 EEG channels were processed in parallel. To be able to better orient oneself in the multiple events, the channels were distributed spatially in the stereo range. In addition, fast and slow electric brain activities are assigned different acoustic qualities using different digital synthesizers. The pitch of the slower rhythms is arranged according to the position of the electrodes on the scalp. The posterior channels have the lowest pitch and the electrodes on the forehead have the highest pitch.

In contrast to the generalized seizure the present focal-onset attack starts in a limited area and then spreads over the entire brain. In our example there are four initial waves of activity. Their intensity increases and, after the fourth trial, a continuous activity takes over which evolves into the fully developed attack. In this type of seizure there is no simple rhythm to be detected, it is a mixture of fast rhythms and slowly waxing and waning waves. A clear synchronization of wide areas of the brain is not being achieved.

Pathologic alterations of body rhythms

Rhythmic disturbances may be the expression of disease. Baier (2001) discussed examples where the disturbed rhythmicity essentially constitutes the disease.

Cardiac arrhythmias are among them, as are the abnormal pulsatile modes of hormone release, and the epilepsies. For such cases the technical term "dynamic disease" was proposed (Mackay and Glass 1977). This term is supposed to express that a disease consists in a qualitative change of the temporal structure of measured physiological variables. The emphasis on temporal structure does not try to imply that there are no organic or metabolic causes. On the contrary, it is explicitly assumed that all organisation of bodily events is based on biochemical or physiologic causes.
However, the notion of "dynamic disease" means that mere quantitative changes (e.g. in metabolic variables) may lead to qualitative changes in the overall organisation and function of an organ or an organism. The corresponding consequences for the rhythmic organisation count with some fundamental theory (mostly bifurcation theory) but this theory is devoloped using very simple idealized models, and it is an open question whether these simple models correctly reflect the complexity of the physiology of the human body.

The largest problem is that the models have to assume stable conditions for most of the parameters in the considered system and its environment to make their statements. Yet, in a living organism this very assumption is not fulfilled in general. Particularly in a dynamic view the aspects of non-stationarity, of instability, of transitoriness, come to be preeminent. Furthermore, it is often not possible to consider one process as if in isolation. Interactions between different processes are the rule, frequently even on different time scales. And exactly in these cases the sense of hearing should come into operation.

Hearing is hardly of advantage for the perception of stable, enduring, and continuous processes. Unaltered sounds or noises are being "filtered" from perception as much as possible after a short time. This means that they are not considered important any more. This allows the sense of hearing to direct its attention to other events that occur simultaneously, to changes and to novelty. Just in this sense the application of sonification will be beneficial: if pathologic changes are not simple and permanent, if they depend on context, if they are blurred by high ambient noise levels, and if they consist mostly in "novelty" compared to the healthy state. By virtue of listening, then, other or new characteristics – for instance rhythm, when it is pathologically altered – will come to the foreground of attention.

Feedback

Brain rhythms with characteristic frequencies between 0.5 and 20 Hz can be perceived directly as auditory rhythms when applying the described event-based sonification without deceleration or compression of the data. This fact not only offers the possibility to observe the rhythms during their recording (monitoring), but also permits a new type of experiment, auditory feedback: not only the recording scientist, but also the subjects themselves can listen to the sonification online. As such she or he has the opportunity to directly interact with her or his body rhythms. What is heard is taken as a stimulus to react to it. Should it be possible to take influence over body rhythms this way, the result of this influence in turn can be perceived auditorily. In addition, it becomes possible to control this influence voluntarily, i.e. to exert a certain control of physiologic processes of one's own body via auditory perception.

Auditory feedback of the human EEG so far has been explored in only a few cases. There is one scientific study where it was investigated whether subjects are able to influence their own brain activity by means of its auditory perception (Hinterberger and Baier 2005). Indeed, all subjects were able in a simple experimental protocol to influence brain wave parameters significantly without further training. The obtained results were not consistent, probably because not only one rhythm but a number of different rhythms were presented simulta- neously. The results indicate, however, that influence on brain rhythms via auditory feedback is possible.

Sonification and listening may become important in the future in an even more general sense. First, it is possible to record the rhythmic activity of an arbitrary number of parameters for the sound synthesis, not only the activity of a single organ. An example practiced since many years is polysomnography, the recording of physiologic activity during sleep. In polysomnography, apart from the EEG muscle activity is recorded by means of the electromyogram, heart activity by means of the electrocardiogram, respiration with the respirogram and so on, all simultaneously. Thus it is possible in principle to find out a lot more about the overall rhythmic condition of an organism. We have to acknowledge, however, that our knowledge of the normal and pathologic interweavement of rhythms is still in its infancy.

Second, it is possible to not only influence brain waves but also other physiologic processes by auditory stiumuli. For example, certain effects of music on vegetative parameters are well studied.

A problem in such studies is that the physiologic reactions to the same stimulus may be different. The reason for this is that physiology is not a constant state. As a consequence, it has recently been tried to choose the auditory stimuli as a function of circadian rhythms or even as a function of ultradian rhythms, the fluctuation of a physiological parameter during the day, in order to obtain more consistent results. This suggests the possibility to generate the acoustic stimuli directly from the physiological data of a given subject. This will probably not be as direct as in the presented sound examples, rather this may be done in a more musical frame of thinking. In any case, sonification may provide a deeper understanding of complex body rhythms. A specific stimulation of these rhythmic structures in real-time sonification, or by means of much more complex structured sonifications with a richness as is encountered in music, is a promising new approach for further investigation.

List of sounds

Sound 1: Direct sound generation or audification of a single EEG channel.

Sound 2: Sonification of the alpha rhythm of a healthy subject. Stereo-rendering of two EEG channels, O1 and O2.

Sound 3: Sonification of rhythmic activity before and during a generalized absence seizure. Stereo display of two channels, F4 and T4.

Sound 4: Sonification of the activity during a partial seizure in a patient with frontal lobe epilepsy. Sound rendering from 20 EEG channels. Rhythms with a frequency around 12 Hz are represented by short clicks, rhythms with a frequency around 1 Hz by sounds with a fundamental frequency.

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Chapter 3

Chronobiology – as a foundation for and an approach to a new understanding of the influence of music

As a science, chronobiology represents a relatively new discipline, even though its roots reach far back in the history of mankind. The physicians of ancient China observed phases in which the activation of certain bodily functions is sometimes stronger, sometimes weaker and coined the terms YING and YANG to express this phenomenon. In the centuries old Tibetan practice of pulse diagnosis (Zydypov 1988), it is recommended to take pulse measurements at dawn, when the patient is still in bed and there is a state of equilibrium between the heat channel 'ro-ma' and the cold channel 'čžan-ma'. Nature itself provides us with countless examples of periodical processes inthe climate, themovements ofthe oceans, light andday, gravitational fluctuation and many more. The Greek word 'chronos' means time. The chronobiologist's task is to investigate temporal processes in biological systems. Consequently, chronobiology itself is an interdisciplinary science. Thus, much emphasis is to be laid on mathematical techniques that help our understanding of the, sometimes complex processes which have effect in biological systems.

Music has represented a consistent factor contributing towards man's development from earliest times. The oldest known musical instrument is the bone flute which was found in the Geißenklösterle cave near Blaubeuren in Germany; it is at least 35,000 years old. Man creates music and he is surrounded by the music of Nature and that which he makes himself. In the broadest sense of the word, man IS of music. Music comes into being as a creative achievement on the part of the human being. From a physical point of view, music is simply a sequence of chronologically ordered vibrations, which are caused through endogenous or exogenous techniques and transmitted via the medium of air. This description in no way explains, however, why music is able to elicit reactions, sometimes of great intensity, from people or other biological systems such as animals – positive and negative reactions, joy, sadness or other emotions. How does music stimulate, even increase a person's 'performance' (Mozart effect) or plunge him or her into a melancholic or even depressive mood? Ernst Anton Nicolai (1745) observed in this context.

What are the mysterious powers that composers or musicians employ when they succeed in taking possession of our beings with their music? Music is a part of human culture. It is an almost universal accompaniment to cultural events and it appears in a multitude of different guises which we call classical, folk, modern, rock, pop, etc. Every people has, in the course of its development, developed a characteristic musical tradition. Music accompanies man even before he is born and beyond his death. And music has been implemented since time immemorial for the stimulation or for therapeutic purposes. Here, too, the question arises: How can we explain therapeutic effects in conjunction with the influence of music?

Today, music is generally created in the form of an expression of descriptions, feelings and emotions. It arises through the creative implementation of a basic knowledge of musical composition incorporating intentional or intuitively engendered effects. The performer first processes a piece of music by cognitive means and then produces an emotional rendering, which is based on his or her personal experience and knowledge. In this process, the composition and interpretation results unconsciously (rarely consciously) out of the constel- lation of the composer and performer as a bio-psychosocial unit, and as a rule without the knowledge of the effect of music on people and in particular on their psycho-physiological state (sense of well-being, agitation, fear, depression, etc.).

The focus of current research on the effects of music is to be found in psychological studies on musical perception followed by research on music therapy and neurobiology in this context. In the field of music therapy, many studies have been carried out on the effect of music on the cardiovascular system. Less common are the investigations concerned with biochemi- cal or immunological (McCraty 1999) issues. In addition, research has been done on the use of music to bring about an increase in performance. In a number of institutions work is being done in respect of mathematical methods for integrating the most varied research results. Few research establishments (only four) could be found in which research on the effect of music under consideration of chronobiological factors is being conducted. Besides this, some indi- vidual institutions and researchers are engaged in the application of mathematical techniques for music analysis, but without the integration of medical or psychological research methods.

The bio-psychosocial unity which we call man is an extremely complex being and it requires a multitude of scientific disciplines to explain the interplay of the various bodily functions. The complex effects of music cause reactions at all levels. Starting with listeners' subjective statements on their psychological reactions (sensations, feelings or emotions), physiological reactions just as well as biochemical changes and also immunological reactions can be demonstrated. In concert, these reactions lead to definable behaviour on the part of the listener. This behaviour may take the form of active participation in the rendering of songs, active musical performance, rhythmical movements as an accompaniment to the act of listening, various forms of listening, but also to rejection of or lack of interest in the music. Furthermore, music has been used for therapeutic purposes since time immemorial.

In the Bible we read: "Let our lord now command your servants who are before you to seek out a man who is skillful in playing the lyre, and when the harmful spirit from God is upon you, he will play it, and you will be well." (1 Samuel 16:16 (English Standard Version)) Saul ('the one who has been prayed for'), handsome but reserved, was chosen to be the first King of Israel around 1012 BC. He suffered from melancholia, a condition which could be relieved through the music from the harp of David, his illustrious successor. In 1658, Rembrandt painted a representation of this early patient-therapist relationship.

And in 1745 Nikolai relates the story told by his renowned Professor Junker, who "assured him that it be the practice of a French Medicus to cure patients who have fallen into a melancholy by means of music".

Music can, on the contrary, have a negative effect; the same Nikolai provides a further historical example with this report from the Danish Royal Court.

Chronobiology – the science of the temporal structure of biological systems

Since the origin of life, its development has been associated with an extremely wide variety of natural processes. These include periodical processes such as not only the periodical rotation of the planets about the sun in our galaxy, but also that of the moons about the planets and the inherent rotation of the planetary bodies. On our own planet we, too, are subjected to a wide range of periodical phenomena, amongst many other things the ebb and flow of the tides, regular climatic progressions, changing lighting conditions owing to the Earth's rotation, alterations in electromagnetic radiation conditions and also acoustic variations such as those associated with regularly recurring autumnal and spring storms, especially in coastal regions.

Thus the perennial question as to the origin of life cannot be addressed sensibly without reference to the natural changes and cycles which have surrounded us throughout history. We are accustomed to distinguish between their inanimate and animated or between their inorganic and organic components. Physical science provides us with an explanation in terms of the wave-particle dualism of light or other elementary particles as well. Time is relative and independent of the location of the observer. The mass of a particle is dependent on the velocity of its translation; its weight, however, is also influenced by the gravitational forces to which it is subjected. In the course of its development, Nature has brought forth a practically unlimited variety of manifestation, in both inorganic and organic structures.

The state represented by an organic or inorganic structure is to be conceived as a space-time structure=matrix which can change in the course of time. Thus, every space-time structure= matrix, whether inorganic or organic in nature, is a bearer of information – which in the simplest case consists just of its inherent order.

Life is determined by the existence of biological, endogenous and exogenous rhythms. We may assume that mainly through the influence of exogenous factors on the life forms developing on Earth, a range of biological rhythms came into existence, became reinforced and finally genetically and socially established. Mankind's conscious perception of these biological rhythms ushered in a new age of understanding in respect of life, health and disease. Even in prehistoric times, people observed their own behaviour and that of animals very closely, and these observations were used by the sages from all the multitudinous examples of human culture throughout the ages towards preserving the health and healing the diseases of the people. Addressing our intuitive and emotional potential, the biological rhythms provided the foundation for the creation of artistic forms in which to find an expression for life – especially those of a musical nature. Therefore, it comes as no great surprise that, keeping pace with our increasing levels of knowledge, we enquire more deeply into both the inherent patterns of biological rhythms and their significance for medicine and psychology and also the mutual relationships between music and our states of health and illness.

Life (Greek: *bios*) is a property of matter. Thus we speak of animate and inanimate Nature and differentiate between organic and inorganic substances. Life begins with movement. In one of the best known textbooks on physics – 'Gerthsen Physik' the proposition is made that "movement is a change in location" (Vogel 1997). But we do not attribute life to the movement of inorganic material. Life is generally a matter of change, dynamics and restlessness. These terms, on the contrary, are the ones which we can count amongst the previously mentioned properties of space and time. Life has many sub-functions, which need not necessarily all be present at once: reproduction, metabolism, sensitivity to stimuli, movement, regulation, heredity, evolution, and mutation.

As a sequel to NOVALIS' train of thought I reach the following conclusion:

Postulate:

Life begins with the feedback of information and is maintained through a continued supply of energy. The basis is an (organic) structure which makes this feedback possible and which is capable of exploiting the energy of its surroundings for the purpose of maintaining its structure. The information feedback and thus the emergence of life can occur spontaneously by virtue of a given constellation of external conditions.

The molecular biologist Bernard Korzeniewski (Korzeniewski 2001) defines life as "A network of inferior negative feedbacks subordinated to a superior positive feedback." That equates to "a living system regulates itself in order to continue in existence"[2].

Systems involving feedback processes are commonly used instruments in electronics: No modern radio

receiver, no radio or television broadcasting station and no cell phone can function without so-called oscillators, electronic amplifiers which implement feedback techniques. To ensure that this feedback functions in a stable manner the oscillator is supplied with energy from a source of current and a portion of the oscillation energy at the point of exit of the amplifier is diverted back to the input with the corresponding phasing.
This induces a process of self-activation which allows the system to remain 'alive'. It is true that any system, whether inorganic or organic, can be stimulated through the input of energy, including, for instance, a crystal of inorganic material. In this case, it usually happens that the crystalline matrix displays a reaction in the form of aperiodic oscillations, i.e. with oscillations that decay in the course of time. The frequency of the oscillations may change during this process as well. Insofar as the excitation remains singular, this means that the response provided by the crystal in the form of oscillations die away again. It is also possible to describe the structure of DNS and of proteins as that of an aperiodic crystal. In this connection, Portelli (1979) observed:

"According to the model presented in this paper, the beginning of life was marked by the coupling of two complementary nucleotide bases: adenine and thymine. The adenine-thymine system received photons from the sun and stored their energy in the form of a chemical high-energy bond between two phosphoric acid molecules, which were beforehand fixed by adenine from the aqueous environment. The energy of the high-energy bond was then delivered in the form of two waves of electronic excitation. These were utilized to synthesize new molecules, starting from the carbonic acid and ammonia molecules, fixed from the aqueous environment by the polar groups of the nucleotide bases. In this way, a nucleotides- histone protosystem (NHPS) was self-synthesized, evolving step by step towards complexity, by means of some internal cybernetic and informational mechanisms. During its evolution, the NHPS synthesized a limiting membrane, produced the organizing elements of the cellular organelles (chloroplastes, mitochondria, ribosomes, etc.) and constructed microtubules and microfilaments. Subsequently, the NHPS evolved to the building of a DNA-histone system and formed the cellular nucleus."

By means of the feedback phenomenon a periodic process is generated which shifts the (biological) system onto another (often higher) energetic level. The energy supply takes effect on account of the gradient between the energy level of the feedback system in question and its surroundings. As long as the structure of the environment is capable of furnishing accessible energy in the form of material, light, etc., then the self-augmenting system can maintain its functionality. When the energy supply is cut off, the self-augmenting system 'dies', i.e. it reverts to a lower level, non-augmenting system.

The term 'information' includes geometric or energetic configurations and=or the alter- ation of defined structures which they bring about on the basis of influences or interaction effects. For instance, the alterations in the geometrical configuration of organic molecular structures are unavoidably associated with the changes in their biophysical fields. If the environmental conditions are favourable, the development of complex, self-augmenting structures is an almost automatic consequence on account of the large number of possible influences and mutually effective phenomena. In this way, more highly organised living structures come into being.

The transition from a highly organised living structure to an organism occurs on the development of a recall capability and of the reflex that becomes established as a conse- quence. Thus, this ability to remember can be understood as the temporary storage of information in a system maintained through feedback. A reflex is the time-delayed response of the system to the information. The more complicated the system, the more complicated will be its response. This forms the foundation of the stimulus-response principle. Regulated periodic systems display complex response reactions depending on the given initial situation. This includes all possible types of response (compare, for instance, filter responses from electronic filters).

The formation and development of different organisms takes place in a way which corresponds with the principles conveyed above: the response capability of organisms, the development of reflexes and the generation or formation of various structures by means of temporary storage and generation or conditioning of different structures by the substitution of temporarily storage of information or their according structures with permanent changes of structures. This provides the prerequisites necessary for the development of more highly organised organisms, leading to the development of lower forms of life such as plants and animals which display structures having clearly defined functions (organs). In this way the lower life forms have evolved in the course of further structuralisation to engender higher life forms such as the mammals and finally man himself. 'Ageing' can be equated with the 'neglect' of the maintenance of regulating processes in organic structures. 'Death' results from eitherthe abandonment or the disruption of certain processes which are vital to the continued existence of either a simple or a complex organism. This essentially amounts to the abrogation of self-augmenting structures or their destruction.

According to Hildebrandt (1992), all models which seek to explain the origin of life are based on circular processes and feedback phenomena. The supposition is that the basic mechanism of the 'inner clock' is to be found in cyclical chemical processes and cellular cycles.
Other scientists make use of the concepts of self-organisation and synergetics or of non-linear systems in connection with chaos theory and the theory of fractal structures. All these mathematically based, cybernetic models are in their own way legitimate. With genetic research delving deeper into the molecular processes of the basic building blocks of life, an ever more complex picture of man's interaction with his environment emerges.

The composite elements and the functions of life have been subjected to scientific description from different points of view, i.e. from different disciplinary perspectives. Chronobiology is the science of temporal processes in the various bodily functions of biological systems which can be measured in terms of periodical phenomena of varying duration. Subdisciplines include chronomedicine, chronophysiology, chronopharmacology, chronotherapy, chronodiagnosis and chronoprevention, each of which describes certain areas of application of chronobiology. The subdiscipline chronomedicine is concerned with periodic processes of bodily functions in humans and animals. The approach is holistic; which is to say that psychological and biochemical functions are subjected to investigation as well as physiological ones. Chronodiagnosis and chronotherapy, as well as chronopharmacotherapy in its own special form, may themselves be considered to be subdisciplines of chronomedicine.

The methodological aim of chronomedicine is to go beyond the usual approach of determining the qualities of bodily functions on the basis of mean values and variance and to regard the regulatory changes which take place in all life processes as representing the norm. This point of view opens up new means and methods for chronodiagnosis and chronotherapy. On the one hand, it establishes links between conventional medicine and psychology; on the other hand, between ancient oriental medical lore and modern western medicine with its primarily organic, morphologically or biochemically oriented approaches. Chronomedicine is involved with the recognition and interpretation of biological rhythms in any given temporal framework. Thus it interprets pathological or sanogenetic processes in terms of disturbances to or the restoration of regulatory sequences.

> "*Disease begins at the moment when the regulatory equipment of the body no longer suffices to remove the disturbances. Not life under abnormal conditions, not the disturbance as such, engenders a disease, but rather disease begins with the insufficiency of the regulatory apparatus.*"

This view expressed by R. Virchow calls for the implementation of suitable procedures which allow us to recognise and analyse malfunctions in the regulatory apparatus. A modern representative of such methods can be seen in chronobiological regulation diagnosis (Balzer 2000) on the basis of time series analyses. The essential issue is always concerned with the cause at the root of the process, i.e. with the distinction between cause and effect, or to put it even more simply, answering the question: "Why?".

A useful answer can only be found when at least two processes are investigated and the influence of one upon the other can be demonstrated in a way which can be reproduced and controlled. A suitable tool for this purpose can be found in the mathematical technique of correlation analysis. This line of thought also gives rise to the question of the so-called independent variables, i.e. the search for and=or the demonstration of regulatory=periodic processes which exist independently of each other in an organism.

The chronobiological term used in this context is 'clock'. From a physical point of view, we are concerned here with the independent factors (eigenvalues) contributing to a complex system. Another mathematical tool with which such independent eigenvalues can be determined is matrix arithmetic. When the eigenvalues of a technical system have been determined, it is, in principle, possible to calculate their mode of operation and depending on the complexity of the system to predict them. With biological systems, the additional difficulty arises that they are capable of adaptation, in which case the eigenvalues may be modified in accordance with altered environmental conditions. Finally, temporal relativity plays a role as well. For biological systems this means that biological clocks, too, may tick differently in another frame of reference moving at a different speed through the universe. In other words, biological time, too, is a quantity subject to variation. Biological rhythms are an expression of the temporal regulation of biological systems, processes or functions. To extend Hildebrandt's (1998) definition, biological rhythms can be distinguished according to the way they come into being as follows:

- Exogenous rhythms are rhythmic life processes, which are generated purely through variations in external factors.
- Exo-endogenous rhythms are rhythms, which arise within an organism and are synchronised by means of external zeitgebers (cue givers).
- Endogenous rhythms are spontaneous rhythms which are independent of external zeitgebers and which represent an increase in the degree of autonomy and temporal emancipation.

The chronobiological categorisation of variations in the regulation of bodily functions is as follows:

Cycle duration (log)	Functional meaning	Denomination
>1 year	Infraanual (rhythms of several years)	Evolution
1 year	Circannual (annual rhythm)	Population fluctuations Growth – Involution Reproduction
1 month	Circalunar (monthly rhythm)	(Fertility – Infertility) Menstrual cycle
1 week	Circaseptan (weekly rhythm	Regeneration – Healing Assimilation – Dissimilation Sleep-Wake Detention – Expulsion ! Storage – Excretion Activation – Deactivation
1 day	Circadian (daily rhythm)	Tonus increase – Tonus decrease (Smooth muscle)
<1 day	Circatidian (tidal rhythm)	Circulatory system, Peristalsis Respiration
>1 hour	Ultradian (rhythms of several hours)	Inhalation – Exhalation, Motor function Locomotion Heartbeat (Systole-Diastole)
1 hour	Circahoran (hourly rhythm)	Brain activity (EEG) "fibrillatory tissue" Neural reactions
1 minute	minute rhythm (10-s-rhythm)	Excitation – Regeneration
1 second	seconds	Depolarisation – Repolarisation of the cell membrane
0.001 second	microrhythms	Muscle fluctuations

Table 1: Spectrum of cycle duration and their functional meaning, modified according to Hildebrandt

Biological processes of regulation serve both to control homeostasis and to maintain bodily functions when they are subjected to encroachments. Their existence has been established for a large number of functional variations in physiological, biochemical and immunological parameters as well as in psychological and behavioural ones.

An attempt to investigate the effect of music on biological systems must include enquiry into music itself as well as its influence on the various structures of an organism and their mutual interaction – especially when music is to be employed as a form of therapy. Just as a physician should not prescribe any kind of physical medicine without the knowledge of the effects of its constituents, musical 'medicine' should only be applied when its content and possible effects are known. However, significant differences exist between normal medicines and the 'pharmakon' music in respect of the latter's constitution and mechanism of action. Whereas conventional pharmaka consist of chemical and possibly organic ingredients, when music is applied for therapeutic purposes, i.e. presented to a listener as a sequence of individual or composed sound oscillations, it reaches him or her in the form of a structure with a pronounced temporal aspect. As a rule, the medium used to transmit the vibrations is air. Whereas in the past, normal medicines have been designed with a view to cause changes in the operating levels of certain processes (e.g. antihypertensives to lower blood pressure, anti- depressives to improve activation), there are now medicaments available – or rather synthetically produced endogenous substances such as peptides (Hecht 1990) – which influence bodily functions by the stimulation of regulatory processes (e.g. blood pressure, sleeping-waking behaviour).

Music as such is perceived by a person's whole organism, i.e. not only by acoustic means but also via the sense of hearing. The question arises in this context as to which parts of the frequency spectrum are represented in musical pieces. Even today, people experience live music at a concert as something special; the richness of the sound is perceived as having a special intense effect on the listener. Manufacturers of recording media and companies which earn their money through the recording and electronic re-rendering of music make great efforts to capture the essence of live performance with ever more refined technological advances, but so far they have not been able to achieve this aim fully. One of several explanations for this may be found in the fact that stringed instruments in particular – through the rubbing action of the bow on the strings – produce vibrations in the ultrasound range (Balzer 2006).
A study (Stelzhammer 2007) has shown that amplitude-modulated ultrasound is perceived unconsciously by deaf people as well as those whose hearing is intact. In this study, ultrasound was applied to the test subject's temple at a frequency of 28 kHz with a period of 6 seconds and a modulated amplitude (modulation level 100%), for the duration of 2 minutes and with a sound pressure of 73.85 dB at the loudspeaker (sound pressure level experienced by the subject ¼ 43.25 dB). EEG recordings obtained from the test subjects yielded simultaneous modulations. The present assumption is that the ultrasound is conducted to the nerve endings situated in the periosteum via the bones, where it triggers corresponding reactions. Similar effects were demonstrated by Oohashi in 2000 and Fujomoto in 2005.

In their simplest forms, control systems consist of an input unit, an output unit, a sensor for registering deviations from the desired or standard state and an actuator which enables that state to be restored. If an organism's regulatory system is subjected to disturbance, this may result in pathological changes within the organism. Complex regulated systems may react in unexpected ways which appear at first sight to be unconnected with the apparent cause.

A number of autonomous internal clocks or biological clocks have been discovered which govern organic regulation systems. According to Döcke (1994) the nucleus suprachiasmaticus (SCN) is the clock responsible for maintaining the cirdadian rhythm. It is a region of the brain located in the anterior hypothalamus above the chiasma opticum and next to the third ventricle (Turek 1994). Döcke (1994) describes this region as a group of tightly packed neurons which are mutually connected. Nelson (2000) referred to the region as the 'master clock', as it may be assumed that it serves to synchronise regulatory processes within the body. There are also connections between the individual local regulatory systems which themselves may be subject to periodic change.

These local regulatory processes are, on the contrary, controlled via sensors, the central nervous system and the autonomic nervous system.

Rossi (1999) represents this connection in somewhat more detail.

In his 'Unification Hypothesis of Chronobiology' Rossi defines four states of psyche-body communication. A rhythmical flow of messenger molecules from the endocrine system (e.g. stress and sexual hormones) provide for the communication between the psyche and the brain, the brain and the body and cell genes in ultradian processes. The brain's neuronal network receives molecular signals via the extra-cellular fluid (ECF) and can be regarded as a complex, self-organising communication process which forms the psycho-biological basis for mental activity, memory, learning and psychosomatic medicine.

A system's response to a disturbance is determined by its own attributes as well as the type and size of the disturbance. Biological systems are adaptive, capable of 'learning' and thus of being modified. Thus over a long period of time it is possible that a biological system's essential attributes undergo change, which in turn means that its limits of stability may be shifted and the response is then different even when a disturbance of identical nature to a previous one occurs. A typical example involving system responses can be seen in the way blood pressure of the circulation system changes during the process of getting up from a prone position.

This portrayal of blood pressure regulation shows periodic changes in transient oscillation behaviour of about 20 seconds or about 6 seconds duration. Balzer (1988) was able to demon- strate the transient oscillation effect in the circaseptan regulation of sleeping-waking behaviour.

In Balzer *et al.* (1988) we have outlined the transient oscillation process of an insomnia patient's infradian rhythm (following many years of treatment with medicines against insomnia) in case of drug detoxication. Only after about 4 weeks did a circaseptan sleeping rhythm corresponding to those of healthy persons become established, whilst at the same time the occurrence probability of this rhythm increased by about 35%.

In 1982, Tiedt demonstrated such a regulatory process for the respiration of patients suffering from dyspnoea in comparison with healthy subjects.

As early as 1993 Balzer (1987, 1993) and Hecht (1987, 1990) were able to confirm typical characteristics of the model describing the modus operandi of biological systems through their investigations into alterations in sleeping behaviour.

Following Halberg and Hildebrandt, we speak of a hierarchy of biological rhythms. Such biological rhythms can be demonstrated to exist for differing regulatory processes as well as for regulatory processes of differing systems. Thus the circadian rhythm is often underlaid by further more or less clearly defined ultradian rhythms.

The ultradian 4 h rhythm is commonly perceptible for the ordinary observer. Sleep researchers speak of so-called sleep windows, i.e. from moments of natural tiredness. They usually occur every 4 hours (09 h, 13 h, 17 h, 21 h, 01 h, 05 h). The 2 h rhythm embedded in the windows is known from sleeping phases as a period of

REM sleep (REM: Rapid Eye Movement). This in turn consists of approximately 90 minutes of activation followed by about 30 minutes of deactivation. During the day, this rhythm is referred to as the Basic Rest Activity Cycle (BRAC) (Kleitmann 1970). In the course of this rhythm the values of a variety of physiological, biochemical, psychological parameters undergo changes: Observations to date suggest that, on the whole, a shifting of values towards relaxation states (in this case the positive upper area) is associated with a slowing down of regulatory processes and vice versa.

According to the modus operandi of biological systems (Balzer 2000a, 2004), the existing period durations become shorter on activation and longer on deactivation. To investigate this, the measurement data – i.e. the skin potential data – were subjected to a chronobiological regulation analysis (Balzer 1988, 2000a). That is to say, the following interrelationship exists:
The higher the degree of activation (for the parameter skin potential this means 'more negative' values), the more rapid the regulatory process or equivalently the shorter the periods. Moments in which a disposition to fall asleep occur display a low degree of activation and thus slower regulatory processes. Correspondingly such 'sleep disposition moments' appear as
local maxima.

Following the regulation analysis, the trend displayed by the change in regulation period was investigated. This involves the presentation of the mean changes in the vegetative nervous regulation of the above-mentioned regulation range. Additionally, an approximation line based on a polynomial adjustment calculation was overlaid on the smoothed trend line. This graph shows the circadian progression.

Whereas circadian rhythms are difficult to detect in the raw data, they become more clearly visible in the regulation analysis, whereby the two complete measurement days displayn opposing phases. It is especially noticeable that the regulatory processes take effect more quickly during the nights, i.e. they tend in the direction of stimulation.

The sleep disposition moments mentioned above with their pronounced phase shifts are clearly apparent, whereas in the original data they are hardly perceptible.

However, neuronal processes also exhibit rhythmic patterns or are themselves influenced by such patterns. The activity and productivity of the brain is affected by a wide range of processes. The cerebral autoregulation system serves to maintain the blood flow level in the brain when the pressure in the total circulation system fluctuates. Blood reaches the brain via the cerebral circulation system. This supplies the brain with both oxygen and glucose as a source of energy. At the end of the 19th century C. Roy and C. Sherrington postulated a local rise in blood circulation in brain regions with increased neuronal activity (Roy and Sherrington 1890, cited in Villringer and Dirnagl 1995, p. 253 after Duschek 2005). The dynamic modification of the cerebral blood flow in association with neuronal processes is known as neurovascular coupling. It is based on an increase in the metabolic rate when neuronal activity increases.

Within the bounds of the autoregulatory system the flow of blood remains largely constant as a result of arterial constriction and dilatation. The exact range of factors, involved in maintaining this steady state has not yet been completely ascertained. According to Duschek the principal mechanisms include especially myogenic and metabolic factors as well as ones involving cerebro-vascular endotheli cells.

The approximately 1-second rhythm of the relative change in the flow of blood can be clearly identified. The step function shown represents the connection with the heartbeat rhythm, whereby the width of one step is equivalent to the R peak interval and the level of each step gives the mean blood flow velocity. Thus the sympathicotonically and parasympathe- tically controlled coronary activity provides us with another example of a feedback response connected with the relative change in blood flow in the brain. Modern medical imaging techniques such as fMRI and PET exploit the changes in blood flow velocity in order to demonstrate increased brain activity. The advantage of functional transcranial Doppler sonography (fTCD) consists in its capacity to record rapidly changing activation processes such as those which are to be observed in connection with listening to music. fMRI or PET recordings, on the contrary, involve a great deal more effort and the sampling intervals are rather long (>several seconds). However, the fTCD method has the disadvantage of allowing only a limited spatial resolution.

The foundation of chronobiological regulation diagnosis according to Balzer and Hecht (2000a), Balzer et al. (2004) is R. Virchow's definition of the way in which disease originates; this has already been cited above. The investigation of regulatory processes requires first and foremost the registration and analysis of time series for physiological, biochemical or other parameters. Vegetative function parameters such as the heart rate (HR) or the parameter heart rate variability (HRV) derived from it, the electromyogram (EMG), the skin resistance (SR) and the skin potential (SP) can be registered relatively easily and reliably, whereas other physiological parameters such as brain activity (Electroencephalogram – EEG), blood pressure (BP), eye activity (Electrooculogram – EOG) and the flow of blood (BF) present more difficulties. At present, it is only possible to achieve continuous and non-invasive recording of biochemical, and certainly immunological parameters (cortisol, ACTH, IgA, SigA, etc.) under certain circumstances and with a great deal of technical effort. As already mentioned, a person not only takes in music via the auditory system but also reacts to musical stimuli with neuronal activity in the brain. We have firm evidence confirming the existence of physiological, biochemical, immunological, psychological and behavioural responses in hu- mans to music. Thus music encompasses the entire spectrum of biological reaction and the question arises as to which of the many parameters should be investigated in order to arrive at an understanding of the effect of music. To be able to investigate cause and effect it is necessary to follow the temporal course of the effect of a stimulus as well as the temporal course of the stimulus itself at one and the same time, and this involves the generation of data in the form of time series.

A time series is a temporal sequence of data containing three components as follows:

- Quasi-stationary (subject to slow change) constituents: Measured or observed data which undergo steady change (linear or non-linear) without periodic patterns within the time interval under investigatio
- Periodic constituents: Changes in measured or observed results which do not display a trend and within a defined interval of time regularly reach maximum and minimum levels.
- Stochastic constituents: Changes in measured or observed results which neither display a trend nor contain any periodically repeating patterns.

Periodic processes are one prerequisite for the existence of physical laws governing regularity. This in turn is the basis for the analysis of the periodic constituents of time series. It is appropriate at this stage to mention a weakness pertaining to the mathematical resources which have been employed in medicine and psychology to date: Frequently, measured or otherwise generated data are examined for significant characteristics (for instance, blood pressure measurements taken before and after therapeutic measures) by means of significance tests. The quantities used are the mean value and measures for the standard deviation of the data, the variance or statistical variability. This approach does not include an analysis of the information which may be hidden in the standard deviation of the data. An extreme case may be depicted as follows:

As biological systems are intrinsically non-linear, it is to be expected that no purely sinusoidal patterns occur, but instead either more complicated periodic patterns based on a spectral composition or a combination of several different regulatory processes. This provides the motivation to investigate the existence of such spectral compositions. However, in order to obtain a fundamental understanding of the modus operandi of biological systems it is above all important to recognise the changes in the main components of a given regulatory system over the course of time.

The first demonstration of change in a biological regulation process over time was provided by Balzer in 1988 with the implementation of the technique which he called 'dynamic analysis'. In view of the three components of time series mentioned above (quasi-stationary, periodic and stochastic) a periodic process can only be demonstrated with a certain degree of probability. In this connection, the question has often been raised as to the significance of a biological rhythm. Generally it may be assumed that naturally occurring processes may contain periodic components within what appears to be 'process noise', i.e. background elements such as those known from sound recording technology. As in time series data for biological systems, it may be assumed that the size of a subsequent value is not independent of the preceding one, and the use of an arbitrarily selected level of significance (e.g. 0.05) is inadmissible. The exact proof of the existence of a biological regulatory process is only possible if it occurs in a reproducible way and the demonstration of its propensity to undergo change under defined conditions is reproducible.

In a series of studies[3] on both humans and animals Balzer and Hecht were able to demonstrate the existence of consistent regulatory patterns in organisms on the basis of *regulation states*, which are also often referred to in medical language as function states. A regulation state can be defined thus:

Definition: *A regulation state is a quasi-stationary state occurring in a regulation system over a given period of time which is characterised by typical regulatory processes. A typical regulatory process is the distribution of a regulation function over time in which the distribution function contains mathematically definable features (peaks, skewness, etc.). Regulatory processes are characterised amongst other things by multiplicative*[4] *or demultiplicative regulation discontinuities.*

The basis of the *analysis of state* ('*Zustandsanalyse*') is dynamic analysis (Balzer 1988), which determines the change of a regulation period over time. A *state function* in this sense is essentially a three-dimensional function involving the variables *time*, *degree of activation* and *quality of regulation*.

The degree of activation is a measure of whether the distribution function is returning a phase in which rapid regulatory processes (short periods) ¼ *activation* or slow regulatory processes (long periods) ¼ *deactivation* predominate. The quality of regulation is a measure of the way in which the periods are distributed. A single column (period) corresponds to a fixed regulatory process. In a completely desynchronised state all periods are equally distributed, similar to a chaotic state.

The characteristic regulatory processes together with the associated regulation states have been drawn up into a *periodic system of regulatory states* (PSR). Every regulation state represented in the PSR is identified with a number. The numbers of the PSR are for the purposes of classification. Each of the state profiles contains a progression from short periods on the left to long periods on the right. The y axis reflects the frequency with which the periods were observed in the corresponding time window.

The characteristic basic regulation states include activation and deactivation, the transition between activation and deactivation, hyper-deactivation, stereotype hyper-deactivation, hyperactivation, dysregulation, stereotype dysregulation and regulation discontinuities[5] (i.e. jumps of the regulation system from the state 37 to the state 31 – called overload inhibition by Pavlov).

An adaptive regulation is characterised by the alteration between activation and deactiva- tion. An example of this is to be found in the sleeping=waking cycle, another in the Basic Rest Activity Cycle (BRAC) (Kleitmann 1970). The two states (activation – deactivation) alternate in the now generally known phenomenon of REM sleep (REM: Rapid Eye Movement) and in its 'counterpart' encountered during the period of wakefulness known as BRAC, containing an approximately 90 minute phase of state 06 (activation) followed by state 02 (deactivation) with a duration of about 30 minutes.

In cases of chronic stress rapid regulatory processes predominate, i.e. ones with short periods.
In states of trance such as those which can occur in daytime trances, hypnosis, meditation and deep sleep, slow regulatory processes predominate with long periods.

In extreme cases of chronic stress over a long period a state of spasm may occur (state 37). In this condition regulatory processes are mainly characteristically rapid with very short periods, as shown by the parameter EMG for the performance situation (1st movement) of a musician.

During the time interval 20:35 h-20:38 h a regulation period of only 2 seconds for muscular regulation occurs; this is an indication of a cramped playing style.

In biological systems in a state of chronic stress (state 17) or in a state of spasm (state 37), further loading can lead to a temporary switch to state 31. This phenomenon is known as overload inhibition after Pavlov (1955).

Pastor (2007) was able to show blackouts occurring for durations of a few seconds in pianists in the course of performance situations. They were to be seen in the parameter SP (vegetative-nervous reaction) in the regulation states 11, 12 and 13. Investigations by Balzer (2003a) have shown that a vegetative-nervous reaction occurs especially in connection with cognitive processes in the brain. Thus it may be that in this form of overload inhibition the overload is brought about by cognitive processes.

Characteristic of the neurotic state is the occurrence of all possible regulatory processes with the same degree of probability over a given interval of time. The system behaviour is chaotic. The biological system alternates in an unorganised manner within the full spectrum of regulatory processes between the most rapid and the slowest. The neurotic state may be indicated in its initial phase by insecurity, nervousness and=or anxiety (see also Balzer 1987, v. Broen 1988, Benecke 2004).

In a pronounced depressive state there are spontaneous switches between activation and deactivation with only defined regulatory processes. In comparison with neurotic states, not all regulation periods do not exist and there is an overbalance of deactivations.

The therapeutic effects of music are based not only on heightening the subject's ability to relax (deactivation), his or her level of motivation (activation), but also on the extent to which regulatory processes in the body can be synchronised so as to eliminate or diminish disturbances within them.

At the outset of the therapy the patient is, from a regulatory point of view, in a transitional area (42-43) (regulation states marked with '1') from the overloaded, concentrated regulation on the deactivated side with the onset of regulation decay and rigid regulatory processes typical of depressive states (62-64, 72-74). As a result of the music therapy sessions, the patient's vegetative regulation state improves and he reaches both the activated region (right-hand side) and the balanced regulation area (state 23). The patient could be discharged in a considerably improved condition. In the sphere of veterinary research corresponding conditions are described as apathetic rather than depressed states (Bennecke 2004).

A state of anxiety can be characterised in a similar way to the neurotic state. A less pronounced state of anxiety appears to correspond to the states 22 and 24 according to recent research findings (Pastor 2007). Thus it is consistent with a cramped=spasmodic state with frequent alternation between activation and deactivation.

It may be assumed that biological regulatory systems do not exist in isolation from each other. The more complex an organism is, the greater the number of possible interconnections between the regulatory systems. But even the relationship between just two regulatory systems, such as those of respiration and the cardiovascular system, is subject to modulation, to some extent of a periodical nature. The best known variable association is that between the heart rate and breathing frequency.

However, more complex interrelationships occur between physiological and psychological regulatory components. Thus the psyche tends to relax when the body undergoes physical exertion and vice versa. An existing state of psychological tension may be relieved by the onset of speech. Generally, running or jogging brings about a state of psychological relaxation. In certain cases, however, physical exertion is combined with a high level of psychological tension, for instance in highly charged competitive situations or with pilots subjected to high g-forces during spectacular flying stunts. In such situations the metabolic rate goes up considerably. A similar phenomenon is to be found with musicians and conductors during performances. An increased metabolic rate is coupled with an accelerated execution of metabolic regulatory processes. These more rapidly executing processes display shorter periods than is normally the case. When we assert that listening to music can have a relaxing effect, this can happen in various different ways. Ideally, all the sub-processes involved in the complex regulatory system relax together. However, on account of the variations inherent in musical presentations, a uniformly relaxing or uniformly exciting experience represents the exception rather than the rule.

Considering a biological system whose equilibrium is normally maintained through the actions of two antagonistic regulatory processes (e.g. sympathetic and parasympathetic regulation), it is characteristic of such a system that the regulation phases are in opposition to each other. For instance, in a balanced, normal situation a person relaxes mentally when he or she does hard physical exercise and vice versa.

One generally assumes that it is necessary to 'pull oneself together' in order to attain a given achievement. According to the modus operandi of biological systems this is only possible by means of an increased expenditure of metabolic energy associated with more rapidly executing regulatory processes . As a rule, this is accompanied by the synchronisation of the regulatory processes, for maximum performance is only possible in a highly synchronised system. Listening to music frequently gives rise to a state of deep relaxation and a sense of well-being, which we also refer to as physical harmony. In other words, a biological system can also be characterised by very slow and synchronised regulatory processes.

Indeed, in many cases more metabolic energy is available than is actually needed. A biological system which is in a chaotic state of (de-)regulation or synchronisation either consumes a correspondingly large amount of metabolic energy without achieving an adequate result or it is in that state because not enough such energy is available. In 1995, in the course of a study on the recognition performance of vehicle drivers, Balzer was able to demonstrate for the first time that such synchronisation processes do actually exist. The following figure shows such an authentic synchronisation process:

To this end the regulatory processes of the parameters SP, EMG and SR were analysed. A comparison with the principle of the synchronisation of regulatory processes as depicted in Fig. 14 shows that the synchronisation process represents an oscillatory movement between the states of excitement and relaxation. This means that the synchronisation itself displays periodic behaviour. Over and above this, various synchronisation levels exist. This could be shown more clearly under other conditions.

In contrast to the singer's performance, in this case the source of stress is of a more cognitive nature: a lesson in mathematics for a pupil with learning difficulties (Schwenk 2003). For this context Balzer developed a simplified cluster analysis procedure, assigning the terms *eustress*, *distress*, *relaxation* and *overloading* to represent the synchronisation levels or synchronisation regions. Ferstl (2005) implemented this procedure in order to demonstrate various phases in the synchronisation of vegetative functions in professional musicians during their performances.

Using the findings gathered so far, the complexity of the synchronisation processes in biological systems allows us to postulate the following hypotheses in this respect:

Hypothesis 1

The rhythmical structure of musical works stimulates synchronisation processes in biological systems.

Hypothesis 2

Higher degrees of synchronisation in biological systems allow musicians to achieve better interpretation performances either in connection with an increased mobilisation of metabolic energy or through the use of metabolic energy 'captured' from reserves intended for other tasks.

Balzer (2002) was able to demonstrate the existence of synchronisation processes between the regulatory processes of muscular reactions and heart rate. It transpired that in some cases the synchronisation took place towardsthe end of the piece of music being listened to and afterwards.

Whereas the validity of the first hypothesis and the first part of the second hypothesis has already been demonstrated in studies published by Balzer (2002) and Ferstl (2005), thu second part of the second hypothesis remains as yet unproved. However, it is generally acknowledged that musicians, singers or other artists who in the course of their perfor- mances 'become one with music' are able to continue over long periods of time without exhaustion. A typical example of this phenomenon can be seen in Romanies who live with their music or indeed 'in' it. Often such performers attain a state of trance which represents a particularly high degree of synchronisation. Further examples are aerobic exercises or musically accompanied water gymnastics, whereby the use of music can contribute to unusual feats of physical achievement.

Not least, it is likely that the so-called Mozart effect (Rauscher 1993) can be attributed to synchronisation phenomena. However, even better synchronisation results can be achieved when the synchronisation is reached in a holistic manner. That is to say that not only music or art generally may lead to synchronisation through perceptive processes, but that synchronisation may also be attainable through synchronically running physical processes. Equally, the human biological system demands a constant alternation between tension and relaxation. As we know that, normally, physical effort can contribute to mental relaxation, this opens up additional ways of increasing the occurrence of synchronisation effects. Ideally, this can lead to achievement on an unusually high level. Grebosz (2006) was able to provide a clear demonstration of this in a comparison of pupils from a normal primary school, a primary school with an emphasis on music and one with an artistic bias in Poland.

The pupils in the music and art primary schools received the same musical education. In addition, the pupils in the art primary school received further tuition in rhythm, dancing and the plastic arts. The comparison revealed that the pupils from the art primary school who received the most comprehensive education clearly achieved the best results in mathematics. This was especially noteworthy in view of the fact that these pupils came mainly from rural catchment areas and their parents pursued mainly rural occupations.

On the basis that better performance in mathematics requires, especially, greater mental effort in terms of cognitive processes, the explanation presents itself that synchronisation effects (e.g. in the circulation system) have brought about the production of extra reserves of metabolic energy in the form of glucose and oxygen which are available for 'extraneous' purposes. This provides the basis on which additional neuronal connections can be made
which in the end lead to better cognitive performances. Thus the synchronisation processes via neurovascular coupling of both physiological and biochemical processes throughout the body advance to

become a key factor towards understanding higher cerebral achievement. Duschek (2005) showed that there is a direct correlation between increased cognitive performance and the flow of blood through the brain.

This experiment provided evidence for a local increase in the blood flow velocity in the arteria cerebri media (MCA). In connection with the effect of music, Roederer (1993) remarked: "The dissemination of a cyclically varying flow of neural signals through the brain matter such as is precipitated by rhythmical sound patterns seems somehow to engage in a kind of 'resonance' with the brain's natural clocks which determine physical and behavioural reactions. These clocks probably work on the basis of neuronal activity which propagates in closed circuits or engrammes, or in neuronal 'wiring networks' which possess natural autonomous cyclical reaction periods".

However, the further course of his elucidation is almost entirely concerned with the semiosis of his approach. In this, musical structures are transformed into topographical structures, e.g. in the form of Eulerian spaces for degrees of pitch. No statements are made in respect of the way the music is registered by a listener, nor of its effect, nor of the concrete communication process which takes place between the composer, the piece of music and the listener.

In a large number of investigations into relaxation conducted using a special blood pressure relaxation test (BRT), Hecht and Balzer (1998), Balzer et al. (2004) discovered that the lowest value of the systolic blood pressure is usually attained during the seventh to eighth minute from the beginning of the relaxation.

Following indications suggesting the existence of biological rhythms in musical works Balzer and Balzer (2001) began to investigate the structure of the movement lengths of pieces of music and thereby found an interesting correlation between the movement lengths of differing genres from various epochs with the times at which the minimum systolic blood pressure during....

Whereas the movement lengths for ancient music show a distinct maximum around the 3-minute mark, the maximum for vocal and pre-classical music can be seen to lie between 3 and 4 minutes. Baroque music again displays a maximum around 3 minutes, although 2- and 4-minute movements are represented more often. For classical music there is also a maximum at 3 minutes, but otherwise the distribution is relatively uniform and also the number of longer movement lengths compared with the previous epochs shows a marked increase. In the course of the romantic period the distribution structure changes. A double peak appears, whereby movement lengths around seven minutes in length predominate. This already represents a very good correlation with the relaxation times alluded to above. Under consideration of the basic chronobiological rule which states that the halving of periodicities is connected with activation processes, the conclusion may be drawn that movement lengths of 3 minutes have a generally activatory character and those lasting 7 minutes a generally deactivatory character. Investigations by Schedlowski (1993) showed that the rise time of Noradrenalin is approxi- mately 7-8 minutes.

The movement length analysis for selected composer (see Fig. 30) yielded the following results:

Whereas with Bach short movements of 2-3 minutes duration predominate, those of Beethoven are longer, with durations around 9-10 minutes. The music of W. A. Mozart displayed a more balanced double peaked distribution, with one local maximum at 3 minutes and another between 5 and 6 minutes. Schubert's music, on the contrary, shows a general shift towards longer movement lengths and a less pronounced maximum between 6 and 7 minutes.

Bachmann (2006) used Balzer's (1988, 2000a) time series analysis method in order to investigate basic musical parameters such as amplitude, frequency spectrum and tone sequence density. As aresult, anapproximately 1 minute rhythm couldbe demonstrated amongst others in the relative amplitude variation for D. Shostakovich's 11th symphony. This rhythm of approxi- mately 1 minute is also, amongst others, to be found as a higher order rhythm inthe fluctuation of the heart rate in a test subject. It has also been established to exist in the sympathetically innervated reaction of sweat gland secretion (parameter skin resistance), in the EMG of the vegetative-nervous reaction (parameter skin potential) (Balzer 1989), EEGs (Fietze 1988, 1989), in the oscillation of membrane-bound redox components of the respiration metabolism, the volume fluctuation of mitochondria (Hess and Boiteux 1971), oscillations in sub-cortical structures (Sinz 1986) in the duration of nightly waking periods (Aurich 1993) andinothercircumstances. This biologicalrhythmplays acentralrole inrespectof synchronisation effects between music and listeners.

Even without the aid of a mathematical time series analysis, periodically increasing amplitude variations can be detected especially in the second part of the movement. The variations themselves display a rhythmicity of approximately 1 minute. It is to be assumed that the composer did not invent these periodic variations in the light of a conscious knowledge of his own biological regulatory processes.

Bachmann analysed D. Shostakovich's 11th symphony in the context of the periodic system of regulation states, whereby in the process recordings from various conductors were compared.

In the analysis, the regulation states were determined as described above using the basic parameters amplitude, frequency spectrum and tone sequence density as a time series and overlaid on the background of the possible regulation states (the interval between the regulation states which was established is 1 second). It can be seen that different interpretations of the same piece of music can lead to different states. Jearvi's interpretation shows a slight distribution bias to the left towards the region of 'more deactivated'. Whereas the interpretation by Schwarz is concentrated on the middle states, that of Stokovski is limited to the upper adaptive regulation states, corresponding to a rather less dynamic rendering. However, this interpretation also attains extreme states, especially in the deactivated range (trancelike states), which is not the case with the other recordings. In contrast, Jansons's interpretation shows the most balanced dynamics. For the first time, this method has made it possible to draw conclusions in respect of psycho-physiological effects of musical works on the basis of their musical structure.

In 2003, Balzer formulated the following hypothesis on the basis of the findings presented hitherto:

A listener perceives music as pleasant when the biological rhythms which are integrated into the music by composers and interpreters begin to synchronise with those of the listener.

However, this can only be regarded as a necessary prerequisite. That is to say, the fulfilment of the conditions contained in the hypothesis does not automatically lead to music being described by the listener as 'agreeable'

In order to test this hypothesis Balzer et al. (2005) conducted a study of the effects of music in 2004 with the aim of establishing correlations between the regulatory processes inherent in music and those of the people listening to it. Twenty-four test subjects took part in the study, whereby 12 of them constituted the group of 'music listeners' and the other 12 a control group.
The complete sample set contained male and female test persons aged between 20 and 40.
Altogether 10 different musical compositions (mainly classical) were examined in respect of their influence on the group. The synchronisation process is clarified here on the basis of an example involving music by W. A. Mozart.

The effect of music on a listener can be shown via the changes that take place in his or her vegetative state. This state is determined by, amongst other factors, the vegetative-emotional reaction (sympathetically innervated, measurement parameter skin resistance), the vegeta- tive-nervous reaction (parasympathetically innervated, measurement parameter skin poten- tial) and the muscular reaction (measurement parameter electromyogram). For the purposes of comparison, corresponding regulation states according to the periodic system of regulation states (PSR) were selected from the rhythmical changes in the musical parameters (change in amplitude, summed frequency spectrum, and frequency-dependent tone sequence density). The course of the synchronisation between the processes of alteration in the regulation states of the listeners and the music can be computed by means of correlation analysis. In the following figures the relationships between the listeners and the music are shown separately for the quality of the regulation and for the activation situation.

The use of music for therapeutic purposes may be divided into two main categories, namely those of active and passive application. The active forms of therapy include those in which the patient becomes musically active himself or herself as well as those in which a trained music therapist contributes towards the restoration of a patient's health with the aid of music, because there is an interaction between the therapist and the patient.

Thus music therapy represents one of the many forms of art therapy.

Tucek (2000) makes use of traditional oriental music therapy (AM) and describes this approach as follows: "AM can be implemented in either a passive or an active manner. The range of methods includes receptive, key-specific listening to music, active movement and dance, passive 'being moved', touch, active collective playing of music, guided and free imaginative forays, fables, poetry, artistic modelling (ebru, decoration), working with elements

(e.g. water, horse, etc.), therapeutic sessions. The position held by the therapist may be grounded in psychological, philosophical or religious-spiritual concepts. In the cognition process through which the therapist goes both rational and intuitive aspects play central roles together and interactively.

The therapeutic effect of receptive AM is based on the reception of a sequence of particular modi and melodies. In this its structurally intuitive modus operandi differs significantly from the planned musical sequences of western music therapies which represent a more analogue-heuristic approach. The concept is 'allopathic' in the sense that it pursues the principle of physiological and psychological compensation of deficits or overabundance by means of harmonisation and strengthening. Music, dance and special sequences of movement serve to counterbalance or abrogate a given affective state. The therapeutic effect of receptive AM is based on a sequence of special modi and melodies, the so-called 'maqamat'. These are microtonally arranged scales based on ninths (i.e. a whole tone is divided into nine subunits) which are built up on a particular fundamental note with specific sound structures and which thus cannot be transposed at will."

A crucial issue for the success of music therapy concerns the question as to whether it proves possible to find access to the patient with the aid of music. It is possible to distinguish between three forms of access: purely emotional, purely rational (via cognitive processes) and a mixture of the two. The latter is most common. The positive effects of music therapy have been confirmed in a large number of mainly clinical studies, e.g. by Aldrige (1994, 2003), Tomaino (1999), Bernatzki (2005b) and Scharinger (2006).

To date, music therapy is most demonstrably successful when brought to bear on the psychosomatic part of an ailment. Thus it was possible to document the effectiveness of receptive music therapy in, amongst others, concrete cases where the consumption of analgesics for pain conditions (Bernatzki 2005a) was reduced or a reduction in blood pressure in patients suffering from hypertonia (Balzer and Brandes 2006) was achieved. The lowering of the blood pressure was verified using the blood pressure relaxation test (BRT) according to Balzer (2004).

At the start of the blood pressure relaxation test, the initial parameters are the values of the systolic blood pressure. In this test, 10 blood pressure measurements are taken at one-minute intervals. The resting blood pressure value in respect of the systolic blood pressure is usually reached in the 7^{th} or 8^{th} minute from the start. The blood pressure reducing effect may take place either through the deactivation of the sympathetic tonus or through the activation of the parasympathetic system. In this study, it was possible to show that the blood pressure reduction was mainly achieved through the activation of the parasympathetic system. The evidence was gathered in the form of a statistically significant increase in the HF power component of the heart rate variability and through the large proportional change in the regulatory quality of the vegetative-nervous reaction (parameter SP).

A rapid onset of effect for the music therapy refers to the change in blood pressure values after a 4-week period of implementation. As in some cases the patients continued to receive treatment with medication during the time in which they underwent music therapy, the influence of the latter on the blood pressure values could only be established through a comparison with a control group (groups A and B). It was possible to attribute a proportion of the treatment success amounting to 40% to the receptive music therapy.

The response of a biological systems to a stimulus depends on:

- the initial state (phase length – activated or deactivated) (whereby the predominating bio- logical rhythm determines the point in time at which a system is activated or deactivated)
- regulation type (the way in which the systems deal with stress situations)
- degree of sensitivity in respect of the type of stimulus
- adaptability
- type of stimulus – cognitive=non-cognitive
- one or several components
- single or repeated stimulation
- intensity

Under consideration of the examples of the effects of music which have been presented above, it would appear necessary to develop a chronobiological theory of musically inspired emotion in order to arrive at a balanced view of the latter's psycho-physiological basis. As a starting point, four fundamental emotions may be identified: a sense of well-being, of joy, of sadness and of anger.

Emotions are components of and expressions of feelings, which may be characterised by their polarisation (negative and positive) and their degree of intensity. The relationship between the fundamental emotions as defined from a psychological point of view and physiological parameters can be established as follows: Emotional reactions can be registered via the autonomic sweat gland secretion controlled by the sympathetic system through the measurement of the parameter skin resistance. Nervous (cognitive) reactions can be autonomically registered via the predominantly parasympathetically controlled changes in the parameter skin potential (bipolar measurement of the slowly changing differences in the summed cell potentials on the surface of the skin (Balzer 2003a).) Behavioural indicators (sitting, lying, resting, sleeping, aggression, defence, etc.) can be typified with the aid of the three autonomic basis parameters EMG, SR, SP and the behavioural parameter 3D-A (three dimensional acceleration). The assignment of physio- logical reactions to psychologically defined fundamental emotions can be achieved through the determination of regulation states.

Assignment of basic emotions in the periodic system of regulation states:

It is possible to distinguish between basic states, extreme states and mixed states (mixture of the two or more states). The basic states finally are indicated according to their temporal representation by the presence of regulation states in defined sections of the regulation scheme. The mixed states display above all temporally variable connections between the regulation states and the regulation levels.

The following hypotheses are put forward:

Joy as a form of expression of human behaviour may be represented in various ways. A principal distinction is to be made between joy which remains 'within' and that which finds outward expression. Characteristic of this outwardly manifested joy is that the regulation states of all 4 parameters (SR, SP, EMG and 3D-A) are to be found in the upper right-hand quadrant; in the activation region displaying a high degree of regulation quality. This gives rise to synchronisation effects in the regulatory functions of these parameters with short regulation periods and high metabolic levels. Thus in this state, energy is expended. This type of joy is accompanied by motoric activity, whereas a state of inner joy is associated with relatively little motoric activity. This means that the parameters EMG and 3D-A may lie on the left-hand, deactivation side and the expenditure of energy is correspondingly less. The highest degree of joy is a state of ecstasy. This is usually accompanied by a large amount of motoric activity; the synchronisation of the regulatory functions reaches its maximum. All the regulation states lie in the upper right-hand quadrant.

A state of well-being is one of deactivation. Thus in an ideal case all four parameters should lie in the upper left-hand quadrant in the deactivation region and with a high degree of regulation quality. Satisfaction, on the contrary, can be seen as a form of introverted well- being which allows for the motoric parameters (EMG and 3D-A) to be located in the upper right-hand quadrant, whereas the cognitive and emotional parameters are to be found in the upper left-hand quadrant. Synchronisation processes between the regulation functions of the parameters also occur in a state of well-being, but on account of the inertia of the metabolic apparatus this actually gives rise to an initial excess of metabolic energy. Trance states can be considered to be elevated forms of states of well-being. They may be accompanied by temporary occurrences of overload inhibitions.

Sadness is an introverted expression of behaviour. In this state, physical as well as mental (nervous) inactivity predominates. The emotional state is also usually located in the deactivated region. The highest degree of sadness is reached on the synchronisation of the regulatory processes of the functions mentioned in the lower, left-hand quadrant. Melancholia and sadness are closely associated, both representing examples of depressive behaviour patterns.

Anger is associated with states of arousal and a low degree of adaptability. The motoric component (EMG) and=or the behavioural component (3D-A) may be located in the deactivation region. On the whole, however, all four parameters are to be found in the activation part of the lower right-hand quadrant. An extreme form of anger is expressed as rage, which may overflow into aggressive physical activity.

In connection with the musical example by W. A. Mozart (Piano Concerto No. 17, 3rd movement, KV 453), which has already been mentioned above, an analysis of the regulation states of the basic musical parameters (volume, frequency, and tone sequence density) yields the following distribution:

Most of the regulation states are to be found in the upper left-hand quadrant and are indicative of well-being. It may be supposed that a similar situation is likely to arise for a person listening to this piece of music. Apart from the part in the activation region as well as joy and the middle, unassigned area, the regulation states found are essentially coherent. The course of the synchronisation between the music and the listener shown in Fig. 39, too, is lost in this representation. In addition, it is conspicuous in this case that especially the regulation states of the musical parameter tone sequence density typify the area of well-being, whereas in the case of the test subject this is, as may be expected, represented rather through the parameter SR (vegetative-emotional reaction or sympathicotonic reaction).

In view of the large number of possible factors that may influence the listener's emotional and cognitive reactions, a wide range of different forms of reaction is possible. To achieve a sufficient appreciation of this there is a need for more research work. A key to understanding the many faceted effects of music in all its various forms may be seen in the synchronisation processes which take place in both listeners and performers.

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Chapter 4

Music as medicine: incorporating scalable music based interventions into standard medical practice

Healing by means of music is a very ancient medical art with many approaches to both learning and practice. Music therapy, as it is practiced today, is the systematic application of music in the treatment of the physiological and psychosocial aspects of an illness or disability. It focuses on the acquisition of non-musical skills and behaviour patterns, as determined by a trained music therapist, through systematic assessment and treatment planning.

MusicMedicine is the term used to describe music interventions based on physiological and psychological parameters that, contrary to active forms of Music therapy, do not require a musician who is trained as a music therapist. "*For today reliable evidence exists to confirm that music produces reproducible effects and has valuable therapeutic properties. Therefore we recommend the use of the term MusicMedicine to designate the therapeutic use of music in medicine*". (Spintge and Droh (eds.) 1987)

MusicMedicine implements music as a therapeutic medium in medical treatment. The patient listens to music that has been selected for him or her by the therapist, whereby the music takes on the role of a prescribed intervention. Where this is performed on the basis of exact knowledge of the various aspects and levels of effect, it would be legitimate to refer to MusicMedicine as music pharmacology.

During the past 20 years significant advances have been made in terms of both research and practical implementation of music as an accompanying factor in the healing process. Recent research results suggest that in certain cases the use of targeted intervention with music can be more advantageous in comparison with conventional forms of treatment.

> "*Through successful music experiences, patients can regain a sense of control, independence, and confidence. Music can be a medium of communication and a strategy for refocusing attention during painful procedures or long treatments, and a source of emotional support.*
>
> *Music is clinically recognized to influence biological responses such as heart rate, blood pressure, respiration rate, cardiac output, muscle tone, pupillary responses, skin responses, the immune system, and endorphin production. Music can entrain the body to calm or to accelerate depending on what type of music is used. Sedative music can lower anxiety, pain, tension and stress levels resulting in less use of anaesthetics and pain medication, a shorter recovery period, higher patient compliance and higher patient and family satisfaction. Stimulative music can be a source of motivation both physically and psychologically and becomes a positive reinforcement during physical therapy and rehabilitation. In summary, music can contribute significantly to medical care providing psychological and physical*
>
> *comfort to patients with various needs.*" (Lane 2008)

By far, the greatest research efforts in the recent years have been directed towards basic neuroscientific research on the effects of music. This has involved investigation into the different ways in which musicians and non-musicians process music, as well as the effects of instrumental instruction. The few clinical practice studies that are available mostly lack data on untreated control groups or those subjected to placebo interventions. Only few studies have been performed to investigate possible differences in the ways people suffering from disorders and healthy people process musical stimuli. Only very recently, imaging techniques have been implemented with a view to demonstrating therapeutic effects of music in patients.

Statistical reproducibility is a prerequisite for any form of intervention to be accepted into the canon of standard medical treatment. Despite the large number of studies that have been conducted to investigate the effects of music, few would satisfy the criteria of evidence-based medicine. Active music therapy comes in many forms, as tailored to individual patients' requirements. To address the multiplicity of active music therapy forms and to improve comparability, researchers have made practicable suggestions as to how studies could be designed in the future. Specifically, if music therapists were to document their patients' courses of treatment according to uniform criteria, this would result in a large database that could allow for diagnosis-specific, quantitative evaluation within a short period of time. A combination of quantitative and qualitative research methods is needed to demonstrate the effects of music interventions on the different aspects of health.

David Aldridge, who for many years has held the Chair for Qualitative Research in Medicine at the University of Witten=Herdecke, and his colleagues have already done pioneering work in documentation of music therapy research. Cheryl Dileo, Professor of Music Therapy, Coordinator of the Master's Program in Music Therapy and Director of the new, interdisciplinary Arts and Quality of Life Research Center at Temple University in Philadelphia, USA, will present further meta-analyses in the coming years. These may be expected to set more milestones in establishing the various forms of both music therapy and MusicMedicine.

Wherever standard interventions are employed in MusicMedicine, and in receptive music therapy, it is possible to conduct randomised, placebo and waiting list controlled double-blind studies. According to the information at our disposal, our research program was the first one in which standardised interventions of receptive music therapy applied in MusicMedicine have been developed and then evaluated in randomised, placebo and waiting list controlled double-blind studies. The combination of quantitative psychometric methods, analysis of physiological parameters, qualitative methods such as in-depth interviews, Morphological Media Effects Research[1] and the ZMET Method (Zaltman Metaphor Elicitation Technique, Zaltman 1996) represents a special focus within our research framework.

Recent decades have seen a continuing and epidemic increase in chronic disorders for which conventional treatment alone appears to be insufficient. These newly emerging 'civilisation diseases', such as essential hypertension, depression, burnout or insomnia, are mostly connected with our present way of life and display noticeable common features:

- Many of the pharmacologic therapies available are symptom-oriented, but do not have a curative effect on the cause of the disorder. Further, some pharmacologic therapies have unfavourable side effects.
- They are induced by disruptions in the biological rhythms that support, in healthy people, the effective self-regulation of the underlying functions and processes involved.

Hypertension affects approximately 1 billion individuals worldwide (Kearney et al. 2005, Hajjar et al. 2006). In the United States, almost 30% of the adult population is hypertensive and over 100 million individuals have either pre-hypertension or definite hypertension (Qureshi et al. 2005). The overall number of adults with hypertension worldwide was recently predicted to exceed 1.5 billion by 2025.

This global pandemic is of great public health concern because hypertension is the single most important cause of attributable mortality (Ezzati et al. 2002). Hypertension is a key contributory factor in the development of cardiovascular and cerebrovascular disease and is a major cause of stroke, myocardial infarction, heart failure and kidney disease. Approximately two-thirds of all strokes and one-half of all ischaemic heart disease are directly attributable to hypertension (Lawes et al. 2006).

Blood pressure rises as the result of a regulatory process that is governed by the two main branches of the vegetative nervous system, the nervus sympaticus and the nervus para- sympaticus. Essential hypertension, high blood pressure that has no discernable organic cause, results from a displacement of the equilibrium between these two influences in the direction of nervus sympaticus. In one of the common pharmacologic treatment strategies, sympathico- lytics are employed to reduce the sympathicus system's activity (central action drugs), blocking the effects on the cardiovascular system (alpha and beta blockers).

Alternatively, ACE-inhibitors can be used to block angiotensin II synthesis (both on a plasmatic and on a tissue level). Calcium antagonists can be employed to promote peripheral vasodilatation, blocking the passage of calcium inside the muscular cells. At last, vasodilators, that act directly on vessel resistance, inducing the arteriolar, or venous, or both, to vasodilate, can be prescribed (Stella 1996). However, these treatments are often accompanied by unpleasant side effects that mainly arise due to the fact that the working blood pressure level required for phases of activity can often not be achieved due to the drugs' influence. This can result in the loss of energy, exhaustion, increased susceptibility to accidents and falls (especially in older patients) and (in higher doses) to impotence and loss of libido. Depending on the agent, pharmacologic therapy may combat one symptom at the cost of introducing others, without improving the self-regulatory powers of the body. In contrast, integrative methods that aim to strengthen the activity of the parasympaticus may restore or improve the balance between the two forces which regulate the blood pressure.

In a randomised, waiting list controlled study (Balzer and Brandes 2005), three groups were compared with each other. Thirty-two participants, with medicated essential hy- pertension, were divided into two groups, starting the music therapy at different times. Twenty-nine participants, with insomnia, served as the control group. The participants were asked to take part in 90 minute laboratory tests to determine their stress and relaxation states three times: at the start of the study (T1) and after intervals of four and eight weeks (T2, T3). The physiological parameters measured included systolic and diastolic blood pressure, heart rate variability (HRV), skin resistance, skin potential and electrical potential generated by muscle cells activity (EMG). All the subjects were asked to take a break of about 30 minutes at the same time, of their choosing, during each working day over the course of 4 weeks. During these breaks, the subjects listened to a provided program of music, via headphones, that had been specially designed for their specific diagnosis. Participants in the waiting list group remained without intervention during the first 4 weeks and then began their therapy in week 5. The participants with sleeping disorders received their intervention, consisting of a special program of music for the treatment of insomnia, from weeks 1 to 4.

For those participants receiving treatment for hypertension, an improvement in the blood pressure values was determined in comparison with the waiting list group. Over 84% of the test subjects who were tested at eight weeks following initiation of the therapy, four weeks after the end of the therapy program, displayed improved systolic blood pressure values. These results were mainly achieved while subjects maintain their prior medicationlevels. However, many participants were able to reduce their medication levels as the music program began to take effect and were able to continue at this reduced level during the ensuing monitoring phase while maintaining the improved blood pressure levels. As expected, based on the differing initial conditions within the groups and the individually fluctuating medication dosages, the changes in blood pressure could not be demonstrated in a simple statistical analysis.

Our analysis of HRV, which is closely associated with the regulation of blood pressure *via* the vegetative nervous system (Di Rienzo et al. (eds.) 1992), however, demonstrated clearer results. Whereas the music program created for the subjects with insomnia had no significant effect on HRV (showing merely a slight decline from weeks 1 to 4), both hypertension groups displayed practically parallel increases in HRV, by approximately 20%, during the first four weeks of therapy. In the group whose intervention began at week 1, the trend continued after the end of the therapy period, and in a considerably intensified manner, so that after 8 weeks the test subjects' HRV had doubled (Brandes, Fischer and Thayer 2008). The magnitude of this change in HRV is equivalent to the average loss in HRV expected during a decade in the course of a healthy person's life.

As early as the end of the 1980s, Achmon et al. demonstrated that the use of the so-called "heart rate biofeedback" brings about a significant reduction in blood pressure (Achmon et al. 1989). In the 1990s, Tiller, McCraty and Atkinson investigated the effects of a special HRV training program on blood pressure. Their findings demonstrate:

" ... *emotional experiences play a role in determining sympathovagal balance indepen- dent of heart rate and respiration and further suggest that positive emotions lead to alterations in heart rate variability that may be beneficial in the treatment of hypertension and reduce the likelihood of sudden death in patients with congestive heart failure and coronary artery disease.*" (Tiller, McCraty and Atkinson 1996)

Since the 1970s, experts have become increasingly aware of the significance of heart rate variability (HRV), a neurocardiac parameter representing the interaction between the heart and the brain, influenced by the dynamics of the autonomic nervous system. It appears that HRV represents a kind of global indicator for the adaptivity inbio-psychosocial functional systems interacting between an organism and its environment (Bossinger and Mück-Weymann 2005). HRV represents a complex, rhythmical set of variations in the heart rate that can be seen as a spectrum of frequencies. To analyse the condition of the sympathetic nervous system=parasympathetic nervous system regulation, the interbeat interval time series is subjected to spectral analysis. This is a mathematical analysis technique that detects resonance components of varying intensity. This results in power spectra that comprise a frequency range of 0.04 Hz to 0.50 Hz. In many scientific investigations it has proved possible to demonstrate that certain parts of this spectrum correspond with the aspects of autonomic nervous system regulation of the heart, including sympathetic and parasympathetic influ- ences. The correlating influences of these branches of the autonomic nervous system, when recorded systematically, may allow for ancillary treatment approaches for disorders such as hypertension, coronary artery disease, diabetes mellitus, autonomic neuropathy, chronic renal insufficiency=dialysis, as well as for psychiatric and neurological illnesses. HRV plays an equally important role in sports medicine and sleep research.

Patients suffering from depression have also been shown to have reduced HRV, along with an increased heart rate (Carney et al. 2000, Hughes and Stoney 2000, Mück-Weymann 2002). It seems, therefore, that depression has an attendant disruptive effect on heart function. In support of this proposition, the mortality rate of depressives with cardiovascular disease is noticeably higher, as compared to that of the otherwise healthy patients. Likewise, heart patients with depressive illnesses show an increased risk of death. After psychotherapeutic treatment, however, a noticeable increase in HRV has been observed. For this reason, HRV analysis is also used as a biological indicator for making diagnoses, selecting therapies, and for therapy control during treatment.

HRV-biofeedback training has further been used as a complementary modality for many years in behavioural-therapeutic approaches to psychotherapy. According to studies conducted in the USA, it is possible to use HRV-biofeedback training to induce favourable effects in the case of depression, cardiac disorders, asthma, anxiety disorders and insomnia. Improving the coherence between respiration and cardiac activity can help to reduce tension and help patients to cope with stress and anxiety and to react to daily challenges with greater equanimity.

The results obtained for the therapeutic method that we have developed are typical of successful regulation therapies and show that the body is able to adopt the information impulses that are provided by the intervention and then continue to utilise them sub- sequently. The effect of the music program was observed in the significant increase in and in the lowering of blood pressure, as evident in dosage reductions for blood pressure medications. In order to provide further, direct evidence of the ability of the music program to lower blood pressure levels, the study is now being repeated with test subjects not under medication.

It is hardly possible to overestimate the importance of non-pharmacologic alternatives in the treatment of essential hypertension. For many years, the medical literature has regularly emphasised the need to couple pharmacologic treatment with changes in lifestyle. Changes in lifestyle generally constitute the initial treatment stage, depending on the severity of the condition. Another important reason supporting the development of alternative forms of treatment for hypertension must be seen in patients' poor compliance in respect to taking their prescribed medication (Bakris et al. 2008). Many do not adhere to drug treatment because it is poorly tolerated. In practice, we find that the patients' willingness to comply with standard recommendations for lifestyle changes also varies a great deal. In our study, patient compli- ance was not a problem. Listening to music as a form of medically effective intervention?

–there is hardly anything that a patient would like to do more, especially when it provides noticeable benefits.

Burnout syndrome is increasingly common and grows, in many cases, into an existential threat to those who are affected by it. Further, burnout may also lead to seriously disruptive consequences for society, organisations and companies. Burnout syndrome is a set of physical and psychological symptoms, including fatigue, anxiety, depression, irritability, cognitive weariness, sleep disturbances, headaches, gastric spasms, non-specific pain and poor health behaviour. Burnout develops gradually; symptoms can appear over several years. Prior studies link burnout with ill-health, including: metabolic syndrome, dysregulation of the hypothalamic- pituitary-adrenal axis and sympathetic nervous system activation, systemic inflammation, and impaired immunity, blood coagulation and fibrinolysis (Melamed et al. 2006).

From a mental health perspective, burnout is characterised by low personal accomplish- ment, high levels of mental exhaustion and depersonalisation, depleted emotional resources, and the loss of stress resilience. Progressive burnout results in decreased productivity. Without effective measures and adequate treatment, affected patients risk mental breakdown, after which complete recovery is difficult and relapse is common.

From an economic perspective, according to the American Institute of Stress, burnout is a significant problem affecting both individuals and higher levels of society. For example, the direct costs of burnout for U.S. industry are estimated to be $300 billion annually, with nearly half of all American workers reported to suffer burnout symptoms and one of four days of absence due to personal illness attributable to burnout. Further, in the 15 member states of the pre-2004-European Union, the cost of stress at work, and related mental health problems, was estimated to average between 3% and 4% of the gross national product and amounts to e265 billion annually (WHO 2005).

There is, therefore, an urgent need to develop and evaluate effective treatment options for burnout symptoms, as currently there are no proven, fast-acting and effective ambulant remedies. To this end, we developed and evaluated a treatment protocol that included listening to one of two specifically designed music programs (P1 or P2) twice daily for 30 minutes, five days per week, for the duration of five weeks. The placebo group was randomised to listening to unspecific nature sounds (PN). The waiting list control group (K) did not receive any listening program during the evaluation period.

The efficacy of the two music programs was investigated within a four-arm randomised, placebo and waiting list controlled, double-blind study, including 150 participants, who had been diagnosed as suffering from burnout syndrome. At the beginning of the study, subjects participated in a baseline examination consisting of a clinical-psychological interview, self- administered questionnaires and psycho-physiological measurements. Similar measure- ments were repeated at the end of the study period. Forty-five subjects were randomised to the P1 treatment group, 40 subjects were randomised to the P2 treatment group and 26 subjects were randomised to the unspecific-nature-sound-control group (PN). These subjects were asked to follow the study protocol and listen to the music programs provided to them between study visits one and two. During this same period, the waiting list subjects (K, *n* ¼ 39) received no intervention. The average age of the participants was 49.4 (þ12:8) years, with 75% of the participants being female. Changes in burnout symptoms were assessed by scores based on 41 self-administered questionnaire items identified as relevant for the condition by comparison with different burnout scores.[5]

In comparison to the waiting list control group, both the P1 and the P2 intervention groups were observed to have a significant, positive effect in reducing burnout symptoms. The effect observed with the P1 program (b ¼ 0.25, p ¼ 0.014) was slightly larger than the effect observed with the P2 program (b ¼ 0.21, p ¼ 0.039). The placebo music program was not observed to have a significant effect. These relationships persisted through various iterations and approaches to model building (Brandes et al. 2008).

Within the study sample, the developed music programs were effective in reducing the symptoms of burnout after a relatively short five-week period of intervention. Considering the amount of time and money involved with other forms of treatment for burnout, these specially developed music programs display clear advantages. Furthermore, the music therapy appears to be superior concerning its long-term effects. Qualitative, in-depth interviews have been completed every three months since study end. After twelve months, all the participants continued to report a sustained degree of stabilisation.

The prevalence of depression is high and continues to rise – an estimated 340 million people suffer from depression, with the WHO estimating that by 2020 depression will become the second most frequent disorder throughout the world (Murray and Lopez 1996). The impact of this trend becomes apparent by considering the interrelation between depression and the risk for physical illness. In a long-term study, the risk of developing heart disease after fifteen years was found to be twice as high for those, amongst 1200 male medical students at John Hopkins School of Medicine (Baltimore, MD, USA), who suffered from depression (Ford et al. 1998). Also, one of five people suffering from coronary heart disease, and one of three with heart failure, is afflicted with clinical depression (Whooley 2006).

The medical costs of depression and stress in the USA, investigated by a three-year health- risk and medical-cost study, were observed to be 70% higher for people with depression, 46% higher for people under high stress, and 147% higher for both depressed and stressed people, compared to the costs of individuals without these conditions (Goetzel et al. 1998). Several studies investigating brain activity (Wang et al. 2005), levels of stress hormones (Kerr et al. 1991) and stress-induced inflammatory responses (Pace et al. 2006) have explored the interrelation between stress and depression and may explain some reasons for the coincidence of physical diseases with depression.

Approximately 75% of men and women described as suffering from a 'depressive disorder' according to standard clinical criteria never receive medical or psycho-therapeutic treatment
(WHO). Further, mild-to-moderate depressive states are frequently chronic and therefore usually difficult to treat (Schmitz 1999, 2004). Mild-to-moderate depression and dysthymia may cause greater impairment than for those with major depression (Klein et al. 1997a), presumably because of the longer duration of depression in dysthymic disorder, which is also a prime risk factor for suicide. Research has consistently shown a strong link between suicide and depression, with 90% of the people who die by suicide having an existing mental illness or substance abuse problem at the time of their death.

On the subject of depression treatment outcome, Thomas R. Insel, Director of the U.S. National

Institute of Mental Health, wrote:

"*Psychiatrists have a range of treatments to offer patients with depression. Randomized controlled trials have demonstrated the efficacy of tricyclic antidepressants, SSRIs, cognitive behaviour therapy, and interpersonal therapy. For each of these interventions, one can say with some confidence that at least 40% of a cohort with depression will show statistically significant reductions in unbiased ratings of depression. This information, while entirely commendable in the world of research, is far from satisfactory in the world of practice where an individual clinician needs to make treatment decisions to help an individual patient.*" (Insel 2006)

The meta-analysis published in 2008 by Kirsch et al. gives grounds to assume that common pharmaceutical approaches, designed to combat light to medium grades of depression, are no more effective than placebos.

"*Drug-placebo differences in antidepressant efficacy increase as a function of baseline severity, but are relatively small even for severely depressed patients. The relationship between initial severity and antidepressant efficacy is attributable to decreased responsiveness to placebo among very severely depressed patients, rather than to increased responsiveness to medication.*" (Kirsch et al. 2008)

Following the publication of the article 'Antidepressiva: Lebensgefährliche Placebos?' ('Antidepressants: Dangerous Placebos?') in the German journal Arznei-Telegramm, in view of the potential consequences of patients' reactions to the publishing of these findings, Fritze et al. accused the journal of negligence. The German Gesellschaft für Psychiatrie, Psychother- apie und Nervenheilkunde (DGPPN) and the Association of Neuropsychopharmacology and Pharmacopsychiatry (AGNP) (Arbeitsgemeinschaft für Neuropsychopharmakologie und Pharmakopsychiatrie) argued that withdrawal studies provide the most faithful reflection of the 'true' degree of effectiveness (e.g., 23%) (Fritze et al. 2005).

Some studies have demonstrated an increased suicide risk for given patient groups associated with the use of certain antidepressants. Many patients suffer from severe side effects (Hansen et al. 2005), including weight increase, headaches, sickness, diarrhoea, lack of drive, and sleeping disorders. It has been proposed that the mechanism of action of these drugs largely derives from their suppressant effects on REM sleep. This effect can cause increased fatigue in patients who take large doses of antidepressants for extended periods of time. Such fatigue can interfere with a patient's everyday activities.

Of the patients diagnosed as suffering from depression, 25% refuse to undergo pharma- cologic treatment altogether. On the other hand, in most countries, psychotherapy is only limitedly available. There is, therefore, an urgent need for the development of a safe, effective and scalable treatment alternative (Paykela et al. 2005).

On the basis of our prior experience and the results of earlier studies, one may conclude that appropriately composed music interventions have the potential to improve depressive states. Based on a recent Cochrane meta-study (Maratos et al. 2008) of active and receptive music therapy, we hypothesised that treatment protocols based on music programs specially designed for the treatment of depression might significantly reduce symp- toms. Symptoms were assessed by the Hamilton Rating Scale for Depression (HAM-D), the Hospital Anxiety and Depression Scale-Depression Subscale (HADS-D) and the Beck Depression Inventory (BDI).

Sleeping disorders take third place in the list of reasons why people consult their doctor, after physical disorders and pain conditions. The WHO ranks the prevalence of sleeping disorders together with coronary heart disease, diabetes mellitus and lung cancer. Within western industrialised countries, 15 to 25% of the population suffer from insomnia. About half of the insomnia patients suffer to such an extent that treatment is necessary. For about one-third of those affected, the insomnia can be traced back to an organic or physical cause, and for another third of the group, no such cause can be determined ('primary insomnia').

Sleeping disorders are very common. It is probable that they represent the most widespread psychosomatic syndrome, being even more frequent than pain syndromes. We may assume that in Germany, 20-25% of patients in general practices suffer from sleeping disorders, especially insomnia. A particularly problematical aspect is that sleeping disorders are often chronic and seldom disappear on their own. Insomnia, especially that which sets in with increasing age, tends to be accompanied by intensified use of hypnotic drugs (i.e. sleeping pills), but in many cases the therapeutic value of this approach is unsatisfactory. Further, the uncontrolled long-term use of tranquillisers (relaxing and sedative drugs), such as diazepam and other benzodiazepines, can result in addiction.

Twenty-seven patients with sleeping disorders took part in a randomised and waiting list controlled pilot study. They were divided into two groups, with different starting dates. The participants, men and women aged between 32 and 78 years, suffered from difficulty in getting to sleep, sleeping through the night, or both. The subjects were selected on the basis of the results from a sleep questionnaire with 43 items (Pittsburgh Sleep Quality Index, PSQI). All of the test subjects, throughout a period of 4 weeks, were asked to listen to a specially created program of music when going to sleep. The intervention group (Group 3A, n ¼ 15) were tested before and after the four-week listening period and again four weeks later. The waiting list group of insomnia patients (Group3B, n ¼ 12) remained without intervention in the first four weeks and started the therapy in week 5.

Our analysis of the physiological data measured in the stress test showed that the ability of participants in the waiting list group 3B to cope with stress decreased during the waiting period from 56.67% to 46.67%. After four weeks of listening, the participants' ability to cope with stress increased from 47.22% to 52.54% (Groups 3A þ 3B). Within the intervention group 3A, the ability to cope with stress increased from 47.62% to 60.00% between T1 and T3. This response curve is typical for effective regulatory therapies. The short-term effects showed a slight improvement, while pronounced improvements occurred as a delayed effect four weeks after the completion of the listening phase.

The shift in PSQI score eight weeks after initiation of the study, four weeks after listening had stopped, demonstrated a similar pattern to what we observed in the hy- pertension study. Quite clearly, the listening phase triggered a process whose effects only became consolidated after several weeks. Comprehensive evaluation of the concluding interviews demonstrated that improvements in sleeping quality took place in 77.78% of the cases.

We also found that 30% of the participants suffered from depressive symptoms and 19% were taking antidepressants. Of this subgroup, two-thirds completely eliminated their usage of antidepressants and only one subject maintained their original dosage. Similar results were shown for the reduction of hypnotic drugs. In view of the length of time during which the subjects had suffered from sleeping disorders (in most cases this was in the order of many years, or even decades), a longer listening phase would be advisable. In a number of single case studies we have since conducted, we observed substantial sleep quality improvements and extended sleep duration stabilising after ten to twelve weeks.

Various forms of cardiac arrhythmia have clearly diagnosable organic causes. However, an increasingly large proportion of heart rhythm disturbances seem to occur for no obvious medical reason. The usual method for getting the symptoms under control is to prescribe anti-arrhythmic agents (amongst other drugs, this includes beta-blockers) whose side effects have already been discussed (see 4.2.1.1.1.). Chronobiological pre-investigations and evaluations of deep psychological interviews that we conducted prior to the main study indicated that all of the arrhythmia patients we interviewed suffered from serious worries and had problems coping with emotional stress. The observation has since been confirmed by several researchers, e.g. Ziegelstein (Johns Hopkins University School of Medicine and Division of Cardiology):

"Episodes of acute emotional stress can have significant adverse effects on the heart. Acute emotional stress can produce left ventricular contractile dysfunction, myocardial ischemia, or disturbances of cardiac rhythm. Although these abnormalities are often only transient, their consequences can be gravely damaging and sometimes fatal. Despite the many descriptions of catastrophic cardiovascular events in the setting of acute emotional stress, the anatomical substrate and physiological pathways by which emotional stress triggers cardiovascular events are only now being characterized, aided by the advent of functional neuroimaging. Recent evidence indicates that asymmetric brain activity is particularly important in making the heart more susceptible to ventricular arrhythmias. Lateralization of cerebral activity during emotional stress may stimulate the heart asymmetrically and produce areas of inhomogeneous repolarization that create electrical instability and facilitate the development of cardiac arrhythmias."

He concludes:

"Nonpharmacological approaches to manage emotional stress in patients … are also appropriate to consider and merit additional investigation in randomized trials." (Ziegelstein 2007)

How specific receptive music therapy works

The majority of physiological and psychological disorders are caused by disruptions in the organism's regulatory functions or can be associated with such disturbances. These bodily functions can be determined through measurement of peripheral parameters. The rhythmical structure of theses parameters may display features which provide typical signatures for the diagnosis of specific conditions. If a receptive music therapy intervention is to be directed at a specific diagnosed disorder, then one of the essential prerequisites in designing such a program is the achievement of a structural correspondence between the music and those bodily rhythms that are involved in the development of the disorder and in the process of recovering a state of health.

Amongst others, Clayton et al. described, in 2004, the so-called 'entrainment phenom- enon' (Clayton et al. 2004). Gomez and Danuser, too, demonstrated that rhythmic aspects are the major determinants of physiological responses to music (Gomez and Danuser 2007). Patel et al. even studied Snowball, a sulphur-crested cockatoo who is able to dance to the beat of the Backstreet Boys' song 'Everybody' with remarkable rhythmic synchro- nicity (Patel et al. 2008). Balzer et al. showed that when a person listens to music whose structure displays a certain degree of association with the initial physiological condition of the listener, at first the psycho-physiological parameters (skin conductance, skin response and EMG) start to synchronise. Then, in a subsequent phase, these parameters actually adapt themselves to the 'biological information' contained in the music (frequency spectrum, volume changes and tone density) (Balzer 2008). In other words, if the 'wave forms' of a musical work are very similar to those of certain bodily processes, then they are capable of causing them to first enter a state of resonance and then 'transpose' into another (better) regulatory state. Thus, appropriate music stimuli have the effect of 'tuning' bodily processes.

If the cause of these effects were nothing more than a physical resonance phenom- enon, it would not necessarily require music to produce them – it would suffice to ex- pose the organism to suitable computer generated frequencies. There is more to music than rhythmic correspondence, however. We have reason to suppose that the thera- peutic results of musical interventions are associated with even more complex mechan- isms that take effect at many levels simultaneously and influence the overall effects synergistically.

One of these levels may be that of the inner images that form as a result of listening. In rehabilitation medicine, researchers have found that badly burned patients were able to reduce their body temperature through nothing more than three-dimensional visual stimuli (Hoffman et al. 2008) (they were shown pictures of penguins jumping into Antarctic waters). This was so effective, as to ensure their survival. In an fMRI study performed on a pianist, it has been shown that the imagination is capable of achieving targeted activation of the cerebral cortex. By simply imagining the music that he had played on the previous day, the same areas of the pianist's brain were active as was the case during the actual performance.

In summary, it may be concluded that we are capable of not only influencing the regulation of our autonomous nervous system by the imaginative recollection of suitable previous experiences (that until recently was held to be possible only after decades of meditation practice); it appears to be possible to induce the improvement of psychoso- matic disorders through suitable musical stimulation, even though or especially when the stimulation is not based on previously learned stimulus-reaction patterns.

However incomplete our understanding of the operating principles governing diagnosis- specific music therapeutic programs may be, we have at least been able to demonstrate that they do actually take effect in the manner described. The findings presented here also point the way towards further avenues of investigation. Thus I begin this concluding section not so much with answers, but with a summary of the questions which remain to be addressed in subsequent research projects:

1. How can the observed effects be explained from the neuroscientific point of view? Can structural changes be observed in the brain? Which mental constructions contribute to the effects? How does music create the space in consciousness that seems to change perspective through subtle layers of musical metaphors (Spitzer 2003) and memes (Sheehan 2006)? Which transpersonal aspects play a role?
2. What further optimisations can be introduced using the neuroscientific techniques of therapy research and methods of real-time monitoring?
3. How does our program for the treatment of depression compare with psychotherapy, with and without pharmacotherapy? To which grade of depression can our program be used on its own? How does it function in combination with antidepressants and=or cognitive behaviour therapy in the treatment of Major Depression?
4. How does our hypertension program affect patients who have not received medication for their condition before they undergo a music therapy program? To what extent can the program be used in combination with pharmacologic forms of treatment in order to enhance their effects? What benefits may music therapy yield for the increasing number
of patients who do not respond to medication? What 'dosages' and treatment durations
for music therapy produce the best and most sustainable reduction in blood pressure?
Do these parameters depend on how long the disorder has already existed or on how long other therapies have been applied?
5. What are the psycho-neuro-immunological implications of our approach? Can our methods be further developed to ameliorate immune and autoimmune disorders?

Notwithstanding the need for much more research, the studies that we have already completed have confirmed one essential finding: It is possible to perform clinical research into at least certain types of music therapy (receptive, media supported) using the instru- ments and the language of evidence-based medicine (EBM), and to present objective and verifiable results. The research of music therapy needs not to be confined to unspecific stimuli that may raise the assumption of uncertain improvements, but can be applied as a diagnosis-specific intervention that produces predictable and quantifiable psycho-physio- logical effects.

Until the present time, music therapy was often surrounded by a mist of prejudice and unfounded supposition (Droesser 2008). The chief of these is that the subtlety with which music therapy works and its dependency on indeterminate, subjective factors, combine to render its efficacy – or the lack of it – unpredictable, and that its effects, if any, are practically a matter of chance. This has frequently led to music therapy being implemented as a last resort, when all other therapies, especially pharmacologic ones, have failed. The unspoken attitude behind this can be summed up with "Well, it may not do much good, but at least it won't do any harm." And, perfidiously enough, where music therapy does bring benefits, their reproducibility is often put into question. When no benefit is discerned, the therapy is readily dismissed as esoteric nonsense or as a placebo, and an ineffective one at that. In the light of some of the lower thresholds of efficacy for conventional pharmacological approaches, this seems at least to be a disproportionate assessment.

What we can present here, however, represents a clear and transferable proof of efficacy in respect to the disorders under investigation. In view of the demonstrably comparable stringency with which the results have been obtained in the clinical pilot trials we performed, the rules of evidence-based medicine suggest further research and comparison with the effectiveness of other medicaments and methods available on the market. Insofar as music therapy can be shown to display advantages, positive results for the tested conditions should provide adequate grounds for music therapy being accepted into the canon of standard therapies and introduced into clinical practice. For a number of disorders, music therapy may then even be recognised as the 'gold standard'.

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Chapter 5

A perspective on evidence-based practice

It is not controversial to assume that, in many ways, there is a set of universal questions among the professionals who are interested in the field of music and medicine. These questions can be generally stated as follows: Is music an effective modality in healthcare? Does music make a difference in the various issues affecting human beings? How does music make a difference? Why does music make a difference? What is the best evidence for understanding this difference? What kind(s) of evidence is=are needed?

In many countries, the predominant standard for addressing these questions relies upon the principles of evidence-based medicine and evidence-based practice. There are numerous definitions of evidence-based practice; however, generally speaking, there is a reliance on systematic reviews of the available and most rigorous scientific evidence in clinical decision- making in an attempt to ascertain that the treatments used for patients are at once safe, effective and cost-effective. Of importance also in evidence-based practice are the clinical skills and expertise of the practitioner as well as the values and expectations of the patient in deciding upon the best course of treatment for him or her.

To assure that decisions are made using the "best evidence," hierarchies of evidence have been established. These are ranked according to their freedom from the various potential biases present in research. Although there are variations in types of research and the relative importance of these types of research within these evidence-pyramids, there is a notable (and sometimes exclusive) reliance on quantitative research methodologies. One such hierarchy compiled by the authors from various sources is shown in Fig. 1. Meta-analysis of randomized, double-blind, placebo-controlled trials is most often at the top of the pyramid, and the systematic reviews published in the Cochrane Collaboration (www.cochrane.org) are considered the "gold-standard" for evidence on topics in healthcare.

With the advent of evidence-based practice, and the subsequent implications of this approach for many professional disciplines, it is not surprising that there is often heated debate regarding if and how researchers and clinicians should and can react! The situation has been similar in the area of music and medicine, and the ensuing debates have yielded productive discourse, divergent viewpoints notwithstanding. However, some de- bates have also created a more salient polarization among different ideologies and theoretical perspectives, and a concern arises when a viable resolution to differences is not forthcoming.

No matter what is one's position concerning evidence-based practice, it is not likely that its significant influence on the field of music and medicine will go away in the near future.
Moreover, it is becoming increasingly likely that it will provide the basis for the allocation of funding, i.e., treatments that yield the most safe, effective and cost-effective results will obviously have the greatest priority for financial support from governmental and private healthcare agencies. In essence, the survival of music and medicine practices may well depend upon the accumulation of rigorous quantitative evidence according to the established hierarchies, and it is naïve to deny the significance of outcome research in the healthcare decision-making process. At the same time, evidence-based practice may indeed have a positive impact on how we treat clients or patients and can ultimately improve the quality of our work.

There does not seem to be an argument at this point as to whether it is possible to quantify the outcomes of music and medicine interventions. Researchers on this topic are indeed responding to the imperatives of evidence-based practice, and a number of systematic reviews have been published or are in progress in the Cochrane Collaboration. Other meta-analyses have also been published (e.g., Dileo and Bradt 2005).

As the field acts with political purpose, e.g., to convince those outside the field of the effectiveness of music in promoting health, as well as to illuminate process-related information for practitioners within the field, it is crucial to utilize research approaches that provide pluralistic-types of evidence. Mixed-methods research approaches may well become the standard for the field in yielding "best-available evidence." Ultimately, the process of engaging critically with evidence-based practice, rather than avoiding or denying its significance, may allow the field to develop its own requirements and standards for the evidence needed.

In conclusion, the evidence-based practice movement can provide the field of music and medicine with a significant opportunity to critically examine its need for varying types of evidence and to determine the standards by which the best evidence may be acquired for the present and future. To best enter into this opportunity, researchers in the field clearly need to abandon positions that can further polarize, and acknowledge, without hierarchical frameworks, the significance of multiple sources of evidence to advance our unique field. As a result, the field of music and medicine will move further in assuming its rightful place 1 in healthcare.

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Chapter 6

The audio-vocal system in song and speech development

Every young child learns how to speak. However, often music teachers complain that children cannot sing. Both modes – speaking and singing – result in activities of the phonatory system, use the same vocal tract and share the same neural circuits. Therefore, it is manifest to conclude that singing and speaking are based on many commonalities in perception and production.

The acquisition of language and music, or more precisely of the competence for song and speech production, makes the uniqueness of humans in course of the evolutionary process and determines the human exceptionality since the separation from higher primates. In phylogeny of men musical abilities played a key role in the evolution of language. Furthermore, the music-making behavior covered different evolutionary functions such as communication, group coordination and social connection (Koelsch and Siebel 2005). Humans have developed a sign system of discrete sounds which goes beyond expressive and emotional communication. Here, we do not argue in terms of evolutionary reasons for this development, rather we will look at the neural conditions that enable only very few beings to learn how to accurately imitate a perceived sound or pitch just by ear. This process is described as audio-vocal learning where a very complex interaction of neural areas evolves which can be traced back to the same molecular level (Haesler et al. 2004).

By this, neurobiology can offer new explanations that interfere with the old debate on the origins of music and language (Wallin et al. 2000). According to his evolutionary theory, Charles Darwin (Darwin 1871=1981) interpreted proto-musical emotional ex- pressions as a step towards language, whereas Herbert Spencer relied on the opposite assumption that only the emotional content of language has led to music (Ackermann et al. 2006). Only in recent times we start to understand the common roots of music and language in an evolutionary and neurobiological sense which has caused the idea of a "musilanguage" (Brown 2000) and initiated new tracks of research on animal and human vocal communication. There is an increasing interest in the emotional prosody of animals (bats, monkeys, mice and rats; see the ECC 2007 Conference, Hannover) as it is in infant cry (Lehr et al. 2007, Zeskind 2007) and infants' early pre-verbal vocalizations (Leimbrink, 2008). Animal research opens a window into a better understanding of the neural activities that underlie different vocalization processes and their communicative functions. Here, we will focus on the neural mechanisms that are activated both in human song and speech.

It is often stated that the anatomical condition for sound production and phonetic articulation is a descended larynx. This, however, is not unique to humans and can be observed in nonhuman vocalizations (Fitch 2000, Fitch and Reby 2001). A roaring deer and a barking dog also show a descending larynx. However, it is also obvious that not every being that can make sounds can sing or speak. Rather, the peripheral anatomy of animals is not sufficient to explain the differences between conspecific calls and human song and speech. Even in rhesus macaques, specific vocalizations evoke distinct patterns of brain activity in areas that are homologous to the human Broca's and Wernicke's areas (Gil-da-Costa et al. 2006). However, it is obvious that vocal signals with voluntary control as in language and music rely on different neural circuits which suppress the innate call system. This reduction, then, allows an increase in lateral cortical control over the imitative sound production.

Regarding the learning of acoustic signals, one has to take into consideration that there is a general distinction between auditory and vocal learning. Vertebrates are able to recognize and understand acoustic signals. A well-trained dog will understand the command "sit". He shows by his behavior that he has understood the meaning of this signal. The association of an intended behavior with an acoustic signal is accomplished by *auditory learning*.
However, a dog is unable to imitate this acoustic signal or the call of another animal. A dog will never answer a cow by mooing. The prerequisite for this behavior is the ability to precisely imitate a sound just by ear, i.e. by an aural input. This is only attainable by *vocal learning* which is characterized by the ability to imitate an aurally perceived sound. To accomplish this task one needs a very specific neural loop that connects the aural input with motor control. Except humans, there are only few mammals (such as dolphins, whales, seals, and bats) and birds (songbirds, parrots, and humming birds) that have developed this particular neural circuit and belong to the vocal learners. It is not quite clear why evolution provided birds or seals with this neural connection whereas others did not develop this neural link.

Imitation plays a crucial role in learning. The neural mechanisms that enable vocal learners to reproduce a perceived sound by imitation is especially well understood in songbirds (Zeigler and Marler 2004). Moreover, it has been shown that even very young infants are able to imitate the facial expression of a person within the focus area of the eyes (Meltzoff 1988, Meltzoff and Decety 2003). Cortical areas in the parietal lobe build the neural correlates that are able to differentiate between the self and the other.

With regard to imitation one can generally distinguish between two types of imitative learning behavior, *instrumental* and *ritual* behavior (Merker 2005, 2006). An *instrumental* behavior tends toward a practical result by any mode of execution. What counts is only the functional result, no matter of what kind of execution it has been achieved. On the contrary, a *ritual* behavior aims to an accurate imitation by just one correct mode of execution. It is the sequence of actions itself or the precise matching of a perception that characterizes a ritual behavior. To match a perceived pitch accurately requires such a ritual attitude. It is not the result (a tone) or its function in a given context, but the correct reproduction of a precisely determined pitch no matter of its function in a melody.

Vocal learning is mainly based on ritual forms of a formalized imitation, and humans are typically vocal learners because they learn the articulation in speech and the vocalization of songs just by listening to them. However, there is another imperative condition: the vocal production must be linked with the perception of the own sound production, since the ear (auditory perception) controls the voice (vocal tract). The interaction of both systems builds a phonological loop. Because of this close connection one can assume that both modes of expression share common evolutionary roots.

In the context of imitation and learning, the discovery of mirror neurons by Rizzolatti and collaborators (Gallese et al. 1996, Rizzolatti 1996, Rizzolatti et al. 2006) seemed to provide the neural correlate for learning by imitation. These researchers identified neurons in area F5 of the premotor cortex of macaque monkeys – a homologue of humans' Broca's area – that discharged when the monkeys performed an action and also when they just observed a similar goal-directed action performed by another monkey or the researcher. In humans mirror neurons could be identified in the premotor cortex as well. Audiovisual mirror neurons react independently of whether actions are performed, heard, or seen (Kohler et al. 2002). This observation was readily interpreted as the neural missing link between the disposition of the early human ancestors and the development of human language including manual gestures rather than a system of vocal sounds (Arbib 2005). "… such a system would be an equal plausible foundation for *audiovisual* matching functions such as song and speech. Both music and speech, like many forms of bird song, develop ontogenetically through a process of imitation of adult role models during critical periods in brain development" (Brown et al. 2004). However, there are also mirror neurons in the pain-related human cingulate cortex that also respond when subjects only watch a pain-causing action on other subjects (Hutchison et al. 1999). In this case, however, mirror neurons are by no means related to imitation.

The function of mirror neurons is far from being clearly understood. They obviously constitute a resonating system which responds to observed actions under certain conditions. However, spontaneous resonance is different from intentional imitation. Rizzolatti has always stressed that Macaques cannot imitate, but they exhibit neural activities in resonance with an observed action. Nevertheless, the data of a recent instrumental learning experiment have been interpreted as an indication of a functional involvement of mirror neurons in imitative learning (Buccino et al. 2004). Given the validity of these data two distinct steps merge: the coding of motor acts present in the action is to be learned and a recombination of these coded acts by imitation. The coding and recombination of these motor elements, i.e. the translation of a visually coded action into an identical physical action refers to the neural process where mirror neurons are possibly involved in learning. However, at the moment it seems too soon to use the mirror neurons as an explanatory model for learning by imitation.

Song learning through vocal imitation is an evolutionary novelty that emerged with the development of a neural control center (Brown et al. 2004). In vocal learners, there is a direct neural link between the larynx representation in the primary motor cortex and the peripheral neural center for vocalization. Furthermore, the supplementary motor area (SMA) plays a key role in motor control. A damage of this area is associated with mutism (Brown et al. 2004). There are two vocal pathways, the anterior and the posterior pathway that are connected with the human auditory system. The posterior pathway sends information down to the vocal part of the brain stem and to the nucleus ambiguus which controls vocal productions in singing and speaking. The anterior vocal pathway consists of a loop between motor cortex, basal ganglia, thalamus and back to the cortex. So, this pathway connects the language strip of the pre-motor cortex with the dorsal thalamus (see Fig. 1).

Additionally and necessarily, these pathways receive information from auditory pathways which enter the anterior and posterior pathways and cause a fine-tuning of the motor control in the larynx. Simply, the auditory information controls the muscle tensions in the vocal tract with the goal to match the produced vocal sound with the perceived sound which is only possible when one hears his own voice.

This neural trait makes humans "consummate vocal imitators" (Brown 2007) who can make use of vocal imitation in learning as well as in musical performance (song reproduction). The imitative audio-vocal processes are essential for song and speech acquisition.

Functional magnetic resonance brain scans during a monotonic vocalization task exhibit activations in exactly those brain areas that are interconnected by the phonological loop: the Broca's area (BA 44), the primary auditory area (BA 41), the auditory association cortex (BA 42, 22), and the supplementary motor area (SMA) in connection with deeper structures in the thalamus and the cerebellum (Fig. 2).

The structure of this neural mechanism separates the production of emotional screams and squeals from the vocal articulation in human songs and language. However, as mentioned above, this mechanism is not unique to humans. However, what is unique is the differentiation that develops from early vocalizations to speech in early childhood within the first year of life.

Language acquisition and speech development rely on the same auditory feedback between sound perception and sound reproduction. The auditory input stimulates the sensorimotor activation which is necessary for the own vocalization and which has to be fine tuned according to the auditory perception. Even songbirds who are vocal learners as well, must listen to their own vocal trials to learn a (new) song. That makes the investigation of songbirds so valuable for the understanding of humans' vocal learning (Brainard and Doupe 2002).

It is often stated that the language instinct (Pinker 1994) is strongly related to or dependent on the gene forkhead box P 2 (FoxP2). This gene regulates the gene expression, i.e. it codes for a transcription factor that produces a protein which facilitates the transcription from DNA to RNA. This factor has the potential to affect the expression of a large number of other genes (MacAndrew 2007). In humans this gene is present even in an early embryonic stage and is found in regions that develop to the cerebellum, the basal ganglia, and the thalamus which hereafter will regulate the motor activities in vocalizations (Haesler 2006, Haesler et al. 2004). The investigation of song learning in zebra finches has shown that FoxP2 is more relevant for the learning of the songs than of the motor activities involved in song reproduction (Haesler 2006). After all, only the FoxP gene is not a sufficient condition for song and speech acquisition.

If human speech and song and birdsong share behavioral and neural similarities which are manifest in the neural circuits for an interaction of auditory and motor centers, then an interaction of language and music can be assumed. There are indications that language and music share some cortical resources as far as the processing is concerned with structural syntactic processing whereas the representation network of music and language is separated (Koelsch et al. 2004, Ozdemir et al. 2006, Patel 2007). Accordingly, the cortical rhythmic changes during continuous vocalization are different in the singing condition compared with speaking and humming (Gunji et al. 2007). This might be referred to the stronger control of the vocal tract and the diaphragm muscles in the singing condition. Beyond apparent differences there is an obvious interaction of auditory and motor control in both language and song so that there is evidence for the hypothesis that singing affects verbal articulation.

Since both forms of vocal expression – song and speech – share common mechanisms and are based on the integration of auditory perception into the motor control of the vocal tract, another aspect of related effects of language and music become apparent.

In bilingual studies, Ellen Bialystok has shown that bilinguals reveal a cognitive advantage in the processing speed, in reaction time and regarding the inhibition of spontaneous reflexes compared with monolinguals when tested in a Simon task (Bialystok et al. 2004, 2005, 2006, Bialystok and Martin 2004). This advantage even increases over age (see Figs. 3 and 4).

On the contrary, a comparison of musicians and non-musicians in a musical Stroop task, which is similar to the Simon task, exhibited comparable differences in cognitive processing speed as it was demonstrated by bilinguals and monolinguals (Bugos et al. 2006). A similar advantage in mental speed was performed by young children in an eye tracking task who had music as an intervening treatment compared with children without music (Gruhn et al. 2003). On the basis of these data it seems reasonable to assume that a robust interaction between music and language takes place that causes a cognitive advantage in mental processing speed for those who are trained early in more than one language and music.

The phylogenetic evolution as well as the ontogenetic development establishes the same neural process of audio-vocal learning that constitutes the option for song and speech acquisition. The early preverbal vocalizations of infants are not yet differentiated in discrete vocal sound as articulated in language and discrete pitches as sung in music. At this early age, children use their vocal tract for emotional communication by an exaggeration of those prosodic parameters that are crucial in emotional expression. In both cases, the auditory feedback of the own voice controls the muscle tension in the vocal folds and establishes a phonological loop which is essential in song and speech learning. Further research is needed to investigate the common neural structures involved in the audio-vocal learning of song and speech in childhood and to identify the neural processes that enable children to pitch matching, time keeping and rhythmic integration. For, these features constitute the essential differences in song reproduction compared with verbal pronunciation. Because of the same neural mechanisms the two modes of expression are still undivided in early childhood. Singing and speaking arise from the same roots, but singing requires a much better aural and oral control and needs a stronger training of the phonological loop. This has implications for music and language education as well.

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Chapter 7

The significance of exposure to music for the formation and stabilisation of complex neuronal relationship matrices in the human brain.

The human brain is not to be compared with a machine which is 'produced' according to a specific construction plan and whose structure and function can be deduced by the inspection of this plan or of the individual components which have been fashioned according to it.

In trying to understand the brain, we must think not in terms of linear cause and effect relationships, but rather we are dealing with complex, multi-modal networks which are related with each other in many different ways and which exercise a mutual influence on one other. The connections involved are not generated according to genetic programmes, but develop in the course of the brain's formative process on the basis of experience and according to the frequency with which they are implemented. Furthermore, the networks which are created at a given time can be modified afterwards throughout the brain's 'operational life' as the need arises by newly emerging usage and activation patterns ('usage dependent plasticity').

Therefore the development of the brain must be understood as a self-organising process which is directed by interaction with the outside world. In the course of this process individual 'items' of experience are registered in the form of neuronal relationship patterns. More than all other factors, the prevailing psychosocial development conditions are crucial for the struc- tural development of a child's brain.

Even before birth, while the emergent brain is establishing more and more links to the outside world, the interconnections and activation patterns which are laid down and develop at that time are increasingly subject to influences from the outside world which are transmitted via various sensory interfaces. When activation patterns are repeatedly triggered by such sensory impulses, this results in the stabilisation of certain neuronal interconnection matrices. From this time onwards brain development no longer takes place in isolation, but is at first increasingly determined by sensory input from its intrauterine environment and later by that received from the prevailing domestic surroundings. This dependent relationship then remains in effect indefinitely (Hüther 2002).

Notwithstanding the complex interconnections existing within the brain, it is possible to identify individual areas which correspond to specific types of activity. That is to say, if a person engages in any kind of activity, this is reflected in the activation of dedicated regions of the brain, and this brain activity can be displayed with the use of functional imaging techniques. However, the fact that hearing and speech are associated with the activation of the language centres of the left-brain hemisphere does not allow the inference that this region is *the* seat of human language. A network, which is specialised in the recognition and generation of words, can only develop according to the degree to which a person has the opportunity to learn speech and learn about the meaning of words during his or her childhood. Correspondingly, every other complex activity which a person directs with the help of the brain must also be practised, 'run in' and anchored in the form of patterns of neuronal connectivity.

This applies, as well, to a person's attitude to and interaction with music, i.e. with his or her ability to recognise certain tones and sequences and also to reproduce them. Both listening to music and playing musical instruments have far-reaching consequences for people's thinking processes, their feelings and their actions. For this reason both receptive and active intervention using music therapy can be employed in order to induce psychoaffective states within patients which have a beneficial effect on psychotherapeutic processes (Hüther 2004). The consequences of such interventions, in the form of both medical and therapeutic instruments, can be measured with the help of various different indicators. On the physical level these range from variations in the activity of the autonomic nervous system, the cardiovascular system and the endocrine system to characteristic alterations in the immune system (Spintge and Droh 1992, Taylor 1997). The point of departure for all these changes in activity levels is to be found within the neuronal networks which participate in the control of such integrated regulatory systems in the patient concerned.

Until only a few years ago it was not possible to prove the existence of such changes within the brain. However, the time is now ripe for gathering new insights in this area of study. Neurobiologists are not only identifying and describing the processes of listening to, recognising and producing music as being especially complex achievements of the central neuronal processing apparatus, but they have also begun to analyse the processes taking place in the brain in more detail. The latest studies in this area utilise the cerebral processes involved in listening to music as a model for the investigation of complex psychoaffective and cognitive achievements (Koelsch and Siebel 2005).

But these neurological findings also underline the limited use of the evermore detailed descriptions of the effects of music on the brain, at least in respect of understanding or making understandable the ways in which music can have a therapeutic effect. It is far more important to improve our understanding of how the neuronal networks and synaptic connections involved in processing musical information are formed in the course of the brain's develop- ment and to find out how and by what means these networks are linked with lower regions and other networks which have been established either previously or at the same time. Finally, to understand how the interconnection patterns formed in each individual development stage themselves become the basis for the next phase of synaptic link formation in all the associative, subsequently maturing parts of the brain.

The impulses which are transmitted from the auditory nerve to the auditory centres located in the brain stem result in an activity pattern specific to the respective acoustical perception, especially in the *colliculus inferior*. The more often similar acoustic signals lead to the formation of such an activity pattern, the more firmly the associated synaptic links will be confirmed and reinforced. In the course of this early pre-natal 'construction phase' for neuronal networks those synapses which are not reused, or only seldom reused, are dismantled again. This formation process in which specific interconnection patterns are distilled from an originally broad-based surfeit of synaptic links has been termed by neurobiologists "usage-dependent synaptic plasticity". The strategy of providing for a superabundance of synaptic linking possibilities followed by a usage-dependent stabilisation process for certain linkage patterns on the basis of auditive perceptions leading to the generation of corresponding activity patterns is also employed later, after birth, in the maturing networks of the auditory system in the thalamus and the auditory cortex.

Thus on all three levels – at first in the brain stem, then in the thalamus and finally in the sensory cortex – specific, usage dependent, structured synaptic interconnection patterns arise which are both caused by and reflect the acoustic perceptions received up to a given point in time. These primary, stabilised synaptic patterns form in turn the starting point for all extensions, refinements and supplements which may come about through additional acoustic input. Especially on the level of the most recently established representations of acoustical signals in the particularly pliant networks of the auditory cortex, modifications of this kind can be brought about by means of individual training throughout a person's life.

In cases where abnormal development of or damage to the hearing organs or nerves prevents the generation of acoustic activation patterns and therefore also the stabilisation of corresponding synaptic interconnection patterns, it is not possible to create these primary representations in the respective brain regions retrospectively with the same degree of complexity. Even when people suffering from such conditions can be treated to correct the original deficit, e.g. by means of a cochlear implant, they can still only process the acoustic signals which they are now able to receive to a very limited degree.

A sensory perception only becomes meaningful when it can be connected with other perceptions or experiences which are being made or have been made in the same context. This is true, as well, for the sense of hearing. Neurobiologists term such an event, when two or more different sensory channels are activated simultaneously through a given experience, 'functional coupling'. In all probability there is no such thing as an acoustical perception which is not coupled in some way or other with another perception received at the same time via another sensory system. Thus coupling is the rule, not an exception – and that is the case right from the beginning, i.e. as early as the pre-natal phase of development, when the respective networks are formed in usage dependent processes.

Through the physiological union of the unborn child with its mother a connection exists with her mental state as well. In respect of hearing this has the following significance: The mother's voice informs the unborn child of her emotional state; as the latter changes, so do her heart rate, her respiration and the hormone levels in her blood. Thus the voice is tied in with shifting rhythmical experiences originating with speech and heartbeat, in addition to vibrations via tactile experience and the effects of hormonal fluctuation.

This means that pre-natal hearing, in this case of the mother's voice, occurs simultaneously via several senses, and it is anchored in the brain through this connection pattern as a comprehensive experience (as a 'gestalt').

For instance, when the mother is excited, her organism produces more stress hormones (adrenaline=cortisol), the oxygen supply is modified, the heart rate accelerates and the abdominal wall tenses up, restricting the unborn child in its freedom of movement. At the same time, the mother's tone of voice may become higher, louder, and shriller. This alteration in the characteristics of the voice is noted by the child, which associates it with the distress or sense of being threatened which it experiences in that situation. On the other hand, when the mother is relaxed and in a balanced state, the child experiences a harmonious sense of being provided for, it is itself relaxed and the corresponding feelings are also coupled with the mother's now calm and tranquil voice.

The extent to which and the way in which a mother's voice changes according to her emotional state varies. Through the coupling process described here, in which changes in the mother's voice are brought together with other somatosensory experiences, the changes gain an individual connotation for the unborn child.

The same applies, of course, to all other hearing experiences, including those emanating from without, ranging from listening to music to loud quarrelling. A slammed door need not necessarily be something stressful, but when it becomes associated with a bodily experience which is felt as stress and which is not then dissipated by a subsequent calming experience, then it will become firmly linked with that experience and correspondingly internalised.

After birth, such coupling phenomena become more diverse and can be more plainly observed. In this respect the coupling of speech, song or music with distinct, associated and simultaneously activated physical experiences can be easily demonstrated: in positive cases these could consist of rocking and swaying, stroking and moving, satiation and the satisfaction of basic needs. All these bodily experiences become inextricably linked with the voice of the mother, with her speech melody, with individual words or with her song. As a baby's ability to process optical stimuli matures, changing facial expressions and gestures on the part of the initial key carers are connected with the acoustic signals coming from the same source. Thus the parents' behaviour at this stage determines the patterns which remain activable in the context of later experiences.

Through coupling phenomena of this kind the perceptions made by the child (in either especially pleasant or especially unpleasant situations) via various sensory organs are not only connected with each other, but also with the feelings which they engender. In this way they are anchored in the brain as a complete 'matrix' formed of linked neuronal networks and synaptic interconnection patterns. The more intensely the emotional centres in the limbic system are activated as well, the stronger will be the bond which develops between them and the most powerful sensory impressions in a given situation, i.e. that which is seen, heard, smelled or felt. And the greater the variety of different sensory perceptions involved in an experience at one and the same time, the more diverse and complex the matrix will be which is anchored in the brain.

A new perception, a new item of knowledge or a new experience can only become anchored within the brain when the activation pattern generated by the newly received stimulus can be associated in one way or another with existing interconnection patterns and corresponding activation patterns. At every moment of the development of a brain, the currently available pool of knowledge and experience provides the basis for 'capturing' and accommodating new input.

Every fresh sensory perception and every new experience must go through this process of being linked with existing interconnection patterns, associated with what has gone before and finally being integrated. Whenever such a process is successful, the extended pattern itself becomes part of the basis for all subsequent connection and assimilation processes. In this way, every person gains not only increasing levels of competence in individual areas during his or her early childhood, but also an ever more extensive and complex ability to make more connections. Furthermore, insofar as a child is able to connect more and more sensory ex- periences with each other, it becomes more able to 'grasp' those phenomena in its life which lie beyond the senses: the invisible, the inaudible, which cannot be felt directly.

These capabilities are in the realm of the meta-cognitive. They are anchored on the most complex association levels in the human brain, in the so-called prefrontal cortex. This is the home of our inner attitudes, our concepts of self-efficacy and of ourselves, of our ability to predict the future course of events, to plan our actions or to control our impulses.

These meta-competences cannot be taught or learned by rote, but can only be anchored in the brain through our own gamut of experiences. Interestingly enough, early experience of music, listening to musical sequences, singing and playing musical instruments such as drums all represent especially effective ways of creating a foundation for the later development of the highly complex areas of meta-competences. As these activities all have a procedural character, they facilitate the formation of an inner understanding of chronological sequence. That which has just been (what is past) allows the prediction of and expectations in respect of what is still to come (the future). Thus music imparts an inner sense of continuity, of the dependability of and involvement in that which is, i.e. Now: Now contains the echo of what has been and it is the starting point for what is yet to be.

Therapeutic experience has shown that an even, steady rhythmical structure conveys a sense of security and continuity. That tempo which we find most soothing in musical works corresponds to the normal rate of a calm pulse, namely 60 beats per minute. This is the received knowledge of great antiquity: All cultures make use of it in their lullabies, but also in more modern esoteric or meditative music.

Thus the harmony and rhythm of music picks up on prenatal experience. But it also develops this pool of experience by means of irregularities. Breaks in harmony and changes in rhythm can become part of a light-hearted interplay between what is already known and what is new. And on the foundation of a basic sense of emotional security, what is new and foreign can be approached with optimistic curiosity rather than apprehension.

Rhythm, especially, creates continuity and a sense of security through the instrument of reliable repetition. It is at the root of what Milton Erikson termed 'basic trust' (1974). Our most fundamental experience of rhythm is, from a biological point of view, holistic, for all life is determined by the pulsating influence of a rhythmical Nature. In the attempt to understand the effects of rhythm at the commencement of infantile perception of sound, we may view it as the regular, alternating sequence of beat and pause. It represents the combination of presence and absence within a temporal framework. Thus it may well be that even before the very beginning of consciousness, the consistently repetitive alternation of beat and pause is one precondition for the development of dependably internalised chronological patterns. This rhythmical continuity experienced during the intrauterine phase of life could be a necessary preparation for a child's capacity to explore and then cope with irregularities in a confident manner. And this process is crucial to subsequent mental development.

To sum up the phenomenon of primary rhythmical experience: At a very early age knowledge of variation, pauses or irregularities becomes anchored not only through biologically determined rhythmical experiences but also through the voice and thus the speech patterns of the mother.

The relationship of a mother and a nursing baby is characterised by vocal interaction, whereby the vocal pattern is a reflection of the basic style of communication between them. At four months, characteristic patterns have developed which allow predictions to be made in respect of the bonding patterns which will have emerged after one year and the cognitive development after two years (Beebe 2004). Interestingly enough, both 'over-perfect' and too little responsivity can lead to insecure bonding patterns. 'Too little' in this case means overlong pauses and the breakdown of contact. At the other end of the scale, going out of one's way to achieve perfectly timed responses generates confinement and prevents flexible interplay. A baby can only develop reliable bonding patterns on the basis of flexible ups and downs, with communication breakdowns followed by happy reunion. It is the process of restoration of the relationship which lays the ground for the flexibility which later life will demand. To this, Beebe asserts that during the 'now-moments' and 'moments of encounter' which will be referred to later a form of knowledge – a perception of the other's current state – becomes reflected in oneself. This reflection is so exact that auto-perception and hetero-perception correspond. Such moments of conformity in encounters with others – i.e. seeing oneself in others – promote the formation of autonomy and identity.

The basic units of implicit experiential knowledge are 'moments of encounter': emotional experiences which take place both in company and in seclusion – and which alter the implicitly felt, inter-subjective pool of experience. This is experience in the moment of its inception. Stern (1992) underlined the fact that we too often see experiences and feelings as 'snapshots' and fail to take account of the inner flow, of a forward moving river of experience. He refers to the inner performances which reflect this dynamic process as 'vitality affects'. These so-called 'dynamic time-shapes' can be connected with movements, sensations and other perceptions and they take place simultaneously, as in a musical score – polyphonically and polyrhythmically. In a similar way to the 'states' in their dynamic subtlety and transience – both characteristics of sound and music – vitality affects reflect the resonant matrix of the inner world of experience (Stern 1992). The vitality affects generate 'temporal feeling shapes', characteristic 'dramatic lines of tension' which are described with the use of musical metaphors such as musical phrases. They attempt to capture the impression left by sensations or the inner contours of feelings. Damasio describes this quality of experience in terms of 'background feelings'. For him, even more so than for Stern, such feelings are closely bound up with the physical body (Damasio 2001).

In this way a baby becomes acquainted with the world – in an atmosphere of mutuality, simultaneity and the sharing of affects and feelings. This remains a part of our experience for the rest of our lives; however, it becomes overlaid by explicit forms which consciously determine our later life.

Positive experience of relationship represents a life-long protective factor (Bauer 2002); it can even prevent a genetic predisposition towards aggressive behaviour from developing (Moffitt 2002, Teicher 2002). Relationship experiences made in earliest childhood give rise to a basic framework which colours the whole of the life which follows. It is this stage that determines whether a person can rely on social relationships and expects these to be helpful to him or herself – or whether he or she develops into an 'independent' loner because of the disappointed anticipations of infancy.

Research into earliest childhood has concentrated much effort on the question as to how nursing babies can have such discriminating powers of differentiation, how they can perform crossmodal linking and how they are able to play such an active part in their relationship with their human environment. To provide a possible explanation for these phenomena, the existence is assumed of the so-called 'inter-subjective motivational system' in addition to the bonding system (attachment motivational system) (Watson and Gergely 1999). The mirror neurons, too, may play a role here (Gallese 2003). Neurophysiological research results suggest that familiarity, repetition and expectability all have a decisive influence on the organisation of neuronal functions and interconnections. The capacity for synchronisation is congenital and exists as a genuine human need in an inter-subjective context. The processing of these experiences provides for the necessary preconditions which enable a person to self-synchro- nise in later life, for instance when he or she is fully preoccupied with a given activity (Pöppel 2005).

In order for changes to take place, a moment must emerge in which two people meet, reach a state of resonance with each other, synchronise with each other and in this way achieve regulation.

The Group of Daniel Stern has coined the term 'now moments' to describe these encounters in which a reciprocal link – a 'meeting of the minds' – occurs between two self-organising systems. At such moments the whole world of experience of those participating, their thinking and their feeling, is raised to a higher level (Stern 1992).

With music, while playing particular musical compositions or just improvising, such moments can transpire practically on their own. For music is a vehicle through which people can connect with each other with a special intensity, in a certain resonance, in the context of a rhythmical and=or dynamic 'happening'. Playing music in a group succeeds when those participating show an inner willingness to become involved, to enter into a state of resonance with the others and with the music. This cannot be brought about by an effort of will – it is an interactive experience, it implies active listening, affective reasoning and response. The significance of resonating with others, of 'being on the same wavelength' can be seen very clearly with improvised music in a therapeutic context: Two people meet, achieve resonance, synchronise with each other and 'something' sorts itself out – feels different, is no longer as it was before. Here it is evident that encounters of this kind are prerequisites for the experience of *now moments* which in turn provide a starting point which enables a therapeutic process to begin.

In this sense, the experience of music is the experience of relationship. This can be used for therapeutic purposes because of the way in which it allows people to let themselves be touched, reached and in their inmost depths moved (Schumacher 1999).

Music therapy works with a person's precognitive and emotional aspects, which enables access to very early patterns of experience, including prenatal ones. This embedded body of experience can be rediscovered through music. Where a person's world at this early age was intact, there exists a healthy foundation which can be used and strengthened to beneficial purpose. We experience this as a process of being 'inwardly moved'; old yearnings reawaken, a feeling arises which heartens, strengthens. On the basis of this feeling, we can engage in the task of redesigning our thought and behaviour patterns.

But what is the use of all these astonishing neurobiological findings to a person who, in the end, has become ill through the effects of the life which he or she has been leading?

In conclusion, some examples of the effects of intervention using music therapy follow to provide a possible answer to this question.

Music, like speech, is used in all human cultures as a medium for communication, to aid in organising social life and to bond the members of social groupings together. Therefore music therapy, like conversational therapy, looks back on a long tradition as a form of psychosocial therapy used to aid the healing and reintegration of group members. Today, music therapists usually work in close cooperation with physicians and psychotherapists together with patients, either on an individual or on a group basis. With the help of free, structured or partially structured sound improvisations and a variety of receptive techniques patients are given the means to become aware of their feelings and conflicts in a non-verbal manner and also to express them. Their conscious awareness of these aspects is then consolidated in subsequent counselling sessions.

Frequently, music therapy is also used with the aim of resolving internal tension and triggering resonance and harmonisation effects, which can prevent the spread and escalation of non-specific states of fear and agitation. To bring about these calming effects three factors are of special significance: familiarity, rhythm and order. The familiarity of received music allows for associative connections to be made with internally stored images which impart a sense of security and 'being in good hands'. When a patient absorbs a rhythm and uses it as a tool for performing inner work, this can bring about resonance phenomena of great power. Synchronisation effects take place which emanate from the auditory cortical regions and spread to associative and motor areas, influencing and augmenting each other. In this way activity patterns generated in very diverse regional networks of the brain can be synchronised and harmonised with each other. This effect is experienced as the unification of thought, feeling and action, both on an individual level and by a group which is bonded together through a common rhythm (social resonance).

Another health promoting component of music consists in its inherent order, which can be perceived by a listener or actively expressed by those playing instruments. This structure, consisting of repetition and alternation, of the development and rediscovery of a familiar theme, supplies precisely the preconditions necessary for the activation of emotional-cognitive processing: through the unexpectedness of what is new, through familiarity with what is known and through the creative act of ongoing evolution. This effect can be best exploited and most effectively implemented in the context of improvisation for therapeutic purposes. By providing the patients with tools with which they can express affective conditions through rhythm and sound, they become empowered to communicate their emotional state in a non-verbal way. As this happens in an environ- ment without evaluation and without constraint on the part of the therapist, patients can become aware of their present feelings, express them and in the course of an interactive process they undergo the experience not only of being understood by another person, but also of receiving a response from them. By engaging in this non-verbal dialogue, patients can grasp that they can exercise a modulating influence over their own affective states.

As a result, the patients' grasp of their own self-efficacy concept is strengthened on the level of affective regulation. The unfamiliar experience of finding access to and being able to express their own stored feelings, i.e. discovering a new mode of communication, together with the exploitation of the harmonising, synchronising and resonance generat- ing effects of music, causes stimulation of emotional centres which most patients regard as beneficial.
The increased production of neuroplastic neurotransmitters associated with such activity promotes

confirmation of the neuronal interconnection patterns which are activated through corresponding priming processes. In this way it is possible to create the conditions which are a prerequisite for the modification of a person's personal world of experience, thinking patterns, feelings and actions through continuing psychotherapeutic treatment.

On the basis of these observations, the following three propositions may be put forward to substantiate the salutogenetic effects of intervention by means of music therapy.

Listening to pleasant music, actively playing musical instruments or singing causes physical alteration of the brain in the form of a harmonisation and synchronisation of the neuronal activation patterns which have been generated in various cerebral regions. These effects can be expected to be all the stronger in accordance with the degree of enjoyment associated with the musical experience, with the degree of openness with which the person concerned can approach such an experience and with the extent to which he or she can allow free associations to arise ('to dream'). The more these harmonisation influences can pervade the subcortical regions responsible for the organisation of integrative bodily control systems (limbic system, hypothalamus, brain stem), the greater the reconstitutive effect on structures such as the cardiovascular, neuroendocrine, vegetative and immunes systems which have become disrupted by tension, anxiety, stress, etc. The long-term influence of these effects is determined by the extent to which they 'reverberate' within the person concerned – as inner experiential images, as melodies which continue to play in the person's imagination, etc.

The harmonising and synchronising effects of music can be utilised specifically in order to overcome fears and sensations (e.g. pain caused by medical intervention) and for the relief of tension (e.g. to ease anxiety while preparing for medical intervention). Also, they can be transferred from one person to another (e.g. when a parent sings or plays an instrument for a child).

Musical experience (listening, playing, singing and also imagining music being played) brings about a reactivation of previously suppressed activation patterns in associative and emotional centres, or aids their reconstitution following disruptive occurrences. The subjective perception of these effects is described in terms of 'relief' and 'revitalisation' by those concerned. In this way, previously suppressed conceptions and desires can be reactivated and, in some cases implemented as well (activation of the noradrenergic 'attentiveness' system as well as the dopaminergic 'motivation and reward' system).

This is the effect which is harnessed for use as a 'collective motivation amplifier' in ritual preparation of forthcoming activities (war drums, marching music, and also pop and rock concerts) and in order to generate specific mental conditions (films, advertising).

Whenever listening to or playing music or the singing of melodies causes the activation of subcortical emotional networks and centres in the brain, this is accompanied by increased production of neurotransmitters: in particular, of those neurotransmitters which contribute to the amplification, reinforcement and priming of all the neuronal interconnections which are primarily involved in this emotional activation.

This applies to the priming processes of the sensory-motoric regulating systems activated through learning to play an instrument, to the enhancement of fundamental processing of auditive perception, but also to the strengthening of bonds between people (playing music or singing in a group) and to the affirmation of healing mental pictures and inner motivation.

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Chapter 8

Music and the self

As we pass through life we interact with and experience music in many ways. Sometimes we pay attention to it; other times we do not. Often we move along with music, not only as performers but also as engaged listeners who tap their feet, bob their heads, or simply follow the music with their minds. Perhaps for most, music intertwines itself with our life narratives. Hearing songs from our past often evokes vivid memories and strong emotions (Sloboda and O'Neill 2001, Juslin and Laukka 2004, Janata et al. 2007). Given the many ways in which we experience music, and the central role it plays in cultures around the world, one is drawn to the questions of why music engages the human brain so strongly and how it is that the brain enables these various forms of musical experience? Part of answering these questions depends on understanding what constellations of brain areas might allow music to interact so profoundly with the self. In other words, what are the brain areas that allow music to move us or to evoke such strong memories?

In this article I suggest a context for thinking about these questions. The context is derived from the broader neuroimaging literature and it emphasizes the contrapuntal roles of two classes of brain networks, one for engagement with the external world and the other for engagement with one's own thoughts, memories, and emotions.

The best studied and understood of the networks is the network generally associated with cognitive functions of language, semantics, working memory, imagery, attention, error- monitoring, and preparation of near-term action sequences (see Cabeza and Nyberg 2000, Corbetta and Shulman 2002, Janata and Grafton 2003, Ridderinkhof et al. 2004, Rushworth et al. 2004 for reviews). The principal regions of this network are parietal areas around the intra-parietal sulcus (IPS), and regions surrounding the inferior frontal gyrus, in particular dorsolateral prefrontal cortex (DLPFC) and ventrolateral prefrontal cortex (VLPFC). This area is commonly known as Broca's area and serves a variety of sequencing functions (Fiebach and Schubotz 2006). The action portions of this network include both medial areas – the supplementary motor area (SMA) and pre-SMA – and lateral premotor cortex (PMC) .

In simplest terms, the back of the brain is involved in sensation and perception, whereas the front half of the brain is involved in the structuring of action. This idea has been articulated in considerable detail by Joaquin Fuster, one of the pioneering researchers of the frontal lobes (Fuster 2000, 2004). Of course, the situation is not quite that dichotomous, and both perception and action influence each other at multiple levels within those processing streams. One example of perception activating motor systems is the existence of neurons referred to as "mirror neurons" which, despite their location in premotor areas, respond to observed actions (Preston and de Waal 2002). An example of action systems influencing sensory systems is evidence that sensory cortices are activated during mental imagery tasks (Zatorre and Halpern 2005). The role of premotor cortices in the uniting of perception and action is nicely elaborated in a recent review article by Ricarda Schubotz (2007). The relevance of these systems to music will be reviewed in more detail below.

For a long time, researchers whose experiments activated elements of the network for external engagement described above were puzzled by decreases in activation during task performance in a different set of brain areas. These deactivations were associated primarily with considerable sections of the medial wall – the region of cortex that is tucked between the two hemispheres – stretching from the posterior cingulate cortex (PCC) and precuneus area of the parietal cortex in the back of the brain, all the way to ventromedial prefrontal cortex (VMPFC) beneath the corpus callosum in front of the brain . Lateral inferior parietal areas are also part of this network. For quite a long time, activity within this network was dismissed as irrelevant to cognition. After all, meandering thoughts and daydreams are difficult to capture and a brain that is not engaged in the task at hand is a brain that is doing nothing of interest. However, due in large part to the interest in the "default-mode" hypothesis (Raichle et al. 2001, Raichle 2005), along with the blossoming of affective and social neuroscience (Lieberman 2007), the functional significance of this network has gained considerable attention over the past five years.

A consensus view that emerges across several recent meta-analyses and review articles is that the areas of this network along the cortical midline are engaged in various forms of self-referential processing (Wicker et al. 2003, Northoff and Bermpohl 2004, Northoff et al. 2006, Gilbert et al. 2006, Schmitz and Johnson 2007, Lieberman 2007). More detailed analyses reveal further functional distinctions within the medial prefrontal cortex (MPFC), though the interpretations of what the underlying processes=functions are for which there is a functional topography depend on the authors' points of view. Not surprisingly, the retrieval and re-experiencing of autobiographically salient information also engages the MPFC (Gilboa 2004, Maquire 2001, Svoboda et al. 2006).

Another way to think about the functional arrangement of the cortical midline in the frontal lobe is in terms of the degree of elaboration of action plans. A hierarchy of action control has been demonstrated in lateral prefrontal cortex, with increasingly specific actions being represented as one progresses from rostral prefrontal cortex to the premotor areas of the caudal prefrontal cortex (Fuster 2004, Koechlin et al. 2003). An argument for such a hierarchy can also be made for the cortical midline. The most posterior regions (the pre-SMA and SMA) are engaged in preparing specific actions and sequences of actions that will be executed in the immediate future, whereas more anterior areas are implicated in motivation and planning of goals and actions that unfold over more extended periods of time (Burgess et al. 2005). Thus, there appears to be a gradient of elaboration of action plans that proceeds from action plans that are largely uncoupled from immediate interactions with the en- vironment to action plans that are part of in-the-moment sensorimotor coupling. One should note that this putative gradient of action elaboration along the cortical midline spans both the "internal" and the "external" networks, with the rostral parts of the MPFC belonging to the former and the pre-SMA and SMA belonging to the latter.

Numerous neuroimaging studies utilizing musical materials and tasks have demonstrat- ed the engagement of what I like to think of as the "lateral" or "external" network. Most of these studies have been structured as target detection and categorization paradigms or simple listening tasks. A common paradigm for studying implicit knowledge of tonal structures in music is to present a context, either a sequence of chords or a melody, which is then followed by a target event. In some studies, subjects make some sort of explicit judgment about the target event whereas in studies that look at automatic processing of musical events the target events are ignored. Memory tasks in which a target pitch is compared with the pitches of a short melody have also been used. Overall, these studies have found involvement of elements of the "external" network, including the auditory cortex in the temporal lobe, the supramarginal and angular gyri in the parietal cortex, as well as ventrolateral and dorsolateral prefrontal cortex (Zatorre et al. 1994, Koelsch et al. 2002, Tillmann et al. 2003, Gaab et al. 2003).

Other types of music studies, including attentive listening to segments of polyphonic music, and a variety of imagery tasks have demonstrated the recruitment of both the parietal and the lateral prefrontal areas, as well as the "action-oriented" nodes of the externa network (Janata et al. 2002a, Halpern and Zatorre 1999, Langheim et al. 2002, Meister et al. 2004). Similarly, these areas have been found to be active in studies of music reading and performance (Sergent 1992, Schön et al. 2002, Parsons et al. 2005), and performance of rhythmic tasks (Penhune et al. 1998, Ullen et al. 2003, see Janata and Grafton 2003 for a review). Attentive listening to simple metrical sequences in which the beat is apparent recruits both sensory and premotor portions of the external network, together with the basal ganglia and cerebellum, but without the parietal cortex (Grahn and Brett 2007). In the case of tapping along with a simple isochronous sequence in which the salience of the metric structure is manipulated, the set of brain areas that are involved is reduced even further. Beyond a simple circuit of auditory and motor cortices in conjunction with the cerebellum and thalamus that form the basis for the repetitive finger movement, a small region of auditory cortex and lateral premotor cortex shows an effect of the metric salience (Chen et al. 2006). Thus, a very small subset of the areas involved in the perception=action cycle is recruited for the relatively simple task of finding the beat in a simple auditory sequence.

Taken together, the studies mentioned here as well as numerous others indicate that musical tasks are capable of recruiting different components of the network for externally directed perception and action, and that the patterns of recruitment depend in large part on the perceptual, cognitive, and motoric demands of the task. While this dependence on task demands is in accordance with the ideas of hierarchical organization of perception=action cycles described above, it also indicates that the forms of musical engagement and experience are multi-faceted.

In contrast to the studies mentioned above, relatively few studies of music have elicited or commented on activations within the "medial" network. This is somewhat puzzling, because, as I described above, the medial network is important for emotional, social, and self-relevant processes, which music is intimately associated with. On the other hand, it is not surprising insofar as the notion of the perception=action cycle does not encompass the concept of emotion explicitly. To the extent that studies of musical processes are structured as perceptual discrimination or judgment tasks with stimuli that are often brief, abstract, or artificial sounding, i.e. not particularly characteristic of the music we listen to, such tasks are expected to drive areas associated with the perception=action cycle and outwardly directed attention, but not areas involved in the processing of emotions.

The relatively few studies that have examined affective responses to, or required self- relevant judgments about, musical stimuli do, however, reinforce the notion that the medial network serves affective and autobiographical functions. Specifically, in one study, Blood and colleagues (1999) illustrated that the activity in the ventromedial prefrontal cortex (VMPFC) is modulated by the relative amounts of dissonance of harmonic accompaniments of piano arrangements of simple melodies. In another study, Blood and Zatorre (2001) found that the amount of activity in the VMPFC depends on the likelihood of experiencing a chill while listening to self-selected music. Similarly Brown et al. (2004) found that simple listening to unfamiliar but pleasant Greek songs activated VMPFC. A study by Platel et al. (2003) showed that the entire extent of the rostral MPFC was active during a task in which subjects made familiarity judgments about pieces of recorded music. A recent study that explicitly studied music familiarity also found heightened activity with increased familiarity in sections of the RMPFC (Plailly et al. 2007).

Further evidence that suggests that the MPFC mediates affective responses to familiar music comes from a pair of independent observations pertaining to Alzheimer's disease (AD). One of these is primarily anecdotal in nature, although empirical evidence is starting to accumulate (Cuddy and Duffin 2005). The observation is that even in advanced stages of AD, individuals, with whom one would otherwise be unable to have a conversa- tion or normal interaction with, remain very responsive to autobiographically salient music from their past. They may even start singing along and continue singing once the piece of music is turned off. The second observation derives from a neuroanatomical study that examined the degree of atrophy of cortical regions with the progression of AD and found that medial prefrontal and sensorimotor regions of the cortex were those that exhibited the smallest degree of atrophy as the disease progressed (Thompson et al. 2003). In other words, those areas that functional neuroimaging studies show to be relevant for affect and self-relevant representations are also those that are relatively spared over the course of AD.

Given two sets of music studies that find evidence for the activation of either the external or the internal networks, the question remains as to how these networks are actually coupled. At an anecdotal level we know that they must be coupled somehow. After all, we often find moving or dancing along with music to be pleasurable and spontaneous. Certain songs or melodies might remind us of our past, or we might hear an unfamiliar piece of music that nonetheless makes tears come to our eyes.

One suggestion for how these networks might be coupled comes from a study I performed a number of years ago in which the objective was to identify regions of the brain that displayed an organization of the tonal space underlying western tonal music (Janata et al. 2002b). The mechanism for doing this was to have subjects perform two different types of target detection tasks as they listened to a melody that systematically moved through all of the major and minor keys over the course of 8 minutes. Because the movement of a piece of music through tonal space can be modelled quantitatively (Janata et al. 2002b, Toivianen and Krumhansl 2003, Janata 2005, 2008), it is possible to analyze the functional MRI data using a parametric model that captures the dynamics of a piece of music as it traverses tonal space. In other words, the output of the model describes the music much more precisely than does a model that simply indicates that music is either playing or not playing, or even that the music is in G-major or f-minor. The most salient result of this study was the observation that the MPFC consistently followed the pattern of movement through tonal space. Using the more traditional analysis in which we simply modelled subject responses and whether the stimulus was playing or not, we also found that the regions of the external network that I described above were involved as subjects performed the target detection tasks. Thus, in this study we saw evidence that both networks were engaged by the music and task that the subjects were asked to perform.

The tonality-tracking result, together with the studies of affective responses to music, familiarity judgments, and Alzheimer's disease that had been published around that time, led me to hypothesize that parts of the MPFC might be intimately involved in binding music together with autobiographical memories and their associated emotions. To begin addressing this hypothesis I developed a paradigm for characterizing music-evoked autobiographical memories (Janata et al. 2007).

One of the challenges to studying autobiographical memories is finding stimulus material that will reliably evoke autobiographical memories without the aid of the subjects or confederates. In other words, it does not really work to have subjects identify songs that elicit strong memories because the act of doing so will generate a memory that is now directly associated with the experimental context. Additionally, there are many songs that we hear over the course of our lives that may not come to mind when we are asked to remember them. Similarly, we may not know the title of a song or even the artist who performed it, even though it is capable of evoking a strong memory or emotion. The music selection strategy that works well in my laboratory, with a population of UC Davis undergraduate students, is to choose short 30-second excerpts of songs from the Billboard Pop and R & B Top 100 charts. Songs are chosen randomly from a rather broad window of time when the subject was between 7 and 19 years of age. This strategy results in the rating of approximately 50% of the songs as familiar and approximately 30% as autobiographically salient. Upon hearing an autobiographically salient song, subjects provide additional details about the evoked memories with respect to the people, places, events, and emotions that are associated with the memories. In a population of 329 individuals, subjects most commonly reported that they were reminded of friends and periods in their lives. Although the songs sometimes evoke negative emotions, the most common emotion adjectives to be endorsed were positive emotions with rather high arousal, such as "happy", "youthful", "excited", and "energized." Nostalgia was the 3rd most common emotion. A full report of this study is available elsewhere (Janata et al. 2007).

I have also performed an adapted version of this study using fMRI in order to test the hypothesis outlined above that the MPFC will become more active when autobiographically salient pieces of music are experienced. Preliminary analyses of the data indicate that the experience of music-evoked autobiographical memories does indeed activate portions of the MPFC as well as a broader network implicated in previous studies of autobiographical memory retrieval (Maguire 2001, Svoboda et al. 2006). An extensive report of these data is presented elsewhere (Janata submitted).

My objective in this paper was to illustrate how different studies of the neuroscience of music illuminate the relationship between different forms of musical experience and what appear to be domain-general principles of the brain's functional organization.

Although considerable attention has been devoted to investigating the parallels between the neural substrates underlying music and language (Patel 2003, Koelsch 2005), the parallels between music and other cognitive or affective functions and behaviors have generally not been emphasized (c.f. Panksepp and Bernatzky 2002). Rather, there has been a tendency, driven largely by the neuropsychological evidence of music-specific deficits, to identify neuroanatomical substrates that uniquely enable musical activities (Peretz and Coltheart 2003, Peretz and Zatorre 2005). While the existence of music- specific deficits associated with patterns of brain lesions is indisputable, it remains possible that there exist domain-general principles of the brain's functional organization at a coarser-grained level that also supports a core set of musical experiences. The principles of the perception=action cycle and attentional networks for internally and externally directed engagement are such coarse-grained principles that encompass significant regions of cortex. It is likely that a finer-grained organization exists within these regions that both provides for domain-specific organization as dictated by the specific mental operations that are necessary to enable domain-specific perception and action, and is shaped by individual life experiences.

Finally, the manner in which the networks for internal and external engagement interact in various musical situations is still poorly understood. While it is clear that we derive pleasure from perceiving and producing music, current neuroimaging paradigms have not been very successful in capturing the dynamic interplay of the two networks described above. It is likely that cognitive neuroscientists will need to rethink the nature of a subject's experience while performing a musical activity in a laboratory setting if progress is to be made in understanding the neural substrates of naturally occurring musical activities that mediate interactions between external sources of music and the self.

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Chapter 9

Neural substrates of processing syntax and semantics in music

Growing evidence indicates that syntax and semantics are the basic aspects of music. After the onset of a chord, initial music–syntactic processing can be observed at about 150-400 ms and processing of musical semantics at about 300-500 ms. Processing of musical syntax activates inferior frontolateral cortex, ventrolateral premotor cortex and presumably the anterior part of the superior temporal gyrus. These brain structures have been implicated in sequencing of complex auditory information, identification of structural relationships, and serial prediction. Processing of musical semantics appears to activate posterior temporal regions. The processes and brain structures involved in the perception of syntax and semantics in music have considerable overlap with those involved in language perception, underlining intimate links between music and language in the human brain.

Music is one of the oldest, and most basic, socio-cognitive domains of the human species. Primate vocalizations are mainly determined by music-like features (such as pitch, amplitude and frequency modulations, timbre and rhythm), and it is assumed that human musical abilities played a key phylogenetical part in the evolution of language (Zatorre and Peretz 2003). Likewise, it is assumed that, ontogenetically, infants' first steps into language are based on prosodic information, and that musical communication in early childhood (such as maternal music) has a major role for emotional, cognitive and social development of children (Trehub 2003). The music faculty is in some respects unique to the human species; only humans compose music, learn to play musical instruments and play instruments coopera- tively together in groups. Playing a musical instrument in a group is a tremendously demanding task for the human brain that potentially engages all cognitive processes that we are aware of. It involves perception, action, learning, memory, and emotion, making music an ideal tool to investigate human cognition and the underlying brain mechanisms. The relatively young discipline of 'neurocognition of music' includes a wide field of biopsycho-logical research, beginning with the investigation of psychoacoustics and the neural coding of sounds, and ending with brain functions underlying cognition and emotion during the perception and production of highly complex musical information (Zatorre and Peretz 2003, Avanzini et al. 2003). This review focuses on two basic dimensions of music perception.

All types of music are guided by certain regularities. These regularities constrain, for example, how individual tones, simultaneous tones (i.e. intervals and chords) and durations of tones are arranged to form meaningful musical phrases. Obviously, many regularities are culturespecific and differ between musical styles. To date, the processing of regularities has mainly been investigated with respect to major–minor tonal music; this music is formed on the basis of the major–minor tonal system that underlies the majority of Western music. Basic principles and regularities of this tonal system have been described in music theory. One aspect of these regularities pertains to the arrangement of chord functions within harmonic progressions (other regularities build melodic, rhythmic and metric structure). The regularity- based arrangement of chord functions builds a harmonic structure, and might be regarded as part of a major–minor tonal syntax (Fig. 1a, b). Listeners who grew up in a Western culture are usually quite familiar with these regularities (even if they have not received formal musical training), presumably because of their listening experiences in everyday life. It is unknown if listeners who are completely unfamiliar with Western tonal music can also recognize basic syntactic irregularities of major–minor tonal music.

Processing of chord functions has been investigated behaviorally (Tillmann et al. 2000), and with neurophysiological measures such as electroencephalography (EEG) (Janata 1995, Patel et al. 1998, Regnault et al. 2001), magnetoencephalography (MEG) (Maess et al. 2001) and func- tional magnetic resonance imaging (fMRI) (Tillmann et al. 2003, Koelsch et al. 2005). These studies used chord sequence paradigms in which chords presented at particular positions within harmonic sequences are structurally more or less (ir)regular. Figure 1b shows musical sequences ending on music-syntactically regular and irregular chord functions (see Fig. 1 legend for details). Note that the final chord of the irregularGo! sequence (right panel of Fig. 1b) does not represent a physical irregularity. It is, thus, not possible to detect the irregular chords on the basis of the operations of cognitive modules that detect physical irregularities (such as the auditory sensory memory).

It is only possible to detect the irregular chords on the basis of the operations of a cognitive module that serves the processing of musical structure.

The event-related brain potential (ERP) data illustrate the time course of activity of this module. Music-syntactically irregular chords elicit an early right anterior negativity (ERAN): this ERP effect is often maximal at about 200 ms after the onset of the chord, and is strongest over right-frontal electrode leads (although the ERAN is also clearly present over the left hemisphere, and is sometimes bilateral). Interestingly, the ERAN can be elicited in participants without formal musical training. That is, even if participants are not familiar with concepts such as 'tonic', or 'dominant', their brains have a sophisticated (implicit) knowledge about major–minor tonal syntax, and process this musical information surprisingly rapidly and accurately according to this knowledge. These findings are in line with several studies indicating that the ability to acquire knowledge about musical regularities effortlessly, and the ability to process musical information skillfully according to this knowledge, is a general ability of the human brain (details have been reviewed elsewhere (Avanzini et al. 2003, Tillmann et al. 2000)). This general ability underscores the biological relevance of music. Musical abilities are important, for example, with regard to language perception: in tonal languages, changes in pitch lead to changes in word meaning, and in both tonal and non-tonal languages prosody (i.e. the musical features of language such as melody, timbre, rhythm and metre) is of crucial importance for the coding of both the structure and the meaning of speech. Corroboratively, recent EEG studies revealed similarities for the processing of intonational phase boundaries in language and music (Knoesche et al. 2005, Steinhauer et al. 1999) and showed that musical training can facilitate the processing of pitch contour in spoken (nontonal) language (Schon et al. 2004).

The neural mechanisms underlying the generation of the ERAN can operate independently of attention (although the amplitude of the ERAN is influenced by attentional demands): the ERAN can be elicited when subjects read a book, play a video game or are lightly sedated with propofol (Heinke et al. 2004). The ERAN is sensitive to musical training (Koelsch et al. 2002b), and can be elicited in children aged 5 years and perhaps even earlier (Koelsch et al. 2003).

Using MEG, it was found that the processing of music syntactically irregular chords activates the inferior part of Brodmann's area (BA) 44, that is, the inferior frontolateral cortex (IFLC; (Maess et al. 2001). This area in the left hemisphere is often denoted as 'Broca's area', an area that has also been implicated in the processing of linguistic syntax. With fMRI, it has been demonstrated that the processing of unexpected chords does not only activate Broca's area (and the homotope area in the right hemisphere) (Tillmann et al. 2003, Koelsch et al. 2002a, 2005) but also activate posterior temporal regions (Koelsch et al. 2002a, 2005). Both Broca's area and posterior temporal regions are crucially involved in the processing of language (Friederici 2002); the interplay between these structures has for a long time been thought to be language-specific. The data presented in Fig. 1e demonstrate that the cortical 'language-network' is also involved in the processing of music. This network often shows a right-hemispheric weighting in the musical domain, and a left-hemispheric weighting in the language domain (specializations of the two hemispheres for different features of auditory information have been discussed elsewhere (Zatorre et al. 2002)).

The ERAN is reminiscent of early anterior negativities that correlate with the early detection of an error in the syntactic structure of a sentence (usually observed with a maximum over the left hemisphere). The early left anterior negativity (ELAN), for example, has been observed in response to words with unexpected syntactic properties in sentences (phrase structure violations) (Friederici 2002). That is, both ERAN and ELAN are sensitive to violations of an expected structure. Moreover, the generation of the ELAN appears to rely on neuronal generators that overlap with those of the ERAN, in that both components receive contributions from the same brain region in the inferior frontolateral cortex (lower part of BA 44) (Maess et al. 2001), and possibly from the anterior superior temporal gyrus . Taken together, these findings indicate a noticeable overlap of neural resources that are engaged for the (early) processing of syntax in music, and syntax in language.

Besides IFLC, two additional structures have been observed in relation to music-syntactic processing: the ventrolateral premotor cortex (vlPMC) and the aSTG (Figs. 1, 1e, 2, 2b). Activations of IFLC along with the aSTG have been reported in previous functional imaging studies on syntactic processing using musical (Koelsch et al. 2002a, 2005) and linguistic stimuli (Friederici 2002, Friederici et al. 2000, 2003).

Activations of the IFLC (BA44), often along with the vlPMC, have been reported by a number of functional imaging studies using musical stimuli, linguistic stimuli, auditory oddball paradigms, pitch discrimination tasks, and serial prediction tasks (Tillmann et al. 2003, Koelsch et al. 2002a, 2005, Friederici 2002, Janata et al. 2002, Doeller et al. 2003, Gaab et al. 2003, Schubotz and von Cramon 2002). On a more abstract level, the IFLC (BA44) and the vlPMC have been implicated in the analysis, recognition and prediction of sequential auditory information (Schubotz and von Cramon 2002, Conway and Christiansen 2001, Huettel et al. 2002, Janata and Grafton 2003). Frontoopercular cortex (along with vlPMC) identifies structural relationships (rather than simple acoustic properties) among events occurring within auditory sequences, and these areas are involved in a fast short-term prediction of upcoming events; violations of predictions activate these areas (Schubotz and von Cramon 2002). The presentation of an irregular chord function violates the expectancies of listeners familiar with the regularities of tonal music. Unusual calculations of the relationship between the irregular chord function and the preceding harmonic context presumably activate a network comprising the pars opercularis in the IFLC, the vlPMC and presumably the anterior STG. These calculations are related to the sequencing of the chords, and the detection of a violation of a serial prediction. Whether neural substrates of these processes can functionally and anatomically be distinguished from each other remains to be specified. Likewise, it is not known if the representation of musical syntax is located in the same areas that are involved in the processing of musical syntax (Patel 2003).

It has been suggested that there might be an immediate link between the prediction of upcoming events and the representation of corresponding motor schemas in the lateral premotor cortex (PMC) that enables an immediate mapping of perception onto action, that is, premotor programs for articulation, or 'vocal plans' (Schubotz and von Cramon 2002). Such an aping is needed, for example, when singing along in a group, and is presumably also involved in the learning and understanding of musical syntax.

The ERAN is not the only electrophysiological index of music-syntactic processing, ERP studies investigating the processing of musical structure report a variety of ERP components such as P300 (Janata 1995), RATN (right anterior temporal negativity) (Patel et al. 1998), and P600 (Patel et al. 1998, Regnault et al. 2001, Besson and Faita 1995). The P600 (a positivity maximal at about 600 ms) appears to be related to processes of structural integration during the perception of music or language. Because the P600 can be observed in response to structural incongruities of both music and language (Patel et al. 1998), it has been suggested that resources for syntactic integration are shared between music and language (Patel 2003).

The similarities between ERAN and ELAN suggest that not only neural resources for late but also for earlier syntactic processes are shared between music and language.

Music can transfer meaningful information, and is an important means of communication. Most theorists distinguish between different aspects of musical meaning: first, meaning that emerges from common patterns or forms (e.g. musical sound patterns that resemble sounds of objects, or qualities of objects), second, meaning that arises from the suggestion of a particular mood (e.g. happy), third, meaning inferred by extramusical associations (e.g. any national anthem), and fourth, meaning that emerges from combinations of formal structures that create tension (e.g. when perceiving an unexpected chord) and resolution (Meyer 1956). The emergence of meaning based on the processing of musical structure requires the integration of both expected and unexpected events into a larger, meaningful musical context.

Such processes of musical integration appear to be reflected in a later negativity evoked by unexpected (irregular) chord functions (Fig. 1b, c). This negativity usually reaches its maximal amplitude at about 500 ms after the onset of a chord and has been denoted as N5 (Koelsch et al. 2000; Fig. 1c). Note that the processes of semantic integration during the perception of language are reflected in the N400 (Kutas and Federmeier 2000), a negativity peaking at about 400 ms after the onset of a word. Similarly to the N400 amplitude, which correlates with the amount of semantic integration required by a word, the N5 amplitude is related to the amount of harmonic integration required by a musical event (Koelsch et al. 2000).

Differences in scalp topography between N400 and N5 indicate that these two ERP components do not reflect identical cortical processes. However, because the N5 roughly resembles the N400, and because the cognitive processes following musical expectancy violations have theoretically been related to the processing of meaningful information, it appears likely that the N5 reflects neural operations that are at least partly related to the processing of musical meaning, and that the N5 entails processes that might also contribute to the generation of the N400 (note that irregular chord functions, and deceptive cadences, are prominent elements of major–minor tonal music that are used by composers as a means of expression). The N5 has not been localized to date, but it is possible that the N5 receives contributions from those posterior temporal lobe structures that have been shown with fMRI to be activated during the processing of unexpected chords. These structures are also known to be involved in the processing of lexical–semantic aspects, that is, meaning of language (Friederici 2002).

The N400 has recently been used to investigate the processing of musical semantics in a semantic priming paradigm (Koelsch et al. 2004). In this study, sentences and musical excerpts were presented as prime stimuli. The prime stimuli were semantically either related or unrelated to a target word that followed the prime stimulus. For example, the sentence 'The gaze wandered into the distance' primes the word 'wideness' (semantically related), rather than the word 'narrowness' (semantically unrelated). Analogously, certain musical passages, for example, those from Mozart's symphonies, prime the word 'angel', rather than the word 'scallywag'.

In the language condition (i.e. when target words followed the presentation of sentences), unrelated words elicited a clear N400 effect (this is a classical semantic priming effect). This semantic priming effect was also observed when target words followed musical excerpts. That is, target words that were semantically unrelated to a preceding musical excerpt also elicited a clear N400. The N400 effects did not differ between the language condition (in which the target words followed sentences) and the music condition (in which the target words followed musical excerpts), neither with respect to amplitude nor with respect to latency or scalp distribution. Figure 2a shows the results of a source analysis of the N400 effects. In both conditions, the main sources of these effects were localized bilaterally in the posterior part of the medial temporal gyrus (BA 21/37), in proximity to the superior temporal sulcus. As mentioned above, these regions have been implicated in the processing of semantic informa- tion during language processing (Friederici 2002, Baumgaertner et al. 2002).

The N400 effect in the music condition demonstrates that musical information can have a systematic influence on the semantic processing of words. The N400 effects did not differ between the music and the language condition, indicating that musical and linguistic priming can have the same effects on the semantic processing of words. That is, the data demonstrate that music can activate representations of meaningful concepts (and that, thus, music is capable of transferring considerably more meaningful information than previously believed), and that the cognitive operations that decode meaningful information while listening to music can be identical to those that serve semantic processing during language perception.

The N400 effect was observed for both abstract and concrete words, showing that music can convey both abstract and concrete semantic information. Moreover, effects were also observed when emotional relationships between prime and target words were balanced, indicating that music does not only transfer emotional information.

The present findings provide information about the processing of musical syntax and musical semantics. Results indicate that the human brain processes music and language with overlapping cognitive mechanisms, in overlapping cerebral structures. This view corresponds with the assumption that music and speech are intimately connected in early life, that musical elements pave the way to linguistic capacities earlier than phonetic elements, and that melodic aspects of adult speech to infants represent the infants' earliest associations between sound patterns and meaning (Fernald 1989), and between sound patterns and syntactic structure (Jusczyk and Krumhansl 1993). Thus, despite the view of some linguists that music and language are strictly separate domains (Pinker 1997), the combined findings indicate that the human brain engages a variety of neural mechanisms for the processing of both music and language, underscoring the intimate relationship between music and language in the human brain.

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Chapter 10

A City Upon a Hill: making scientific progress in brain based music research in typical development, autism and other disorders

The enrichment of personal and shared musical experiences is a central component of ongoing pursuits of individual happiness and healthy, educated and prosperous communi- ties around the world. In 1630, in America, John Winthrop spoke passionately of what he called "A City Upona Hill". Although in a religious setting (Winthrop purged his church of organ music in favor of *a cappella* metrical psalms) his passion and purpose applies directly to many research endeavors. We and other investigators seek to harness the power and neuroscience of music to enrich and improve the lives of individuals. We describe our vision of a music research "City Upon a Hill" and a scientific plan to build it. From our perspective, the plan starts with the acquisition of detailed knowledge of the "bedrock" of internal musical experiences within the human brain.

What is already known about the brain regions and networks involved in music, language and emotion in the typically developing brain? What needs to be known? What explains variations between individuals and what is invariant? Many impaired individuals have been helped by regimens of auditory stimuli when no other approach had reduced the effects of their impairment. Amassing collections of case studies and anecdotal reports or to focus solely on elemental aspects of music, however, does not the bedrock make. We propose creative and innovative applications of the inductive scientific methods of Bacon, Newton and Kuhn to the study of actual musical experiences in listening, composition and performance. Brain-based music research that captures actual experience has the potential to add to the scientific understanding of brain development not only in typical individuals but also in those burdened with developmental brain disorders.

We identify and outline key elements of the design and analysis of basic science and clinical studies of music-brain-behavior experiences that are essential to making solid progress towards one of our common goals.

An example from the current brain-based music research in autism is provided.

There are critical gaps that need to be filled in understanding the role of music in typical development and brain disorders and translating what is learned into effective and practical interventions. Clinical studies aim to realize lasting changes that enrich and improve people's lives by increasing our knowledge of the brain basis of musical experiences. They observe changes in brain function in response to changes in controlled auditory stimuli. They are disorder-driven, not curiosity- or music-driven, asking: how can the neuroscience of music be employed to decrease daily impairment and improve daily function in the everyday world? – and they are vital.

Analogous to the replacement of the outdated notion of a fixed, hierarchical "great chain of being" with the theory of evolution, boundaries and hierarchies between classical disciplines in many scientific domains are now being replaced by interdisciplinary teams united for a common purpose. Members of these "matrixed" teams (in contrast to old hierarchical orders) interact as equals in cooperation rather than competition. The in- vestigators bring and integrate unique expertise from their respective academic disciplines. Because the neuroscience of music investigates several dimensions of the human experience simultaneously, many intellectual and experiential perspectives need to be engaged to ask and answer its central questions.

The most valuable studies from a clinical perspective are those that gather new longitudinal clinical, neuropsychological, functional, neuroanatomic, and physiological data to advance the understanding of the neurobiology of music. Analysis and interpretation of findings from such efforts are essential to be able to drill down, reach and understand bedrock principles. Moving forward from bedrock, and often in parallel with finding it, brain-based music studies that develop efficacious interventions without deleterious side effects are also required. Testing novel, brain-based musical interventions within carefully designed and executed sci- entific frameworks is critical for true progress. All too often, one reads a report whose premise and conclusions have not included any inductive empirical investigation. Studies that are poorly planned and executed and have ineffective data analysis do not reflect favorably on the field. A valuable study is one that derives valid and reliable quantitative measures induced by parametric changes to auditory stimuli that are correlated with clinical symptoms. The development and testing of interventions must be evidence-based.

In the remainder of this section, we describe specific and necessary the design and methodological components of a valuable study that seeks to understand the brain-basis of music experience, how it interacts with clinical features of a disorder, develops an intervention targeting an impairing feature of the disorder, and conducts a clinical trial to test the intervention.

A study is "cross-sectional" if no repeated measurements on the same subject are collected. Otherwise the study is "longitudinal": over time (a "prospective" study), or space (for example, a brain imaging study at one point in time), or both time and space (follow-up brain imaging studies with the same subjects). Combinations of longitudinal and cross- sectional measurements in large-sample, population-based studies are becoming more useful and common. It is obvious that the only way to study individual change over time is to conduct a longitudinal study. Some researchers, however, attempt to draw conclusions about individual change over time from cross-sectional studies, a questionable approach. Small-sample randomized, controlled and prospective longitudinal clinical trials for the evaluation of auditory=musical interventions followed by larger, multisite trials are requisite. Such trials do not necessarily need to adhere to the phases of pharmaceutical trials because they are typically of very low risk to the participants.

It is advisable to test only one or two well-articulated a priori hypotheses. Sub-hypotheses may be required to test a main hypothesis, but these should be kept at a minimum. It is far more important to test one or two specific questions than to investigate many conjectures loosely defined and not able to be tested by empirical observation. Exploratory analyses without a priori testable hypotheses are of course useful, but should not be regarded as conclusive.

When selecting study participants, definitions and criteria for clinical groups and inclu- sion/exclusion must be defined and strictly applied. Other factors beside clinical groupings could masquerade as clinically important group differences. Such extraneous background factors need to be balanced by individual or group matching. For instance, imbalanced group differences in measures of intelligence or stage of development could give rise to differences in brain responses to musical stimuli that appear, falsely, to be due to the trial intervention when, in actuality, there is no clinically important difference between them. It is very important to do all that is possible to "neutralize" the groups with respect to everything except the intervention being evaluated. The basic principle of matching on exogenous factors is easily understood yet difficult to achieve in some contexts. When testing a novel intervention, subjects with the disorder in question should be randomized to intervention/no intervention groups. Randomization can be done in matched pairs or in blocks of participants balanced with respect to exogenous factors. To reach bedrock, from which to examine potentially significant intervention effects, there should also be a randomized group of typical individuals without the disorder who do and do not receive the trial intervention whenever possible.

All subjects, regardless of group, should have the same number, mode, and duration of contacts with research staff. This will help minimize any "contact bias" that could interfere with the measurement of intervention effects, if any. In addition, participants should be asked if they have received conventional or alternative medical treatments other than the inter- vention in question, such as changes in medications, for these could also affect measured outcomes. Changes in life situation can also obfuscate intervention differences. If any of these exist, they need to be taken into account in subsequent data analysis. In some cases, such subjects will need to be replaced by new ones, but only when absolutely necessary. The researcher should also attempt to minimize the likelihood of needs for additional interven- tions by selecting only clinically stable subjects.

Important tradeoffs need to be made when choosing musical probes. The key choice between atomistic and ecologically valid stimuli, or a combination of the two, of course depends on the specific question(s) being asked. The stimuli of choice should be presented in exactly the same way to all participants and without deviation from this intention. All stimuli should be equalized with respect to their spectrotemporal content without sacrificing essential auditory or musical nuances whenever possible.

In many if not all in vivo brain-based music studies, repetition and averaging are essential in experimental design and analysis to identity signal structure above numerous sources of "noise". In brain imaging, recording devices include EEG, MEG, PET, functional MRI (fMRI), MRS, optical imaging and many other techniques with varying signal-to-noise ratios (SNRs).
For example, in fMRI under static magnetic field strength of 1.5-3 Tesla, the SNR is typically in the order of only 2-4%. Repetition of the same stimulus under the same conditions enables the researcher to improve SNR by signal averaging beyond what averaging is already performed in the scan sequences. Roughly speaking, with signal averaging the magnitude of extraneous variability in a single brain response that can be attributed to random "noise" is reduced in direct proportion to the number of signal averages.

There are more aspects of effective studies that could be outlined; yet these are perhaps among the most important. The preceding guidelines draw from the principles of experimental design that are widely available in the literature. The accessibility of this material, however, varies widely and depends strongly on the previous background of the researcher. If the reader is unfamiliar with these concepts, or finds them hard to grasp without taking an inordinate amount of time or effort, he or she can find an individual or a written description that speaks intelligibly to learn and apply them successfully.

On a par with the proper design and conduct of a music-brain-behavior study, performing a high-quality, principled analysis of its resulting data is also critical. Experimental data need to be recorded blindly and reported objectively in their entirety. If data are not reported, the researcher is obligated to state this and say why. Objective data analysis that employs state-of- the-art mathematical and biostatistical methods will reveal hypothesized group differences when they exist, have a low chance of missing them, and claim significant differences when there are none only occasionally.

Longitudinal mixed effects models. Mixed effects models are among the most appropriate statistical approaches for the analysis of longitudinal studies (Lange 2003). These models employ "fixed" and "random" effects; hence "mixed models". Fixed effects are unknown effects of covariates on the trial outcome, and are included in the linear and nonlinear regression models employed in much of our research. Individual random effects, however, are unobserved random variables introduced to capture the effects of unmeasured covariates on the trial outcome(s). Mixed effects models often provide more precise estimates of fixed effect than simpler linear models, employ hierarchical empirical Bayes techniques (Efron and Morris 1977), and can be much more general than those presently encoded, for instance, in the SPM software package for image analysis. These models should be informed by previous results through extensive literature review and by existing or novel theory whenever possible. For selection of a best-fitting model given observed data, the Akaike Information Criterion (AIC) or the Bayesian Information Criterion (BIC) should be applied to yield a best-fitting yet simple model that includes the most important factors in the study design, does not leave any out, and does not include unimportant factors. In this way, the selected model resolves the ubiquitous bias-variance tradeoff in scientific research. Deviation from these statistical principles can lead to highly misleading and inaccurate interpretations and conclusions. Corrections for test multiplicity, such as taking many looks at the data in multiple post- hoc subgroup analyses, need to be performed. Corrections of *p*-values that account for correlated outcomes and minimize false discovery rate should also be applied when appro- priate. Model simplicity coupled with clinical interpretability is to be maintained as the highest priority.

What is an "interaction"? In a model containing two factors, a (first-order) interaction is an effect on the trial outcome of a third factor defined as the product of the two factors. For instance, the interaction between a grouping factor (Control ¼ 0, Autism ¼ 1) and a treatment factor (No Music ¼ 0, Music ¼ 1) is the effect of the product of the grouping factor and the treatment factor: (No Music, Control) ¼ 0, (No Music, Autism) ¼ 0, (Music, Control) ¼ 0, (Music, Autism) ¼ 1. It is not a problem that some of these values of the third factor are identical for different factor combinations as long as the factors themselves are included in the model. The multiplication of factors to form an interaction extends to cases when one of them is "discrete", as in the example, and one is "continuous" (such as height or weight measurements), or both are continuous. As in individual or group matching, this is a simple concept but sometimes not applied in practice. For instance, suppose one reads a peer- reviewed report claiming that, relative to people without autism, people with autism behave differently after exposure to an auditory regimen than do people with autism without the intervention. This is a claim for the significance of an interaction on the trial outcome. To substantiate this claim, however, one should determine whether the main effects of the grouping and treatment factors have been taken into account in the model. Too often one finds that they have not been included. This omission can falsely inflate the effect of the interaction and can lead to false and misleading interpretations of study data.

Autism was first described in a classic paper by Leo Kanner (1943). His seminal paper should be read by anyone seeking to understand the life stories of children with the dis- order. Autism is a common disorder occurring in 13 per 10,000 children that usually causes severe lifelong impairment (Fombonne 2005). Autism spectrum disorders (ASDs) are characterized by impairments in social and communication skills and impairing repetitive and stereotypical behaviors. Despite advances in research, educational, and pharmacological interventions, outcome in adulthood has not improved significantly over the past 30 years, even for the half of individuals with autism who function cognitively at high levels (Howlin et al. 2004, Billstedt et al. 2005). ASDs are considered to be among the most genetically based neurodevelopmental disorders (Bailey et al. 1995). Although many impairments in the ASDs are "hard-wired" in the brain, at least some of these and others can likely be changed (Faja et al. 2008).

Brain-based music research in autism provides a novel means by which to attempt to change some of its impairing features. When given a choice, individuals with autism may have an innate preference for musical over verbal stimuli (Blackstock 1978). Children with autism tend to spend more time with musical stimuli than typically developing children (Thaut 1987). Many individuals with autism are able to produce musical constructions and enjoy music (Thaut 1988, Heaton et al. 1999). This suggests that music-based interventions may be particularly appealing to individuals with autism. The neuroscience of music in autism is in its infancy. Most of the work to date has focused on pitch perception in children. Recent advances in music research, however, allow this powerful, unique human sensory experience to enter the center stage of autism brain and intervention research.

The current director of the US National Institute for Mental Health (NIMH) recently emphasized the pressing need to re-focus current autism research towards interventions that fill enormous gaps in current health care. Research goals in autism need to develop interventions in the daily lives of people with autism whose effects can be quantified and are individually and socially beneficial. He suggested a short-term objective to employ 40% more adults with autism by 2012 and a long-term objective to employ 50% more by 2015 and encouraged research scientists to take novel interdisciplinary approaches to meet this and other compelling needs. Brain-based music research should seek to use the powerful unique human sensory experience of music to engage people with autism to decrease its impairing features so that they can become higher functioning individuals and members of society.

During the past 20 years, most research in autism has focused on the general aspects of the disorder, such as social reciprocity, language, and the heterogeneous domain of stereotyped and repetitive behaviors and interests (SRBI). In regard to SRBI, neuropsychological studies have focused on determining if they are related to deficits in executive function and central coherence. Neuroimaging has found an association between the striatum and the SRBI domain that has been replicated in multiple independent samples in both children and adults with autism. Volumes of the caudate nucleus are enlarged, particularly on the right. This laterality remains after correction for total brain volume and is a reversal of the typical left- dominant volumetric asymmetry in the caudate nucleus. Obsessive-compulsive tendencies in autism are correlated with levels of metabolites such as N-acetylaspartate in the frontal lobe. Atypical fMRI activation has been observed in the rostral anterior cingulate cortex and magnetic resonance diffusion tensor imaging has demonstrated decreased fractional anisot- ropy in the underlying white matter of people with autism. Both these disturbances have been shown to be related to the SRBI.

The left hemisphere of the brain is specialized for processing temporal variations, and the right hemisphere is specialized for processing pitch, prosodic, and melodic variations, in both music and language (Zatorre and Belin 2001, Limb et al. 2006). Syntax and semantics in music are processed in the same brain regions that process syntax and semantics in language (Maess et al. 2001, Koelsch et al. 2004). Some researchers believe that music and language networks share common components yet are separable. But this conjecture has not yet been demon- strated The neural experience of music and changes in music seem to be related to basic mechanisms involved in survival behavior. Music processing activates primitive neural systems involved in affective response (reviewed in Limb et al. 2006). Some of the brain regions involved in rhythm in music, such as the striatum, orbitofrontal cortex, cingulate gyrus (Geiser et al. 2008), medial temporal lobe and basal ganglia (Grahn and Brett 2005) including the amygdala and putamen (Grahn and Brett 2007) are those implicated in stereotyped repetitive motor mannerisms in autism. Preliminary evidence suggests that the primitive novelty detection network that is critical in adaptive survival is impaired in autism. Although some children with autism may have relatively preserved and sometimes superior ability in detection of change in simple aspects of pitch in music (Heaton 2003, Heaton 2005, Jarvinen- Pasley and Heaton 2007, Heaton et al. 2008), this advantage is lost when complex, higher-level aspects of music are processed (Mottron et al. 2000, Heaton et al. 2007), such as those present in ecologically valid music. This finding is consistent with complex information processing and disconnectivity theories of autism (Minshew et al. 2002, Just et al. 2004, Geschwind and Levitt 2007). More studies of brain-behavioral responses to salient change in ecologically valid music that attempt to mirror abnormal brain-behavior responses to change in everyday life in autism are needed. Their findings will also be of immense value in understanding the central issues of music perception and cognition.

Images were acquired on Siemens 3 Tesla Trio scanner. Subject monitoring has performed throughout acquisition by real-time eye tracking using an infrared camera (Avotec, Inc.) mounted on 12-channel head coil (Siemens). The scanning protocol consisted of 1 mm isotropic MPRAGE acquisition for the neuroanatomic template. A field map sequence was acquired for offline distortion and magnetic inhomogeneity correction. BOLD echo-planar images (TR ¼ 2 s, TE ¼ 28 ms, GRAPPA parallel acquisition with acceleration factor ¼ 2, 33 slices at 3 mm slice thickness) were obtained in response to musical stimuli as well as for 10 minutes in resting state: eyes closed, subjects instructed to remain awake but relaxed and let thoughts pass through their mind without focusing on any one idea. A sparse temporal sampling design was considered initially but we choose to employ continuous equal-TR sampling with fiber optic headphones with maximum machine noise suppression (but not noise cancellation) and extra noise suppression earplugs. Prospective motion correction was performed for all BOLD images with a PACE sequence. Initial offline statistical post-processing analysis was performed in Matlab (Mathworks R2007a) using SPM5 software (Wellcome Trust) with MarsBar toolbox extension (Brett et al. 2002). All images were motion- corrected using a realign and unwarp procedure. BOLD images were coregistered to the MPRAGE sequence. Two subjects were not included due to poor image quality.

Figure 1, displayed in radiological convention (left is right and right is left), depicts a possible functional relationship between right-sided activation of the lateral premotor area (LPM) and left-sided amygdala in autism during speaking trials that is not seen in the typically developing brain. With controls as baseline, participants with autism showed definite activation (t ¼ 3.5, $p < 0.005$, uncorrected) of right LPM concurrent with an equally signifi- cant left-sided amygdalar activation while listening to changes in speech rhythm, prosody and semantic content. These differences in activity suggest more disruption in the autism group's attempts to deal with unexpected auditory disturbances including assigning emotional valence to these signals. Brain responses to these changes in speech vs. music also differ between autism and control groups. A larger and more tightly focused follow-up study has been completed and will be reported elsewhere.

The many challenges of clinical brain-based music research are met and overcome by asking critical, difficult questions that stretch conventional understanding of music and the brain. These inquiries are to be answered by coupling them with creative scientific thinking and innovative empirical-inductive observation. New ways of thinking about music and the brain demand new modes of experimental design. For novel studies to achieve their goals, however, they are required to respect and apply many of the long-standing and highly effective principles of scientific methods. We have not yet understood the bedrock. Adherence to scientific principles does not limit new explorations. It energizes them and greatly increases their effectiveness and long-term value. The adoption of important scientific principles includes the careful selection of subjects; individual and group matching on extraneous factors that could otherwise appear, falsely, to be the evidence of intervention effectiveness; specific definition of the hypotheses to be tested; removal of potential biases due to unequal contacts with research staff; accounting for other medical treatments and life changes that could also appear as significant differences due to the trial intervention; deriving a clear correspondence between the question(s) being asked and the chosen auditory stimuli; inclusion of many repetitions of identical stimuli presented identically to all subjects; and conducting principled analyses of study data with the best mathematical and statistical methods available. Increasing the number of well-designed studies that are grounded in the neurobiology of music will enable us to reach our City Upon a Hill. As pointed out by John Winthrop over four and one-half centuries ago, "… the eyes of all people are upon us…". Acceptance of music neuroscience discoveries by the larger scientific and medical community and application of the knowledge gained to the development of effective interventions depend critically on the quality of the research we do.

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Chapter 11

The rhythm of the heart – the tempus of music Mozart, Ligeti and the Rat

Almost all physiological functions of living organisms, including man, are characterised by regular circadian variations (Aschoff 1963, Reinberg and Smolensky 1983, Lemmer 1989, 2004). Descriptions of rhythmical biological processes were reported already 300 years ago, so we cannot regard this area of study as a recently discovered one. However, today there is scientific evidence available which confirms the existence of 'biologic clocks' governing the circadian=biological rhythms down to the level of molecular biology. So-called 'clock genes' have been discovered in almost all cells, whereby the 'master clock' is situated in the core area of the nucleus suprachiasmaticus (SCN) in the brain. A rhythm of this kind is referred to as 'circadian' (circa, dies, i.e. approximately one day) if it is maintained by an inner mechanism even in the absence of external time cues, for instance, during a period of permanent darkness.

However, the term is generally used in a wider sense as well, simply denoting a 24-hour rhythm. Circadian rhythms can be demonstrated to exist for systematic functions (blood pressure, pulse, organ functions, mental processes, etc.) down to the levels of hormonal activity, receptors and signal transduction processes between and within cells, enzyme kinetics and gene regulation. Man, too, is an organism whose functions are completely organised according to chronobiological patterns. Pathophysiological events such as heart attacks, angina pectoris, strokes, asthma attacks, allergic reactions, rheumatic complaints, gastroin- testinal ulcers and so forth do not occur at random the 24 hours of the day, but rather take place according to a prominent circadian rhythm (Lemmer 1989, 2004). As early as 1846, Casper published comprehensive tables which demonstrated that not only the beginning of people's lives ("most births occur between the hours of 9 o'clock in the evening and 6 o'clock in the morning"), but also their termination ("the highest rate of mortality is concentrated in the hours of the morning") are subject to a circadian rhythm.

Many interrelationships exist between rhythms in biological systems and music (Lemmer 2002). Centuries ago such relationships were described by J. Struthius [1510-1568]. Struthius even went so far as to equate the various rhythms of the pulse which can be observed in the human body to the annotation of musical notes (Fig. 1). This article is concerned with both historical aspects of this relationship and an experimental investigation performed on normotensive and hypertensive rats. In these experiments on healthy rats as well as ones with high blood pressure, we were able to show that music by Mozart (Symphony No. 40) and Ligeti (String Quartet No. 2) has an effect on blood pressure and heart rate as well as their daily rhythmic patterns in very different ways. Our lives are governed by rhythms from birth until death – and music exercises and influence on these rhythms.

11.1. Chronobiology and chronopharmacology of the cardiovascular system

During the Age of Enlightenment, scientific activity was not limited to posing questions relating to natural phenomena, to exact observation and to careful recording of the results, but the savants of the day pondered as well over the types of mechanism which may underlie these phenomena. For the first time, the idea was promulgated that health or lack of it in living organisms – whether animal, vegetable or human – must be dictated by parameters which are subject to objective measurement (Lemmer 2004a, b). One of the first modern physiologists who embraced the experimental approach was Sanctorius Sanctorius [1561-1636], a professor at the University of Padua. It was he who introduced measurement and numerical assessment into the world of physiology so as to be able to describe functions and the manner of their progression (Sanctorius 1631).

In this day and age it is easy to forget that at that time the technical means to take such measurements, e.g. to measure the pulse and its rate, were severely limited. Thus, Sanctorius himself invented the *pulsilogium*, a measuring device with an adjustable pendulum (see Fig. 2), which was designed to allow for the measurement of the pulse rate on a given day during the course of an illness or at a certain time of day.

Around 200 years ago the physician Christoph Wilhelm Hufeland published a book entitled "*Die Kunst das menschliche Leben zu verlängern*" (The Art of Increasing the Length of Human Life) (Hufeland 1797) in which he wrote: "The 24-hour period which the regular rotation of our Earth imparts to all of its inhabitants as well, is especially to be observed in the physical economy of man. This regular period is expressed in all illnesses, and also all other such marvellously exact cycles of our physical existence are originally determined by this single 24-hourly period" (Fig. 3).

We now have well-documented evidence confirming that practically all functions of the cardiovascular system such as blood pressure, heart rate, stroke volume, circulation and peripheral resistance as well as ECG parameters are subject to a circadian rhythm (Lemmer 2004b, 2006). Both humoral and neural mechanisms contribute to this. Therefore, it is not surprising that the symptoms of cardiovascular diseases also display a marked circadian rhythm, whereby in the case of cardiovascular pathophysiological events the part directly governed by the 'internal clock' remains asyet unclear. A characteristic feature of coronaryspastic anginapectoris attacks displaying the accompanying ECG responses such as anincrease in the ST segment is that theyare more frequent in the early morning between four and six o'clock. Stable exertion anginas, on the contrary, with an ST-segment depression are observed more often during the day because they are associated with diminished coronary reserves and are triggered by physical exertion. The greater incidence of myocardial in farctions and cases of sudden cardiac death during the morning hours between eight and twelve o'clock is well documented (Muller et al. 1985, Lemmer and Portaluppi 1997). The same applies to the increased frequency of ischemicstrokes within the same time window. In contrast, brain strokes without embolisms occur most often around 3 o'clock at night (Manfredini et al. 1997). From the haemodynamic point of view the raising of the blood pressure and the increased heart rate as well as the significantly accelerated myocardial oxygen consumption all play a role affecting the frequency of cardiac events in the morning hours.

Similarly, it has been known for a long time that disease of the heart is not distributed uniformly over the day, but occurs more often at certain times of day. Thus the Italian doctor Anton Joseph Testa reported – as far as can be determined for the very first time – that in Heberden's disease angina pectoris symptoms tend to occur most frequently in the early hours of the morning.

With the introduction of ambulant long-term ECG measurements, it became possible to perform systematic investigation of the 24-hour rhythms of myocardial ischemias. A large number of studies have revealed that asymptomatic and symptomatic angina pectoris attacks occur more often during the day than during the night, but in contrast coronary-spastic angina pectoris attacks (so-called Prinzmetal's angina pectoris attacks) are more frequent at night.

Most of the studies documented a dominant peak during the morning, and in some of them an additional small peak in the late afternoon was observed as well. Possible causes are to be found in a reduced supply of oxygen or, alternatively, an increased demand at these times. There is indeed evidence to show that the resistance of both peripheral and coronary vessels is higher in the early morning than at other times.

In addition to the changes in the vascular tone there is an increase in the cardiac load because both blood pressure and heart rate rise, leading to an increase in the oxygen demand of the myocardium. The increased cardiac load during the morning hours is based, in addition, on the activation of the adrenergic nervous system. The activation of the sympathetic nerve activity is often seen as being directly linked to the process of awakening and getting up. However, studies show that the plasma concentration of norepinephrine begins to increase even before getting up (see Lemmer 2004a, b).

Heart attacks happen more often in the early hours of the morning than at other times of day, as has been demonstrated in numerous studies (see Lemmer und Portaluppi 1997, Lemmer 2004a, b). In view of the fact that in most cases a rupture of atherosclerotic plaque is generally associated with a consecutive thrombotic vascular obstruction, on the one hand changes in various coagulation parameters play an important role; on the other hand so do factors which promote plaque rupture (Willich und Muller 1996).

Here, too, we may refer to historical findings, which date back to over 300 years ago, especially in respect of the heart rate (see above). As early as the time of the Enlightenment exact observation and description of the functions of the coronary circulation system revealed a marked regularity of these bodily functions (Lemmer 2004, 2006). Since the introduction of 24-hour ambulant blood pressure measurement devices (ABPM), this has become common knowledge in the medical world. In addition to the more exact registration of the blood pressure, the ABPM also enables us to assess its daily variations (Middeke 2006). Thus, the distinction made between the conditions 'dipper' (i.e. with a fall in blood pressure during the night of more than 10-15%) and 'non-dipper' (lack of or insufficient fall in blood pressure), 'super-dipper' (with a greater reduction in blood pressure) and 'riser' (with a nightly increase in blood pressure), which now forms a part of normal clinical practice, is only possible on the basis of long-term ABPM measurements.

To date, the circadian central regulation of the blood pressure rhythm has not been investigated thoroughly in humans. However, there remains no doubt that the mechanisms, which have already been proved to exist in rats, for instance such as the SCN with its significance in respect of the rhythm generation (Witte et al. 1998), also play a role in the human organism. This view is supported by findings related to a rare disease known as fatal familial insomnia. In this illness, in which the central nervous system is subjected to a prion disease, the internal clock is destroyed, leading to the loss of circadian rhythms (Portaluppi et al. 1994). The disease develops in advanced manner and results in the patient's death. It was possible to demonstrate that patients suffered at first from massive disturbances to not only readily verifiable endogenous rhythms – sleeping=waking cycles, temperature cycles – but also the 24-hour rhythm of blood pressure and catecholamines, culminating in their complete disappearance prior to death. These findings do not represent actual proof that the human blood pressure rhythm is endogenous, i.e. directly linked with the internal clock, but it does show that central regulatory mechanisms of rhythms of the central nervous system play a decisive role.

Clinical studies on normotensive and hypertensive patients who were obliged to remain in bed for 24 hours per day showed that even here the 24-hour blood pressure profile with a nightly reduction remained the same. Finally, studies on healthy test persons who agreed to abide by a 'constant routine' (36 hours in constant bodily position, no sleep, constant supply of nutrients and liquids, etc.) indicated that the heart rate pattern is more strongly affected by endogenous influences than that of the blood pressure (Kräuchi und Wirz-Justice 1994). It should be borne in mind, however, that these results were obtained from observations of a completely artificial test situation, which was also not without stress potential.

For many years now the so-called 'Mozart effect' has been the subject of speculation and experiment in respect of both animals and humans. This Mozart effect was the centre of attention during the congress 'Mozart & Science' which was held in Baden near Vienna in 2006 and of which the papers given have been collated in this volume. For this reason no further literature references will be provided in this connection.

In the 'Mozart year' of 2006 we posed the question as to what effect the essential music of Mozart may have on an organism which has never previously heard the music and never had contact with its composer. To this end we chose the rat (Lemmer and Abu-Taha 2006) (Fig. 5), something of a favourite species in experimental research.

In order to collect physiological parameters of the cardiovascular system in rats a radio- telemetry device (Data Sciences, St. Paul, USA) was used (Fig. 6) which allows for continuous data registration without restraint, without a stress reaction in freely moving animals (Lemmer et al. 1993). The system can record the systolic (SBP) and diastolic (DBP) blood pressure values, heart rate (HR) and motoric activity (MA). The system used consists of a transmitter implanted in the rat's abdominal aorta, a receiver, a multiplexer and a computer for storing and processing the data. To ensure that the data can reliably be associated with the correct animal, they must be kept in individual cages.

The experiments were conducted on male normotensive Wistar-Kyoto rats (WKY) and spontaneously hypertensive rats (SHR). The animals were kept under standardised environ- mental conditions: The room temperature was maintained at 23°C ± 1°C. The animals were given normal tap water and unrestricted access to standard feed for rats and mice (Altromin, Lage-Lippe). The lighting conditions consisted of synchronised light=dark phases (LD 12:12), with the lighting being switched on at 7.00 h and off at 19.00 h at an intensity level of 100 lux. It should be borne in mind that in contrast to humans, rats are nocturnal animals. They were kept in individual cages, whereby several cages were placed in an isolated chamber in which the music was played via loudspeakers. The effects of the music were calculated according to the significance in relation to control values obtained from the same animals, so-called AUC-24 hours values (Area Under the Curve over 24-hour values).

In view of the possibility that music or a sound level around 75 dB could cause a stress reaction in rats, a stress model was used to investigate the rats' blood pressure and heart rate profiles telemetrically. To this end the rats were moved individually from one cage to another which had previously housed another rat (so-called 'cage switch'), whereby SBP, DBP, HR and MA were registered without and then with these stress conditions. As Fig. 7 shows, the resulting stress reaction produced a massive and immediate increase in HR and in SBP and DBP both in the healthy WKY rats as well as in the hypertensive SHR rats. This reaction continued for about 60 minutes, whereby the effect was stronger amongst the WKY rats. It can be seen as a stress related reaction of the sympathetic nervous system.

After a wash-out period of some days in which the animals lived under the normal control conditions each animal was subjected to a two hour period in which music was played. The music started at the beginning of the rest period, i.e. after the lighting was switched on. The music consisted either of Mozart's Symphony No. 40 or Ligeti's String Quartet No. 2, each played at around 75 dB. The telemetric data was recorded again. Ligeti's work was used to represent so-called contrast music in respect of Mozart.

As shown in Fig. 8, under the control condition of no music the nocturnal rats (both SHR and WKY) displayed a significant circadian rhythm in HR and BP, with lower values in the rest period during the day and raised values during the nocturnal period of activity, confirming results which we had already described previously (Lemmer et al. 1993, Lemmer 2006) which revealed a phase shift in comparison with the profiles obtained for day-active humans (see Lemmer 1996).

Mozart's music had only a slight reducing effect on the heart rate of the SHR rats, and the blood pressure remained unaffected (Fig. 7). The normotensive WKY rats showed no reaction at all. Ligeti's String Quartet No. 2, on the contrary, caused a massive increase in SBP of around 20-30 mmHg in the SHR rats which remained discernable over 24 hours (Fig. 9). The WKY rats also reacted to Ligeti's music with a raised SBP.

In the SHR rats, the HR was reduced by about 40 beats=minute up to 6 hours after the period of music exposure was terminated. The MA for both rat strains was influenced by neither Mozart nor Ligeti.

It is worth noting that exposing the rats to 'white noise' – i.e. random background noise – using the same experimental framework and also at 75 dB produced no reaction in respect of any of the registered parameters, neither in the WKY nor in the SHR rats.

There remains no doubt that the sympathetic nervous system plays a major role not only in regulating blood pressure and its rhythmical patterns, but also in respect of the emotional household. Any kind of stress reaction can lead to the activation of the sympathetic nerve, with an increase in both the heart rate and blood pressure and accompanied by increased cardiovascular risk. This applies to humans, but also to rats, as the findings presented here confirm. Equally beyond doubt is the fact that music can influence the emotions (see elsewhere in this volume). The present study yields the significant discovery that the kind of stress reaction that we were able to induce in the rats by means of the cage switch was NOT precipitated by the music of neither Mozart nor Ligeti, neither in the normotensive nor in the hypertensive rats.
Mozart's music even led to a slight reduction in the heart rate, which in turn reduces the heart-minute-volume where the blood pressure remains unchanged, thus easing the load on the circulation system. But even Ligeti's music caused no stress reaction, for although the blood pressure increased greatly, in contrast to the stress reaction, this was accompanied by a relative reduction in the heart rate. The long-lasting effects are also worthy of note. What may be the causes of the effects on the cardiovascular system in rats which were observed for the two pieces of music? The supplementary investigation of the effects on the rats of white noise at the same volume of 75 dB suggests that we are dealing with a differentiated reaction here. We suspect that both rhythm and tonality must be present to cause an effect. In 2001, Bernardi et al. were able to show that saying the rosary or chanting a mantra also has a reducing effect on blood pressure (whilst at the same time synchronising and reducing the respiration frequency). Referring to this interesting result, we may dare to suggest that Mozart's music – in this case the Symphony No. 40 – has an effect on the cardiovascular system which is similar to that of meditative practice.

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Chapter 12

Music and child neurology: a developmental perspective

The development of a sound environment starts as early as in utero, as was demonstrated by the work of Lecanuet (Kisilevski et al. 2004) who showed that fetuses could modulate their behavior in response to musical stimulation, according to their gestational age, displaying more processing abilities in fetuses older than 33-35 weeks of gestation. However, given all the limitations in these studies, due to the acoustic properties of the media around the fetus, a word of caution must be mentioned as to the specificity of musical stimulation in causing these reactions. Minna Huotilainen and colleagues (Huotilainen et al. 2005) demonstrated that fetuses are indeed capable of frequency discrimination as recorded with Magnetoencephalography (MEG), a recording technique that combines optimal time- resolution with non-invasiveness.

In the first months of life, infants are exposed to a complex sound environment, reflecting infant-directed speech and harmony and rhythms in music that are strongly culture dependent.

At 6-7 months of age, infants can combine frequencies into a single percept, be it a tone or a phoneme (Clarkson et al. 1988). Furthermore, children learn to prefer music that i ecologically valid for their experience, and this preference is tuned around 6-7 months of age (Volkova et al. 2006). When being exposed to different frequencies, children learn to recognize them within a relative framework, that is, comparing pitches and relating them, rather than categorizing them in absolute terms. A limited number of individuals (about 1-5=10,000) can instead name pitches by their label even without a reference tone (for a reference see Levitin and Rogers 2005). Absolute pitch has first been attributed to an effect of learning, which does not, however, explain why all children who are exposed to early training do not develop this trait. This ability seems to be more widespread in an early stage of development, when children are first exposed to changing pitches, and, according to Trehub (2001), it is a necessary phase of development followed by a more economical way to group percepts. Usually language, speech and music rely more on relative rather than absolute cues, so children learn to understand speech regardless of who is talking and songs regardless of who is singing. Laurel Trainor described the "maturational switch" that all children make from absolute (local features) to relative (global features) processing (Trainor 2005).

The demonstrated heritability of the absolute pitch trait has elicited an impressive amount of research in genetics (Baharloo et al. 2000, Zatorre 2003) and has lead to the opinion that in order for absolute pitch to develop in a measurable way, this trait must be "nurtured" in childhood within the first 6 years of life and would be the result of an interaction between genes and experience.

Normally developing children will display an increase in abilities to discriminate and chunk their sound environment probably on the basis of the statistical properties of both speech and language (Saffran 2003). Children as young as 8 months can infer language patterns from two basic cues: visual and auditory. According to Saffran, children at 6-8 months of age would be able to detect repetitive patterns within a continuous stream of sounds, then categorize them on their probability to be followed or preceded by another pattern, and finally use this information to infer words=sounds and interval position within the stream. The term Motherese defines precisely the infant-directed speech in its basic features. It has exaggerated vowel frequencies, it is usually one tone higher than adult-directed speech, has relatively simple grammatical structure, and the salient parts are repeated and are always at the same position in the sentence. The visual cue gives the neonate a particular information on how to articulate sounds and where a salience is to be found in a particular utterance. The discovery of the mirror neurons could probably better explain how these connections are made (Westermann and Reck Miranda 2004).

There are some principles to keep in mind. While neuronal proliferation is almost complete by 36 weeks of gestation, neuronal growth, dendritic proliferation and synaptogenesis are responsible for most of the brain growth from the 3rd trimester of pregnancy into childhood, considering that, by 2 years of age, the brain has reached the 80% of its final weight, which is achieved by 18 years of age. The next developmental process that greatly contributes to brain growth and maturation is myelination. Myelination begins early in the 3rd trimester with the most rapid period of myelination occurring in the first two years of life. The myelination process follows a specific time course and pattern. The acquisition of neurodevelopmental milestones parallels and reflects this pattern. Myelination occurs early for motor-sensory roots, special senses and the brainstem; those structures necessary for reflex behavior and survival.

The corticospinal tract starts to myelinate at 36 weeks of gestation and myelination is completed by the end of the 2nd year of life. Myelination of the corticospinal tract begins at the proximal portion of the axon and the shortest axons are the first to myelinate. The axons for the upper extremities and the trunk myelinate next. The axons for the lower extremities, which are the longest axons, are the last to myelinate with the process being completed by 24 months of age. This myelination pattern correlates with the progressive head-to-toe acquisition of developmental milestones.

The motor patterns of the immature brain are predominately under brainstem control and lack cortical modulation until there is the necessary maturation of these higher brain center connections.

The areas of the cerebral hemispheres that are first to myelinate are the posterior portion of the frontal lobes, the parietal lobes and areas of the occipital lobes. The frontal and temporal lobes then myelinate and by the end of the second year, myelination of the cerebrum is largely completed, although there are interconnections of the association cortex that are still being myelinated into the 2nd and 3rd decades of life.

Primitive reflexes such as the Moro, Galant, grasp and plantar reflexes also follow a specific temporal pattern, being evident from birth to 4-6 months when they decrease and disappear to be substituted by postural reflexes, such as the positive support reflex, Landau, lateral propping and parachute. Persistence of primitive reflexes and lack of development of postural ones could indicate upper motor neuron abnormality.

Music has been shown to reduce the effects of environmental stressors in the Neonatal Intensive Care Unit (NICU) or even reduce mild pain perception (Golianu et al. 2007), but this aspect needs further research, with more objective measurements.

The influence of music on developmental milestones relates to language, motor coordina- tion, and cognitive development.

From the research available in the older children, we know that one year of musical training with a method that includes early performance, like the Suzuki method, at the age of 4 to 6 can improve musical abilities, defined by neurophysiological responses to violin tones, as well as non-musical skills, such as digit span (Fujioka et al. 2006) which is the base for the development of other skills such as verbal memory. Also visual spatial skills can be enhanced by musical training (Schellenberg 2004).

Cognitive skills are characterized not only by experience but also by the ability to quickly integrate the incoming stimuli from the environment in a meaningful sequence of events, programs, and actions. The role of an enriched environment is, of course, to generate different stimulations that will enable the child to perform all these operations. The specificity of music in providing an additional advantage to the environment relies mainly on its multimodality. Music can be heard, seen and touched, but also anticipated, and retained. And it can promote motor programs that become more selective as a function of specific training, but can already be observed in young children, just rocking to the beat.

When dealing with the applications of music, there may be a confusion in selecting between therapy and teaching. It is quite obvious that all studies devoted to understanding normal functions and development can rely on proper interactions on behalf of the typically developing child. In this case a more complex set of instructions and rules can be administered, as long as the child in his=her environment is willing to undertake the program. Thus, although attention must be paid to select the appropriate method to teach music, according to objectives and child's age, there is a reasonable assumption as to the total duration of the program, the child's compliance to the instructions, and the reliability of the results.

On the other hand, the term therapy refers to a situation of special need, be it temporary – i.e. undergoing surgery, or during delivery or hospitalization – or not, like in the case of developmental or acquired disability. In these cases, there are many options of intervention, at the bedside, through active playing or through other techniques that refer to various methods or models (for a reference, see Wigram and De Backer 1999). There is a general distinction between receptive music therapy, which relies mainly on listening and processing of the listening experience, and active music therapy, mainly concerned on activation, improvisation, and observation of the patient's sonorous musical production. The need to establish an evaluation of efficacy is becoming prominent in rehabilitation, and it is one of the most interesting pending issues in music therapy. In music therapy the protocols are usually linked more to the state of the child and his=her possibility to participate and interact. A thorough evaluation is performed as to the patient's interaction with the therapist, the musical instruments provided in the setting, the use of his=her voice and the space around him=her.

Given these basic distinctions between therapy and training, there is the possibility to combine the two options, based on the specific aims of intervention. For example, music therapy can be used to help explore one's feelings and emotions, or music training can be used in people with special needs provided some adjustments are made to both instructions and instruments.

One of the most fascinating applications of music is autism. Autistic children are characterized by restricted interests, abnormal social interaction and abnormal communication skills. In this case both music therapy and music training could be useful with the above- mentioned *caveats*. Most of the recent research in autism deals with the hypothesis that autistic children cannot attribute mental states to others and thus understand that others have beliefs, desires, intentions that are different from one's own. The lack of this ability, called Theory of Mind, seems to be the most important limitation in autistic children even when they have quasi-normal cognitive functioning. Music therapy in this case concentrates on the idea of exchanging instruments, and taking turns in playing them, trying to understand the other's intention.

Another important issue is the use of instruments and sounds in the environment. Autistic children tend to utilize objects and to elicit or avoid sounds in a non-conventional way. A musical environment can help in this matter and teach these children that objects have specific uses, functions and meanings. In this sense, music therapy can be a valid support to a cognitive behavioral approach, which is currently recommended as a primary form of intervention in autistic spectrum disorders.

A complete discussion on each possible intervention is beyond the scope of this chapter, so a schematic set of suggestions can be summarized in the following table, keeping in mind that a thorough evaluation of the specific needs of each patient needs to be carried out before proposing an intervention (Table 1).

Music certainly satisfies all criteria to be considered an enriched envinronment. It has intrinsic qualities that can be appreciated at various levels ever since birth and maybe before that. The power of music in healing, comforting, stimulating and inducing emotions is known, and now thanks to the new advances in research it can be studied and characterized so that its applications can become standards in both education and rehabilitation.

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Chapter 13

Prenatal “experience” and the phylogenesis and ontogenesis of music

We may confidently suppose that the fetus does not "experience" anything at all – at least not in the everyday sense. So the word "experience" is a little misleading. More precisely, I will be talking about fetal *perception*, *cognition* and *emotion*, and what these aspects of "experience" might have to do with the origins of music. Moreover, I will consider both the *phylogenetic* aspect (evolutionary developments over many generations) and the *ontogenetic* aspect (individual developments within a single lifespan) of this question.

Other talks from today's program have addressed the aspects of the interaction between music, the body and biology. My presentation will also address this interaction. The theory that I will present can explain why music has bodily and biological functions and implications. It can also explain why music is associated with movement (dance) and personal identity, and why it can evoke strong emotions in spite of its lack of obvious survival value.

First, I would like to address the question of music's definition. What is music? In the literature you can find hundreds of definitions, or attempts at definitions. Every theory of the origins of music must deal with the problem that music is not necessarily a clearly defined concept. How can you explain the origin of something that does not exist? Ethnomusicol- ogists, who are well aware of this problem, talk about "music" as if they know what it is, without necessarily saying what they assume it to be. After all, many cultures have no umbrella term for music – instead, they talk about specific musical activities such as singing and dancing, or the ritual meanings and functions of such activities. The reason why ethnomu- sicologists avoid defining music is that every definition of music implies the existence of musical properties that are common to *all* forms of music. In other words: musical *universals*. But for decades, ethnomusicologists have worked on the assumption that there is no such thing as a musical universal. While the ethnological approach has emphasized the diversity of world musics and made us more aware of the arbitrariness and arrogance of Western culture, it may also be inherently contradictory, because if music cannot be defined, musicology has no object of study.

When we talk about music in the West – and any such discourse must by definition be ethnocentric – we assume that "music" is something like the following. Music is primarily an *acoustical* signal – something that we can hear. But music also implies physical *movement*: in most cultures, movement is an essential and intrinsic aspect of all musical behaviour. Music evokes recognizable *patterns* of sound and movement that can be reproduced, repeated and varied; music perception thus involves the perception and cognition of sonic organization. Music is a *social* phenomenon: it is the product of interactions between members of a group and as such tends to unify the group and strengthen its identity, and hence the identity of its members. Related to this point, music is *meaningful*: people are motivated to engage in musical activities because of its specific cultural, social, and hence also personal meanings. Music is *intentional*: people engage in musical activities deliberately, and they intend with their music to create an emotional effect – to manipulate emotions that are simultaneously felt by different members of a group. Finally, music is generally an *acceptable* form of behaviour in a specific cultural, geographic and temporal context; if a culture has a word for music, the sound patterns only become "music" if they are accepted as such, at least by a definable subculture. Since all of these points may also apply to language, it is important in such a definition to define the difference between music and language. The main or definitive difference is that music is *not lexical*: its meanings are not specifically associated with environmental objects or actions. If someone asks you for directions to the railway station, you cannot help them by playing the violin.

If that is what we mean by "music", the question about music's origins may be rephrased as follows. How and why did that complex combination of features that we now call "music" originally arise? It is a fascinating observation that music exists in all cultures and that different musical styles emerged independently in cultures that were isolated from each other for long periods. Recent research by Isabelle Peretz and others in the cognitive neurosciences has even demonstrated that music has dedicated brain structures, which is presumably the case in all cultures. Researchers interested in the question of music's origins have the task of explaining not only these points but also the social, emotional and religious functions of music that seem to be common to all cultures, as well as the main structural commonalities of most musical styles – even if there are occasional, but important, exceptions to all such "weak universals". For example, musical form often involves thematic repetition and variation (development) as well as call-answer structures. The major second interval, or something close to it, is the most prevalent interval between successive tones in melodies from all over the world. In most music, phrases tend to go up at the beginning and down at the end. The average speed of a rhythmic pulse or of music in a moderate tempo (neither fast nor slow) is around 100 beats per minute (or 600 ms per beat).

For centuries, thinkers and researchers have wondered about the origins of music. Here is a quick list of some of the theories that have been proposed and are still being discussed. One theory is that music is related to mating or flirting behaviour. Just as birds attract each other by means of their colourful feathers and impressive displays, humans (presumably males) may attract other humans (presumably females) by the auditory equivalent of plumage: a musical show. That was Charles Darwin's idea, and many people still take it seriously today. Juan Roederer has suggested that music exists because it trains cognitive and motor abilities. Humans that made more music were more likely to survive because they had better cognitive and motor abilities, so gradually musical behaviours were selected for. Other researchers have considered the importance of music for the survival of groups. Music may hold groups together and thereby enhance their survival in competition with other groups by means of its role in long distance communication or rhythmic working activities. Still others have considered the relationship between music and speech, and the role of imitation.

Of the many theories that are currently being considered in an attempt to explain the origins of music, it is clear that most contain more than a grain of truth. This suggests that music may not have a single origin, just as it does not have a single function. Instead, many different factors may have contributed to its prehistoric emergence.

A problem that is often addressed by theoreticians of the origins of music is the question of whether music is an *adaptation*. Does music really help humans to survive and reproduce, or is it simply a byproduct of other adaptations? This raises a host of unanswered questions. Why is music so strongly emotional and connected with spiritual life? What is the causal relationship between musical structures like rhythm and melody and biological patterns like walking and speech? Did men and women contribute in different ways to the origin of music?

This last question might seem a bit odd. But if you look at discourse within anthropology, or in fact any human discourse, you often find that there is a tendency to assume that "humans" are normally men. Women are implicitly regarded as special or unusual. They are other humans. This sexist bias, which seems to be built into just about every language, culture and research discipline, has also influenced theories of origins of music, not to mention the rest of musicology. The theory I am going to show you today breaks from this time-honoured tradition by putting women in the foreground. It is presumably no coincidence that

women such as Ellen Dissanayake, Diane Mastropieri, Mechthild Papousek, Isabelle Peretz and Sandra Trehub carried out some of the most important research that I cite in support of my theory. More importantly, if the theory is correct, women played a more important role than men in the origins of music itself. In the course of my argument, I will also assume that women play, and have always played, a more important role than men in caring for babies and raising children – especially in the prehistoric period when "music" (as defined) was "emerging".
I certainly do not mean by this to suggest that women *should* be primarily responsible for raising children. On the contrary in a modern post-industrial context, it has become possible and reasonable for men and women to share these tasks equably. But this is another issue.

The theory that I will describe differs from other theories of the origin of music in another way. It attempts to describe what actually happened as music was "emerging". It sets out a specific scenario for the origins of music. I will start at the very beginning, so to speak, by talking about the human fetus and the sounds that it hears ("perceives" – not "experiences") before birth. I will then propose that the fetus learns to associate emotions with the patterns of sound and movement by a process akin to *classical conditioning*, and that the resultant associations play a role in biochemical and behavioural interactions between the fetus and the mother. On that basis, I will talk about interactions between infants and adults (usually mothers) and the relevance of prenatal classical conditioning for that interaction – as well as for recent research on infant sensitivities to musical patterns. I will go on to address the possible role of postnatal *operant* conditioning (i.e. active rather than passive conditioning) in carer-infant interactions (*motherese*), children's *play,* and adult *ritual* – all based on prenatally established associations between sound, movement, and emotion. Finally, I will address the possible mechanisms whereby all of this might be projected into adult life, to become what we know as "music".

First of all: What sounds are available for the fetus to hear? Intrauterine recordings in humans and animals have confirmed that prenatally audible sounds include the mother's vocalizations and breathing, heartbeat, body movements, footfalls and digestion. The interesting point for a theory of the origins of music is that all of these sound patterns depend on the mother's emotional state. Any recording of internal body sounds carries information about whether the person is happy or sad, aroused or not aroused.

The fetus can also hear sounds that are external to the mother's body, but these sounds play no role in the present theory, for several reasons. First, they are considerably quieter for the fetus, and therefore more often inaudible. Second, they are less repetitive, so the fetus is hardly likely to learn to recognize them. Finally, it is hardly likely that their perception could be of any use to the fetus. An ecological psychologist would say that external sound sources do not *afford* anything for the fetus, because it cannot interact with them. An additional important point is that every sound the fetus hears, regardless of whether it originates within or outside the mother's body, is muffled by the passage through human tissue and amniotic fluid: the higher frequencies are inaudible.

We also need to consider the separate question of the fetus's *ability* to hear. A large number of empirical studies have addressed this issue. They leave no doubt that the fetus can perceive sound and motion throughout the third trimester, that is, the last three of the nine months before birth. Since the ability to hear emerges gradually, it is not possible to specify an exact point in time at which this ability begins, but a comparison of various literature sources suggests that this point lies between the 20^{th} and 24^{th} gestational weeks – just after the middle of the 40-week human gestation period. The same applies to the sense of balance and movement: the cochlea and semicircular canals are part of the same structure in the inner ear, which appears to develop as a unit. The perception of balance and movement is of central importance for music, since most music involves or implies movement. The perceptual and cognitive processes of hearing speed up with the myelinization of the auditory pathways, which begins around the end of the second trimester.

Now let us talk about classical conditioning of the fetus. For the purpose of argument I am going to compare the human fetus in the third trimester with Ivan Pavlov's famous dog. The two organisms have the following features in common: both have developed, complex sensory systems, and both lack reflective consciousness. Please do not be insulted by the comparison: of course the human fetus is more important to us than a dog, because it will one day become a human. But in the prenatal period, this human potential has not yet been realized. Besides, this kind of comparison is perfectly normal in the behavioural sciences.

It is important in this kind of theorizing to be aware of our parental instincts and of the possibility that they might cloud our scientific judgment. We perceive babies to be cute and are motivated to protect and nurture them. We can also feel love for a fetus, knowing that it will soon be a baby. As important as such feelings are for human survival and quality of life, we should not let them influence our logical thinking. If a fetus is behaviourally similar to a dog, then so be it.

In Pavlov's classical conditioning paradigm, a dog repeatedly experienced a specific series of events. First, it heard its master's footsteps. Then came some food, and then it salivated. Initially, the salivation was an automatic response to the food. After this series of events was repeated several times, as it often is in real life, the dog learned – implicitly – that the footsteps *predict* the food. It therefore began to salivate on hearing the footsteps, even if no food arrived. This process was automatic in the sense that it happened without any kind of reflective consciousness. The dog did not "know" what it was doing – it just did it.

Since any animal can be classically conditioned, it is no surprise that the human fetus can, too – as several empirical studies have confirmed. In such a study, the fetus might first be presented with some kind of signal such as a vibration, followed by a loud noise to which the fetus reacts by moving – again, a kind of automatic reaction. If this series of events is repeated many times, the fetus "learns" that the signal predicts the loud noise, and begins to react to the signal as if it were the noise.

The interesting question here is what happens to the fetus when the *mother's emotional state changes.* This question is not intended to refer to those special emotional ups and downs that pregnant mothers experience at different times during a pregnancy. Instead, I am referring to the emotional changes that everybody experiences everyday. For example, my emotional state changed when I walked onto the stage to give this talk. If I were a pregnant woman, my unborn child would have shared that emotional change – at least on a biochemical level.

When the emotional state of a pregnant woman changes, and she is in the third trimester, the fetus can pick up a change in the sound patterns created by her voice, her heartbeat and, if the mother is walking, her footsteps. The fetus receives and presumably cognitively processes auditory, tactile and kinaesthetic signals. Shortly after that, it receives a biochemical signal indicative of the same emotional change: emotional states are reflected by hormone levels in the blood. When the biochemical content of the umbilical blood changes, the emotional state of the fetus changes accordingly. The fetus reacts automatically, just as Pavlov's dog salivated when exposed to food.

Now consider what happens if this series of events happens many times, as of course it does during the third trimester. The fetus "learns" to respond to the auditory, tactile and kinaesthetic signals without having to wait for the biochemical signal, which tends to arrive a little later. In this way, it associates patterns of sound and movement with emotions. Might that be a first step toward the emergence of music?

One function of hormones is to help an organism react quickly and effectively to a new environmental situation. The classic example is the fight=flight response. When an organism is surprised by a dangerous situation, hormones allow its muscles to get extra sugar. This must happen quickly enough that it can either get away safely or win a fight. Thus, hormones are associated with emotions such as fear and anger. But the correspondences are not simple or one-to-one, because every biochemical has various functions, both physiological and psychological.

A complete account of physiological emotional communication between mother and fetus must also consider two important physical barriers that lie between the mother's circulation and the fetal brain: the *placenta* and the (fetal) *blood-brain barrier*. For the present theory to have any validity, changes in the hormonal levels of the blood must be able to pass quickly across both these protective barriers. In fact, these filters pose no barrier at all to hormones. Because hormones are lipophilic (fatty, lipid-soluble), they easily and quickly diffuse across cell membranes.

The expression "biochemical communication" suggests that biochemical messages between mother and fetus travel in both directions. So far, we have considered only the mother-to-fetus aspect. The fetus-to-mother aspect involves fetal manipulation of maternal nutrient supply, which happens when the placenta changes the hormonal content of maternal blood. From a broader evolutionary viewpoint, this effect may be regarded as an example of *parent-offspring conflict*: the offspring tries to get more from the parent than the parent is willing or able to give.

Why might the fetus be sensitive to messages about the mother's emotional state? The survival of an infant depends on *bonding,* aka maternal love. The basis of bonding is mutual attraction: each partner regards the other as centrally important. But there is more to it than that. The mother needs to understand the needs of the baby in order to satisfy them. It helps if the baby can also to some extent monitor the mother's emotional state, which is a reflection of her ability to satisfy its needs. A baby that demands care that cannot be provided wastes the energy of both parties and in that way puts both at risk. The details of this interaction differ considerably from one mother-baby dyad to the next: mothers have different personalities and experiences, and raise their children in diverse physical and cultural situations. Therefore, an infant's chances of survival are greater if it is born with some practically oriented knowledge about its mother's personality and the way she expresses emotion. Diane Mastropieri and Gerald Turkewitz confirmed this hunch in an empirical study. They concluded from their data that the fetus learns to perceive the emotional implications of its mother's speech, and that the resultant acoustic-emotional sensitivity of the newborn is confined to its mother's native language. In evolutionary psychology, any ability or behaviour that increases an organism's chances of survival is assumed to be the subject to natural selection. Since infant mortality is high in most human societies – think of pre-industrial and prehistoric societies – the fetus is under strong evolutionary pressure to acquire information about its mother's changing physical and emotional states.

The second stage of my account is postnatal. First of all, we have to ask the question of whether, to what extent and how long prenatally learned associations might be retained after birth. What is the duration of *transnatal memory*? A number of experiments have addressed this question. In such experiments, pregnant women in the third trimester are repeatedly exposed to short musical excerpts at moderate levels of loudness – loud enough that the fetus can hear them. While the mothers are perceiving this music, their unborn children, who of course have no "idea" of "music" (or anything else for that matter), perceive meaningless patterns of sound. After birth, the baby is placed next to a loudspeaker and is presented with a series of sound patterns, some of which it heard repeatedly before birth and others that it has never heard. If babies consistently look at the loudspeaker for a longer or shorter time when certain sound patterns are being played, and all other variables are accounted for according to the usual principles of experimental design, we may conclude that the baby is discriminating between the sound patterns according to familiarity, and is therefore able to recognize the sound patterns that it heard before birth. The published empirical data clearly confirm that this is the case.

On the basis of such an experiment, Peter Hepper concluded that postnatal memory for prenatally learned sounds lasts for a few weeks. A more recent experiment by Alexandra Lamont, whose results were not published, suggested that this memory might last for up to one year. While such experiments are interesting and it would be useful to carry out more of them, the present theory does not depend crucially on their results, because the duration of "memory" for prenatal associations between emotions and sound=movement patterns can be prolonged by another mechanism. *Motherese* – that playful interaction between adults and babies that involves acoustic experimentation with the vocal chords and vocal tract as well as touch and movement – begins soon after birth. Presumably, motherese reinforces – but also modifies – prenatally established associations between sounds, movements and emotions. Repetitions of such rhythmic and melodic patterns in motherese may enable prenatal asso- ciations to be projected into childhood. Later repetitions during play and ritual may allow these patterns and associations to be projected further into adulthood. A further reason why the present theory does not depend on the specific results of experiments about transnatal memory is that the internal stimuli that underlie prenatal associations between sounds, movements and emotions happen much more often than the external stimuli that are typically presented in such experiments. The resultant associations are presumably stronger and more durable.

Empirical studies by Sandra Trehub and colleagues have convincingly and repeatedly demonstrated that infants are sensitive to musical parameters such as rhythm, phrasing, melody, and even the consonance and dissonance of musical intervals. The researchers have tended to assume that this sensitivity is inborn and somehow genetically transmitted. The theory that I am presenting today suggests that this sensitivity might at least partially be prenatally learned from associations between sound=movement patterns and emotion.

Motherese is presumably a feature of all human cultures. It appears to play a role in speech acquisition, although the exact nature of this role has been questioned by linguists. Perhaps more important is its role in bonding. In both cases, motherese can be regarded as an evolutionary adaptation, because it enhances the infant's chances of survival. The present theory suggests that the specific meaning of the gestures used in motherese, as documented by Mechthild Papousek, may in part be prenatally learned. In recent research about the origins of music, Ellen Dissanayake has proposed that motherese might have contributed to the emergence and development of ritual, which plays an important role in theories of the origins of music.

I have not yet presented a specific scenario whereby prenatally acquired associations between sound=movement patterns and emotions might become "music". This process may be separated into two stages, which I identify as *operant conditioning* and *reflective consciousness*.

Operant conditioning appears to play an important role in motherese. While interacting, both the mother (or other carer) and the baby experiment with patterns of sound and movement. Patterns that they like are repeated. The mother is motivated to continue with the game of infant-carer vocal-gestural interaction when the baby smiles. Thus, the emotional connotations of sound and movement patterns play a central role. These emotional reactions may be based on what the baby "learned" before birth. During an interaction with the mother or other carer, the baby might hear, or accidentally produce, a sound that "reminds" it of prenatal "experience". This association produces an emotional reward that motivates the baby to repeat the actions that led to the sound, which in turn motivate the mother to repeat the action.

This process may be compared to B. F. Skinner's well-known paradigm in which a rat pushes a lever that releases sugar. If the rat pushes the lever accidentally, it gets the reward. This in turn leads to an increase in the frequency with which the rat pushes the lever. Again, this comparison may seem ethnically problematic to some readers. We need to ask to what extent a human infant can or should be compared with one of Skinner's rats. For the purpose of this argument, the answer is essentially the same as for the comparison between the fetus and Pavlov's dog: if the infant and the rat have similar abilities and behaviours, the comparison is valid, provided that it is restricted to those abilities and behaviours.

The final part of my account addresses the question of musical *intentionality*. The above definition of music assumes that music (as we normally think of it) is always performed and experienced deliberately.

When did humans first become capable of intention and deliberation – in other words, of planning, considering the past and future from the standpoint of the present? The archaeological record suggests that a *cultural explosion* oc- curred between 100,000 and 50,000 years ago. Sometime during this period, people started to use symbols consciously. Since you cannot directly observe reflective consciousness from the outside, you certainly cannot observe it directly in the archaeological record. But you can witness the remains of wall paintings and body decorations, and evidence for the existence of funeral ceremonies and migrations, and draw conclusions about corresponding human abilities. The archaeological record of such behaviours began some 50,000 to 60,000 years ago, but to enable this development humans must have been using symbols deliberately in language for a longer period. Going back even further into prehistory, every kind of acoustic communication in animals may be considered to include symbols. The question here is when – and why – people became *aware* of the symbolic nature of their acoustic communication, an issue addressed, for example, by William Noble and Iain Davidson. It could be that music as we know it emerged at, or following, the point when reflective consciousness gave people the ability to deliberately create sound patterns in ritual contexts, based on what they could already do in motherese and play.

This completes my speculative story of how music may have emerged and evolved. Before closing, allow me to address the distinction between *adaptations* and *exaptations* in evolu- tionary theory. An adaptation increases an organism's chances of survival and reproduction – of passing its genes to future generations. An exaptation is a byproduct of an adaptation that itself has no survival or reproductive value. Evolutionary psychologists and theorists of the origins of music and language often address the question of whether a given skill or behaviour is an adaptation, an exaptation, or a mixture of both.

The present theory assumes that music is a byproduct of prenatal audition (hearing), prenatal proprioception (the vestibular sense of gravity and movement), postnatal bonding, and motherese. Prenatal bonding and preparation for language may be considered adapta- tions, because they increase the probability that an infant will survive to reproductive age. But the classical conditioning of the fetus that I have referred to, which can explain infant sensitivity to the emotional implications of sound and movement patterns, may be no more than a byproduct of the fetus's ability to hear and the emotions, sounds and movements that happen to be available in the fetal environment. The fetal ability to hear is in turn presumably an adaptation that improves postnatal bonding and accelerates language acquisition. Mother- ese may be regarded as an adaptation for the same reasons, but the operant conditioning I talked about, in which infants in the context of motherese, and children in play, prefer sound and movement patterns that give them an emotional reward, may be a byproduct of prenatally formed associations between emotion, sound, and movement. Finally, reflective language –which evidently is an important ingredient in the emergence of that deliberate act of acoustic- emotional manipulation that we call "music" – is presumably also an adaptation in the sense that groups of humans with reflective language were more likely to survive than groups without it. No one knows why the Neanderthals died out – but one of many possibilities is that the modern humans with whom they were competing for resources had more advanced reflective language and consciousness.

The topic of today's presentations has been music and the body. The theory of prenatal origins suggests that music has bodily implications because the human body, and in particular the female human body, represents the origin of music. For example, the reason why the rhythm and pitch patterns that we find in music correspond to the typical frequency range of the human voice, heartbeats and footsteps may be traced back to prenatal experience of these sound patterns.

Music also has personal qualities that go beyond corporality. It may be perceived as loving, angry, male, female, and so on. For that reason, music is often regarded in music philosophy as a *persona* or virtual person. People also identify strongly with musical styles. In the present theory, the strong role that music plays in forming and maintaining human identity – an important area of research in music sociology – can be traced to the relationship with the mother as "experienced" by the fetus. Presumably, the fetus in the third trimester begins to develop a cognitive representation or *schema* of its mother – the first of all cognitive representations or schemata that an individual develops. This representation may at first be no more than a vague and poorly defined combination of sensory inputs that seem to correlate with each other, suggesting that they come from the same source. As the pregnancy progresses, the representation might become more specific, enabling the baby after birth to quickly establish a complex and sophisticated representation of its mother. If this representation is transferred to music via motherese, play and ritual, it may explain some of music's personal qualities.

The mother schema may also contribute to an explanation of the strong link between music and religion in all cultures. For that schema may underlie the strong feelings of reverence and divine presence that are regularly experienced by participants in religious rituals, including private prayer and meditation. It may also explain cross-cultural commonalities in the concept of god in monotheistic religions. But that fascinating, speculative question is beyond the present scope.

Chapter 14

Music and the evolution of human brain function

Multidisciplinary research during the last three decades has led to notable progress in the understanding of the relationships between aspects of music common to all cultures and characteristic features of acoustical information-processing in the human brain. Increasing evidence of a parallelism between many structural aspects of music and human language points to a common, perhaps even simultaneous origin of music and language during the early phase of human brain evolution. And robust arguments are emerging about the neural mechanism of musical emotions and the possible origin of the human drive to listen to music, make music and compose music. In short, answers to the questions of *why did music develop in the early days of human evolution* and *why is there music still now* may be around the corner.

Historically, the scientific study of musical tone perception started with the work of Hermann von Helmholtz, described in his monumental treatise *On the Sensations of Tone as a Physiological Basis for the Theory of Music* (1863). The next big steps followed hundred years later, led by Georg von Békésy (*Experiments in Hearing*, 1960) and Reinier Plomp (*Aspects of Tone Sensations*, 1976). These studies shed light on the perception of individual complex musical tones, tone superpositions and sequences, and fundamental attributes such as pitch, loudness, timbre, consonance, roughness, chroma, tonal dominance and scales. Initially, the main interest of these studies was to measure and quantify the sensations reported by subjects exposed to tone signals in systematic experiments and correlate the results with the physical parameters of the stimulus – *musical psychoacoustics* thus became a science in its own right.

Later the scientific interest shifted more and more to the underlying physiological and neural mechanisms, particularly to the higher level processing involved in musical imaging (internal hearing and composition) and the affective response to music. This required a truly interdisciplinary approach, with cooperative participation of musicians, physicists, psychol- ogists, physiologists and neuroscientists. The goals became rather demanding, addressing ultimate questions like: Why are humans from all cultures virtually "immersed" in something like music? Why do specific musical forms lead to different moods like happiness, sadness, courage or fear? What was the survival value of music during the early history of human evolution, notwithstanding the fact that, apparently, music does not convey any "concrete" information like language? Why can music be used to treat mental illnesses and why does it affect the immune system? If extraterrestrial civilizations exist, would they have music? These are all "trans-cultural" questions, addressing universal properties of music, and as such, can only be answered by finding out in detail *how* the human brain works. But this is a tall order:
the human brain is recognized as the most complex system in the Universe as we presently know it!

It is interesting – and auspicious – to note that Austria has played a prominent catalyzing role in the promotion of the required interdisciplinary research. The world-renowned music psychologist Diana Deutsch wrote in 2004 in her guest editorial for the 20th anniversary of the international journal *Music Perception* (Deutsch 2004):

"A series of interdisciplinary workshops on the Physical and Neuropsychological Founda- tions of Music … were held in Ossiach, Austria [during the Carinthian Summer festivals], and it was at these workshops that many of us learned for the first time, and with great excitement, about studies on music that were being carried out in each other's fields. It became clear at these exhilarating workshops that an interdisciplinary study of music, with input from music theorists, composers, psychologists, linguists, neuroscientists, computer scientists, and others, was not only viable but even necessary to advance the understanding of music".

After the first Ossiach workshop, similar interdisciplinary meetings started to be held elsewhere, among them a Symposium on Brain Processes in Music Performance and Perception in 1982 in Vienna, organized by the Herbert von Karajan Foundation which was playing a key role in support of scientific research on this subject.

Most revealing are the six fundamental questions proposed as a focus for discussion in the program of the first Ossiach Workshop in 1973:

- What subjective attributes of music are related to physiological and neurological mechanisms and which emerge as a result of cultural conditioning?
- To what extent are we able to ultimately "explain" music on the basis of complex operations of acoustical information-processing in the brain while we listen to it?
- Has music emerged as a "byproduct" of the evolution of language-processing and -interpretation mechanisms in man?
- In particular, is music a consequence of the fact that, since language is processed mainly in only one cerebral hemisphere, the equivalent network of the other is free to "play" with the incoming auditory signals – just for the pleasure of it?
- Through what mechanisms does music affect our behavior?
- In summary, can we ever expect to find an answer to the question: Why do we make music?

That was in 1973! Today, these six questions are still valid to a remarkable extent – but much progress has been made in finding answers. There are three contributing factors: 1. The availability of new *non-invasive tomographic imaging techniques*, which in combination with more traditional electro- and magneto-encephalography reveal in detail where and when specific information-processing tasks are carried out in the brain; 2. The increasing *participation of physicists* who, in cooperation with neuroscientists, psychologists and musicologists, formulate quantitative models of relevant mechanisms and contribute to the investigations with a strictly reductionist systems-analysis approach; 3. The emergence of a new *objective definition of information*, particularly apt for the description of biological systems, which leads to a better understanding of the concept of "representation of information" in the brain, and of the transformations the information undergoes between primary perception, memory storage, associative recall, cognition, emotional response and imagery.

In this presentation I will focus on recent scientific understanding of brain functions relevant to the how and why of music perception, gained as the result of the above-mentioned factors. Details about the most significant experimental results will no doubt be presented and discussed during the course of this conference. May this meeting in Austria become another catalyst for further progress!

14.1. Information, brain and music

Music is a form of acoustic information – but information about *what*? The answer will depend on whether you ask a musician, an electroacoustics engineer, a psychologist, a neuro- logist or a physicist! One of the reasons for such ambiguities is the confusion among people, including scientists, about what information really is. This seems, indeed, quite puzzling, taking into account the fact that we are living in the "information society" to the point that our species has been called the "infovores" among the vertebrates (Biederman and Vessel 2006).

Of course, there is *Shannon's information theory* (Shannon and Weaver 1949). It is of technological importance and works with mathematical expressions for the uncertainty in the outcome of alternatives and the amount of information in a given message, but it does not offer any formal definition of information *per se*. And there is the concept of *algorithmic information*, important in physics and complexity theory, but it, too, is a mathematical measure defined by the minimum number of bits required to describe an object or a symbol (for instance, the number *p*, which has an infinite number of decimals, can be generated with a short, few-bit recurrence formula).

To understand biological systems and their interactions with each other and the inanimate world we need a truly objective definition of information. The digital pits on a CD disc, the fonts in the books, the oscillations of air pressure in the ear canal, the electrical signals in the brain, or the genetic code in the DNA molecule all *express* information, but they are not *the* information. Shuffle them around, change their order or form ever so slightly – and you may get noise, nonsense, or destroy an intended function! On the contrary, information can take many different forms and still mean the same thing. Clearly then, in biological systems what counts is what information *does*, not how it looks or sounds, how much it is, or what it is made of. Information has a *purpose*, and the purpose is, without exception, to cause some specific *change* somewhere, some time – a change that otherwise would not occur or would occur only by chance.

Only recently has an objective and general definition been formulated that is adequate for use in biology, namely that of *pragmatic information* (e.g., Küppers 1990). It is the agent that mediates a univocal correspondence between the pattern in a "sender" and a change elicited in a "recipient" (which also could be a pattern) every time the sender is put in some specific interaction with the recipient (Fig. 1). We may call this an *information-driven interaction*, in which "information from a sender has been received and processed, leading to a specific change" (Roederer 2005). Only living systems can entertain information-driven interactions; inanimate, non-artificial systems like elementary particles, rocks or planets entertain force-driven interactions, in which energy, not form, shape or pattern plays the fundamental role.

All this sounds rather complicated, because it involves at least three complex systems: (i) the pattern in a sender, (ii) a specific change elicited in a recipient, and (iii) an interaction mechanism. But information alone, all by itself, cannot be defined: it has to be there for a purpose. A Chinese character is not information if, when you are looking at it, it does not cause some specific changes (neural patterns, see below) at higher levels in your brain. But if you know Chinese, certain mechanisms have been built up in your brain that will lead to a very specific response pattern when you see that character (the "aha" effect – cognition). Likewise, there are many acoustic patterns which do not elicit any specific response beyond the primary auditory areas – they trigger no information-driven interaction and thus carry no pragmatic information. But many acoustic patterns do – for instance speech sounds, provided you know the language involved, or environmental sounds provided you have the knowledge of what is producing them. One class of acoustic patterns may elicit specific response patterns at higher levels in the brain *without* any previous learning requirements, engaging inborn information- processing mechanisms: the superpositions and sequences of periodic tones which make up the *music* in all cultures (e.g., Trehub 2001). The question of what information is involved in music has thus become a question of identifying the relevant higher level neural response patterns it elicits in the human brain and their behavioral consequences.

Before we deal with this matter, we should say a few words about how information is actually represented in the brain. There are two fundamental ways. One is dynamic, expressed in the form of a rapidly changing pattern of neural activity, specifically, the *spatial and temporal distribution of electrical impulses* which individual neurons send to other neurons, representing the operating state of the neural network. The other is quasi-static, given by the *spatial distribution and efficacies* of inter-neuron connections (the synapses), representing the internal state or "hardware" of the neural network. In addition, there is also a *chemical* *information transmission* system: certain substances (neurotransmitters and hormones) injected into the blood stream under neural control, which play the role of a temporary modulator (stimulator or inhibitor) of the neural activity in specific brain regions; they determine the affective responses of brain activity and control many internal organ functions and the immune system.

The dynamic form varies on a time-scale of a few milliseconds to seconds and usually involves millions of neurons even for the simplest information-processing tasks, requiring a substantial supply of energy to be maintained. It is the increased vascular blood flow and oxygen consumption that appear mapped as images in functional magnetic resonance (fMRI) and positron emission tomography (PET), respectively (item 1 in our list of factors of progress). Unfortunately, such techniques do not reveal the exact, microscopic distribution of neural patterns; such a task seems hopeless, at least today: in the human brain there are over hundred billion neurons in the cortex, each one connected to thousands of others. Yet it is the detailed microscopic spatio-temporal distribution of electrical activity at the neuronal level and the spatial distribution of synapses which taken together represent the *integral state of the functioning brain* at any instant of time.

There are well-defined stages of information-processing in the neural circuitry of the brain, extending from the primary sensory receiving areas of the cortex to the frontal lobes, and from there to the motor areas that command the muscles. There is also a feedback system from the higher processing stages back to the primary areas. How a specific spatio-temporal neural activity distribution elicited by the sight of an object or by listening to a sound becomes a specific *mental image* is an old question that has puzzled biologists and philosophers alike. Today neurobiology provides a radicalanswer: the pattern does not "become" anything – it *is* the image!

Let me restate this with an (oversimplified) example. When you see a "shiny red apple"; when you close your eyes and imagine a "shiny red apple"; when somebody says the words "shiny red apple"; or when you are reading these very lines, there appears a spatio-temporal distribution of neural activity in certain specific regions of your brain, part of which is nearly the same in all cases. That common part represents the cognition of "shiny red apple", and is your mental image – your *neural correlate* – of the concept "shiny red apple". It is yours only;

physically=physiologically it would be very different from the one that forms in my brain or in anybody else's under the same circumstances (only the participating regions would be the same) – but still these patterns are all expressions of the *same pragmatic information*. Also the ulterior behavioral response to a pattern representing cognitive information may be the same for you and me. What counts is the univocal character of the correspondence "object ! neural activity distribution", not the actual form of the activity.

There are no direct experimental proofs of this yet, but indirect evidence is overwhelming. First, there is ample evidence for the consistency of *where* in the brain-specific processing operations take place (see sketch in Fig. 2 for the sense of vision). Concerning the microscopic distribution of activity little is known as yet, but neurons have been found that respond consistently to one very special type of complex input like the face of a person, or to an expected input feature even if it is absent from the current stimulus (e.g., Koch 2004).

One fundamental brain function is memory. To retrieve information in a *memory recall*, the brain must recreate the neural activity distribution that prevailed during storage, i.e., the neural activity pattern that is specific to the object, event or concept that is being recalled. This is accomplished by feeding into the relevant network a partial pattern or *key*, which may then trigger the full activity distribution if some minimum information threshold is surpassed. This process is called *associative recall* (for example, the acoustic perception of the name of a person triggering the visual image of the person, or vice versa). The external key may be just part of the image to be recalled, in which case we have an *autoassociative recall* (e.g., hearing the ta-ta-ta-tah, and remembering the sounds of Beethoven's Fifth Symphony).

The act of long-term *memory storage* consists of appropriate changes of the synaptic architecture during a learning process. When two or more near-simultaneous sensory input events (e.g., the sound and the sight of a previously unknown musical instrument) are presented repeatedly, parts of the affected neural circuitry change in such a way that, in the future, only one of the input events will trigger the neural representation of the other(s); this represents the basic *learning process* in the brain. Note that the brain's mode of distributed memory storage and associative recall is fundamentally different from the familiar modes of addressed memory storage and retrieval.

The re-elicitation of neural patterns that represent the images stored in memory requires *feedback mechanisms* – reverse information-driven interactions in which higher level patterns trigger associated patterns at lower levels (Fig. 2). A consequence of this brain mechanism is that the expectation or *anticipation* of a sensory input will trigger neural activity in relevant sensory and association areas of the cortex even *before* an actually occurring external feature can elicit the corresponding response; if the expected feature is missing, the corresponding neural pattern appears anyway. This has been verified in many experiments in which the response of feature-detecting neurons in the visual primary cortex is measured while the laboratory animal is exposed to stimuli in which the expected feature is sometimes present, sometimes missing.

Perception and cognition is based on appropriate transformations of spatial and temporal neural activity distributions. In the case of the auditory sense, the distributions are initially directly linked to the excitation (vibration) along the basilar membrane in the cochlea (spatial coding of frequencies), and on the neural impulse firing sequence in the acoustic nerve fibers (temporal coding). By postulating simplified but otherwise realistic and quantifiable *models* of the neural networks in the afferent auditory tract and primary cortical receiving areas, many characteristic features of the perception of complex tones have been explained (e.g., see Roederer 2008, or Zatorre and Peretz 2001, and references therein). Examples are the perception of the pitch of a complex tone even if the fundamental and other lower harmonics are absent (fundamental tracking); beats of two mistuned sinusoidal tones fed separately into each ear; perception of tones one or more octaves apart as belonging to the same pitch family (the chroma); perception of two-tone superpositions as consonant or dissonant depending on the relationship of their fundamental frequencies; assignation of a "natural" order to two successive tones; the high tolerance to tuning deviations when tones appear within a musical context (use of equally tempered scale).

In addition, these explanations, entirely based on neural information-processing mechan- isms, shed light on the apparent role of numerology in music (ratios of integer numbers, circle of fifths, etc.) which has intrigued generations since the times of Pythagoras (I say "apparent", because the ultimate reason is how frequencies of the upper harmonics of a periodic oscillation relate to each other). They also help explain the interesting fact that recently found musical instruments (flutes made of bone) from Neanderthal sites dating 40,000 or more years ago have finger-holes that point to the use of the just musical scale (Gray et al. 2001).

Finally, the rhythmic structure of music may have a relation to the natural clocks in the brain that control body functions and motor response, as well as the characteristic times of the working (short-term) memory. There is indeed a mechanism in the brain responsible for the operation of a "stopwatch": it involves the so-called striato-cortical loops connecting the basal ganglia (a region that coordinates voluntary muscle movements) with the frontal cortex, and a neurochemical action by the substantia nigra in which squirts of dopamine secreted by the neurons of the latter act upon an "accumulator" in the basal ganglia (the "hourglass" effect – see Morell 1996), thus providing a time signal to the information-processing machinery of the brain.

So far we have focused mainly on input. The neural *output* of the brain controls the organism's striate musculature for posture and both voluntary and stereotyped movement, some of the smooth muscles of internal organs, and the chemical endocrine system. The more advanced an animal species, the more options it will have for the response to a momentary constellation of the environment. This requires decision-making based on some priorities. Such instructions are coordinated by brain structures historically called the *limbic system* (brain scientists are quite reluctant to use such "umbrella" designations for processing centers that interact in different ways depending on context). The structures in question include a group of subcortical nuclei located near the midline of the brain, which in conjunction with the hypothalamus, the amygdalas, the hippocampus and the basal forebrain check on the state of the environment and the organism, ultimately directing the animal's attention and motiva- tion, and making sure that the output – the *behavioral response* – is beneficial to the survival of the organism and the propagation of the species in conformity with evolutionary and ontogenetic experience (see sketch in Fig. 3) (for a recent review see Dolan 2002).

The limbic system works in a curious "binary" way by dispensing sensations of "reward or punishment": hope or anxiety, boldness or fear, love or rage, satisfaction or disappointment, happiness or sadness, and so on. These are the *emotional states* of the brain (generated by the deeper subcortical nuclei). They evoke the anticipation of pleasure or pain, whenever certain environmental events are expected to lead to something favorable or detrimental to the organism, respectively. Since this anticipation comes *before* any actual benefit or harm could arise, the emotional state helps guide the animal's *motivation* (controlled by the anterior cingulate cortex) to respond in a direction of maximum chance for survival or procreation, dictated by the information acquired during evolution and experience – the so-called instincts and drives. Of course, only human beings can report to each other on emotional states or *feelings*, but higher vertebrates also experience such a "digital" repertoire. The pleasantness or unpleasantness of a feeling is controlled by the chemical information system of the brain (opioids and monamines).

Most behavioral responses of vertebrates are governed by this cortical-limbic interaction. As a matter of fact, without the guiding mechanism of such a "control mechanism", animal intelligence could not have evolved: without instincts and drives, the survival of a complex mobile organism in a rapidly changing, unpredictable environment would be highly improb- able. Without the motivation to acquire information even if not needed at the moment, a repertoire of environmental events and appropriate responses thereto could not be built up in the memory. Without the coherent, cooperative mode of two distinct information processing systems, a cognitive one (mainly handling ontogenetic, recent information) and an instinctive one (mainly working with phylogenetic past information), giving rise to the single "main program" we call consciousness, animal-like intelligence would not be possible.

Even simple perceptional acts elicit responses from the limbic system. An example is the elementary sensation of pleasure when a consonant superposition of two complex periodic tones is heard, i.e., two simultaneous tones whose acoustic signal is easier to process because it has many coincident overtone frequencies (Roederer 2008). Other examples are the reward for a confirmed short-term prediction, such as in the resolution of a chord sequence, or the goose flesh elicited by a sudden, unexpected turn of a chord progression.

Here we come to a fundamental question: wouldn't all the preceding discussion mean that higher animals should experience these musical sensations, too? Experiments with cats, chinchillas and chimps indeed show that they process complex tones as humans do – but do they enjoy consonant intervals and anticipate endings of a tone sequence, do certain chord progressions raffle their fur, do they instinctively move in synchrony with music? Before we turn to an answer, we should examine some fundamental differences between human and animal brains.

Aristotle already recognized that "animals have memory and are able of instruction, but no other animal except man can recall the past at will". More specifically, the most fundamentally distinct operation that the human, and only the human, brain can perform is to recall stored information as images or representations, manipulate them, and re-store modified or amended versions thereof *without any concurrent external sensory input* – this is information generation par excellence (Roederer 1978). In other words, the human brain has internal control over its own feedback information flow (Fig. 2); an animal can anticipate some event on a short-term basis (seconds), but only in the context of some real-time somatic and=or sensory input, i.e., triggered by "automatic" associative recall processes. The act of informa- tion recall, alteration and re-storage *without* any external input represents the *human thinking process* or *reasoning*.

The capability of recalling information without any concurrent input had vast conse- quences for human evolution. In particular, the capability of re-examining, rearranging and altering stored images led to the discovery of previously overlooked cause- and -effect relationships, to a quantitative concept of elapsed time and to the awareness of future time. In animals, the time interval within which causal correlations can be established (trace conditioning) is of the order of tens of seconds and decreases rapidly if other stimuli are present (Han et al. 2003); in humans it extends over the long-term past and the long- term future. Along with the ability of ordering events in time came the possibility of *long-term prediction* and *planning*, i.e., the mental representation of events that have not yet occurred.

In parallel with this development came the ability to encode complex mental images into simple acoustic signals and the emergence of *human language.* This was of such decisive importance for the development of human intelligence that certain parts of the auditory and motor cortices began to specialize in verbal image coding and decoding, and the human thinking process began to be influenced and sometimes controlled by the language networks (e.g., Premack 2004) (but it does not mean that we always think in words).

Concomitantly with this development came the postponement of behavioral goals and, more specifically, the capacity *to overrule the dictates of the limbic system* (e.g., sticking to a diet even when you are hungry) and also *to willfully stimulate the limbic system*, without external input (e.g., pleasure by remembering a musical piece or getting enraged by thinking about a certain political leader). In short, the body started serving the brain instead of the other way around. Mental images and emotional feelings can thus be created that have no relationship with momentary sensory input – the human brain indeed can go "off-line" (Bickerton 1995). It is important to point out that the capabilities of recalling and rearranging stored information without external input, making long-term predictions, planning and having the concept of future time, stimulating or overruling limbic drives, and developing language, most likely evolved hand-in-hand as neural expressions of human intelligence.

Quite generally, the human thinking process involves the *creation of new images*, i.e., spatio-temporal distributions of neural activity that do not correspond to any previously sensed or experienced information input. Patterns or objects can be crafted and changes in the environment can be effected that did not exist before and which would never be a deterministic consequence of physical laws and natural initial conditions. Let us turn to the case of *music imagery*, the "tune inside of your head". This neural process is now being explored scientifically with the new tomographic techniques. Gradually one is reaching the conclusion, anticipated years ago, that in many regions of the brain the neural activity involved in the processing of imagined sounds is nearly the same as that evoked by actually perceived sound (Halpern 2001). There is evidence today that in the process of imagining music, other, non-acoustical, brain centers are also activated systematically: the motor areas controlling hands (instrument performers), larynx (in singers), arms (in conductors) and legs (rhythm), as well as the vision areas (imagery of the score, the instrument, and the audience).

We may now ask: How did Mozart compose? And do it so fast, so prolifically? There is evidence that he possessed the equivalent of an "eidetic" acoustic memory: he could remember practically not only every musical piece he heard, but also those he imagined. As he willfully retrieved sound images and pieced them together in different, novel ways or created entirely new combinations of tones (in other words, created the corresponding neural representa- tions), he obviously was able to store immediately in memory everything that was being pieced together, and experience new emotional sensations triggered by these recently stored images – a true "reverberation in the composer's head", not of sound but of the correlated neural activity distributions representing the mental images of the sound.

We are now in a better condition to address the question: *Why* is there music? Let me state at the outset in quite general terms: without a cortico-limbic interplay and without the capacity of internal information recall and image manipulation detached from current sensory input, there could be no music (and no art – perhaps even no science). We can envision robots programmed (by a human being!) to compose and perform music according to preset rules, but it would be hard to imagine a robot *enjoying* to listen to and make music and *wanting* to compose!

It is not difficult to try to trace the origin of the motivation to perform certain actions that have no immediate biological purpose, such as climbing a mountain (instinct to explore), playing soccer (training in skilled movement) or enjoying the view of a sunset (expectation of the shelter of darkness). But why have "abstract" musical tones and forms been of advantage to early hominids? Of course, this question must be considered part of a more encompassing question related to the emergence of esthetic motivation, response, and creativity.

There is an increasing amount of evidence that music is a co-product of the *evolution of human language* (e.g., see Koelsch 2005, and references therein). In this evolution, which undoubtedly *was* the essential factor in the development of hominids, a neural network emerged, capable of executing the ultra-complex operations of sound processing, analysis, storage, and retrieval necessary for phonetic recognition, voice identification, and analysis of syntax and grammar of speech. It is therefore conceivable that with the evolution of human language a drive emerged to train the acoustic sense in sophisticated sound pattern recogni- tion as part of a *human instinct to acquire language* from the moment of birth. Animals do not possess the ability of propositional language, and they do not experience the specific motivations and drives that humans experience in relation to musical sounds[1] – this is why they hear consonances, but do not necessarily enjoy them, as we hinted at the end of section 3.

During the later stages of intrauterine development, the acoustic sense of the fetus begins to register passively the intrauterine sound environment. At birth there is a sudden transition to active behavioral response in which the acoustical communication with the mother or her surrogate plays a most fundamental role. An acoustical communication feedback cycle is thereby established, which may reinforce the emotional relationship with the mother and feed both the motivational drive to acquire language in the infant and the motivational drive of the mother to vocalize simple successions of musical tones (Roederer 1984). Note that an infant reacts first to the *musical* content of speech, but so do dogs; when adults speak to infants or dogs or any pets, they use the same pitch contour in the tone of voice, quite independent of the actual language being used. But here the similarities end. The mother's song arouses the attention of an infant as a prelude to the acquisition of language. This motivation to listen to, analyze, store, and vocalize musical sounds, even when there is no apparent need given by present circumstances, leads to limbic rewards, i.e., triggers feelings of pleasure when this is done (Trehub 2001). When we sing to a puppy, nothing special will happen, except for an eventual attention to the sound source.

To facilitate the acoustical information processing of speech the motivation emerged to discover symmetries and regularities, to extrapolate, predict, interpolate, to tackle with redundancy and repetition and with the surprise of sudden change. Each one of these tasks elicits affective responses, which taken together contribute to the emotional effects of music, ranging from those of instantaneous or short-term character related to the subjective sensations of timbre, consonance, tonal expectation, sense of tonal return, to the longer- term structures of melodic lines. These affective elements may be manifestations of limbic rewards in the search for the phonetic or phonemic content of sound and for the identification of grammatical organization and logical content of acoustical signals. They represent a predisposition for musical skills; the fortunate fact that these feelings are irrepressible and occur *every time* lies at the very foundation of modern music theory (e.g., Lerdahl and Jackendoff 1983). The timing aspects involved in this kind of acoustical information processing may engage the "clockwork" circuits mentioned at the end of section 16.2, and trigger limbic rewards in association with musical rhythm.

Finally, in the evolution of the human brain the immense requirements of information processing that came with the development of verbal communication led to the appearance of large special purpose regions and the emergence of *hemispheric specialization* (e.g., see Roederer 2008). In a division of tasks, the analytic and sequential functions of language became the target of the "dominant" hemisphere (on the left side in about 97% of the subjects) and the "minor" hemisphere emerged as being more adapted for the perception of holistic, global, synthetic relations, as they abound in musical structures. The most plausible reason for this development was the need to keep the areas responsible for processing speech and directing the vocal, gesture, and mimicry output as close as possible to each other, in order to minimize transmission delays between the participating neural networks. The complex sequential operations of speech processing simply could not afford the approximately 50 ms it takes to transmit neural signals from one cerebral hemisphere to the other. As a result of this development, substantial "processing space" in the left hemisphere became unavailable for other, slower tasks of holistic, integrative nature, as they appear in music, which then by default were taken over by the right hemisphere.

The evolution of music exhibits two stages, both historically as well as ontogenically in each individual. First, there is a stage driven by geneti factors that have co-evolved with the appearance of language during the early days of the human species. Second, there is a "non- adaptive pleasure-seeking" stage, driven by the feelings evoked by structures and rhythms of ton superpositions and sequences (Huron 2001). It is the latter which plays the primordial role in today's music enjoyment.

Since an early stage in life, most persons are exposed to a limited class of musical stimuli. Cultural conditioning rapidly takes hold, and emotional response begins to be influenced by external factors, some fortuitous and subjective, like the emotional state experienced by a person during the first listening of a given musical piece or passage therein; some more con- trollable, such as the degree of repetition of characteristic musical forms pertaining to a given musical style. In addition, the innate drive to diversify the possibilities of human endeavor plays an important role: technological developments such as the appearance of keyboard instruments or, more recently, electronic synthesizers have had substantial impacts on devel- opment and on why one particular style or type of music is preferred over some other kind[2].

Concerning the development of the second "pleasure-seeking" stage of music, we may search for further contributing elements to a survival value. Like a good public speech, music can succeed in arousing and maintaining the attention of masses of people, overruling their normal limbic drives for extended periods of time. Since music conveys information on affective states, it can contribute to the equalization of the emotional states of a group of listeners just as an oral lecture may contribute to the equalization of the intellectual state (knowledge) of the audience. The role of music in superstitious and sexual rites, religion, ideological proselytism, military arousal, even antisocial behavior, clearly demonstrates the value of music as a means of achieving behavioral coherence in masses of people. In the distant past this could indeed have had an important survival value, as the increasingly complex human environment demanded *coherent, collective actions* on the part of large groups of human society (Benzon 2001, Roederer 2008). A fundamental aspect of this is the role of rhythm; indeed, recent studies point out the importance of the relationship between the longer term ultradian biological rhythms of the human body and the shorter term biological rhythms of the music. When music is perceived, the biological system of the listener reacts to the signals as a whole, and a number of physiological effects can be observed and analyzed. According to chronobiology, a musical experience can be a pleasant one or a disturbing one depending on the synchronization between the rhythms of the organism and the acoustic input, especially when the experience of the music begins.

In the end, what does remain invariant from the original instincts, independent of the exposure to a given musical culture, are (i) the *fact* that there are some components of music that are common to all musical cultures; (ii) the *fact* that motivation exists to pay attention to musical sounds and forms; and (iii) the *fact* that an emotional reaction and feelings can be triggered.

Some musicians take offense at the "materialistic" approach of neuroscientists, physio- logists and physicists, who explore, measure, model, analyze, theorize, and speculate about mental activity while music is listened to, performed or composed. They object to the view that their sublime art is all the consequence of electrical signals running around in their brain. This is really an old issue – there has been a battle for centuries between "the two cultures", the humanities and the sciences. For instance, when I invited Carl Orff to the first Workshop in Ossiach, he exclaimed, quite irate: "I don't *want* to know why I love music!" In the other extreme, Herbert von Karajan offered many times to the scientists of his Foundation to let himself be wired up with EEG and EKG electrodes while he was conducting (and also while piloting his aircraft) to help them find out details about the physiological reactions provoked by his almighty limbic system.

There is so much to be learned about ourselves and our place in the world from the study of how our brain works. In the case of music perception, the benefits range from achieving a better understanding of the evolution of musical culture; improving music pedagogy; dispelling common fallacies (about piano touch, tone colors, absolute pitch, etc.); improving the design of musical instruments, electroacoustic equipment and concert hall acoustics; to exploring the brain itself and curing its illnesses. So I can only exclaim: "Musicians of the world unite – *with* the scientists! *There is work to do*!"

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Chapter 15

Clinical applications of music therapy in neurologic rehabilitation

Current clinical research indicates that music and the components of music, i.e., rhythm, melody, harmony, can stimulate complex cognitive, affective and sensorimotor processes in the brain, whose functions can be generalized and transferred to non-musical therapeutic purposes. This is possible because music is not processed in only one area of the brain. For example, research in music perception indicates that pitch is processed in the right temporal lobes but this is also the area indicated in speech prosody. Memory systems can be stimulated by the associative memories connected to a particular piece of music or the harmonic structures that induce emotional responses – simliar but different in how the brain is stimulated to result in memory recall. Similarly, the processing of rhythmic cues (rhythm being a time ordered or temporal process) involves the prefrontal motor cortex, the cerebellum and other areas resulting in the stimulation of various neural networks. With the process of music, a non-invasive medium, involving such a variety of neural networks, it has the power to engage patients with disability who have difficulties in executive function, bypass their functional and psychological impairments, and effect therapeutic outcomes. Areas of the therapeutic effects include speech and communication, motor and movement, attention, memory and learning, and emotion, and interpersonal relationships.

Music therapy is appropriate for all patients regardless of their functional and cognitive levels because music has the power to provoke responses in us from both our conscious and our unconscious levels. Some of the most extensively researched and practiced music therapy techniques include the use of familiar songs for memory recall, musically cued speech for persons with non-fluent aphasia (impairment in producing meaningful words, phrases, and sentences), rhythmic-auditory stimulation and sensory enhancement using musical patterns for limb movement and gait training, and improvisatory music-making for emotional support.

When I use the term music therapy, I am principally referring to active music therapy, i.e., the interaction between the therapist and the client, in which the music therapist manipulates music=sound=rhythm in real time to maximize the therapeutic benefit. There are also situations where the passive use of music is indicated. Certain types of recorded music can be used to induce auditory entrainment, and aid in relaxation and pain reduction. Recordings can be used for reminiscence, speech remediation and motor cueing. Even when recordings are used, the music therapist makes an assessment of which type of music or component of music will be the most beneficial for the intended goals. Most often these recordings are made after working actively with the client to establish the most appropriate music to use.

Particular attention has been given to the notion that music has unique power to tap the minds of elderly individuals with dementia for its ability to stimulate both their conscious and their unconscious minds thus provoking spontaneous responses. Clinical studies have reported that singing and listening to familiar songs can have positive therapeutic influence on patients' cognitive skills such as attention and associative memory recalls. While engaged in group musical activities such as a drumming circle or a therapeutic sing-a-long, dementia patients who suffer from depression and isolation often feel empowered and motivated to communicate and interact with others. Music relaxation techniques can be used to help patients with bodily tension, agitation, and poor impulse control. In addition experimental studies have suggested that music has a positive effect on cognitive performances such as attention and memory when the music can successfully elicit positive mood, such as positive familiar regards or calming effect, i.e., mood-dependent cognitive performances.

Other researchers found the positive effect of musically cued or associated reminiscence and autobiographical recalls. These findings seem to be congruent with clinical reports, and thus lead to hope for further use of music in mediating emotion and cognition. Other research topics of music and dementia include musically provoked P3 aspects of event-related potentials (ERPs) and its effect on alertness and attention, musically induced purposeful activities and self-initiation, listening to favored music and its calming effect on agitation and wandering, and relationship between pre-morbid interest=training in music and therapeutic outcome.

Why is music such an effective tool to enhance recognition memory and aid in other types of recall tasks? Research studies in music and memory indicate that pairing information with music is mutually reinforcing – the presentation of one element without the other will induce recall of the missing element. This is easily illustrated with early childhood education methods that utilize songs to teach nonmusical concepts, e.g., the alphabet, counting, months of the year, grooming skills, and even social rules. With so many ideas, skills, memories, and feelings paired to music over the course of one's lifetime, it is possible to understand why music can be a powerful tool to access this information when memory problems arise.

Many individuals with dementia, who have lost the ability to recall personal information, can often be stimulated to recall meaningful life events if those events were associated with a particular song. Most of us can think of a song with strong personal importance – so strong that we can no longer hear it as just "a song" but rather as inseparable from the memory or feeling associated with it.

One of my first patients was an elderly man who, after a stroke, stopped speaking. In fact he had not spoken for five years. He was admitted to the nursing home and was physically rigid and mute. He gazed into the room but did not fix his sight onto anyone or anything. During my regular sessions on the unit, I played a particular old folk song. I noticed that this man would turn his head toward me only during this song. In this moment he and I made eye contact and I had sensed the he had a connection to this song and that he "knew" the song meaning that he recognized the song as well as had a personal connection to it. I started to play this song everyday for him and soon he started to make sounds with his throat as if trying to sing. These sounds soon became the melody of the song. Within a few weeks of this repetition he started to sing the actual lyrics – the first words he had spoken in five years. When I told his wife that he had started to speak and how this came about she told me that that particular song was the lullaby he sang to their children every night. That personal connection was so strong that eventually he was able to recover function – first came the singing of the words and then the full recovery of speech. It was as if his speech was locked yet still available to him – he just needed the right stimulation to bring it back. This is no miracle but rather occurs because the residual ability may be stimulated by music through the stimulation of an alternate neural pathway or system.

Length of engagement is crucial. The amount of time a person with dementia is engaged in an activity the more possible the chance for meaningful response. Repetition is also important. Learning takes place when one attends to the information and it is repeated. Likewise for memory to be stimulated the information needs to be repeated, but repeated while maintaining the attention of the person listening to it. Without attention there is no memory. And so by engaging somebody for a minute, two minutes, three minutes we have a way of providing access to short-term memory as well as the possibility of retrieving memory.

Memory recall, more specifically, word recall can be stimulated by using familiar song lyrics and omitting a key word. People in early stages of dementia will find this a useful task for improving the speed at which they can retrieve a word. In late stages of dementia, when memory recall is no longer possible, rhythmic based activities can provide enough structure and stimulation to engage physical responses as well as attention in such patients.

Music can be used to convey ideas and concepts as well. In a study I undertook several years ago, we compared the use of songs compared to the use of photos and verbal techniques to reinforce reminiscence in persons with dementia. For example, in the music reminiscence group the concept of family would be reinforced by singing songs about family members while in the control group the concept would be reinforced through pictures or poetry. At baseline most individuals had very low scores on a mini mental status examination. After several months of participating in group sessions three times a week those in the music therapy groups showed significant increases in these scores. All sessions were videotaped and reviewed by neurophysiologists. The subjects in the music therapy groups were found to have more on target verbal responses than those in the control group.

Music therapy has been shown to be effective in post-stroke rehabilitation. Collaborative research in music and neuroscience has suggested that the systematic use of music may contribute to brain plasticity (i.e., the ability of the nervous system in the brain to adapt to changed circumstances and to find new ways of learning), whereby restoration of brain function can be naturally enhanced. Other research topics include shared neural properties between music and language processing both involving bilateral hemispheric activities in the brain, musical rhythmic stimulation and sensorimotor enhancement, musically assisted breathing and muscle relaxation, use of rhythmic cues to enhance speech prosody and word initiation, and therapeutic singing to enhance melodic speech intonation. The findings from research have illuminated a promising outlook for advanced clinical applications of music for post-stroke rehabilitation.

People who have had a stroke or those with neurological diseases that effect motor function, such as multiple sclerosis or Parkinson's disease, often have problems with coordination, gait, and balance. In these patients the use of rhythm as an auditory cue to help structure time and stimulate the synchronization of physical function is extremely effective. Although these patients may also appear to have lost a particular skill they may actually have lost the ability to access that skill. They may appear depressed, lethargic, rigid, un-motivated but this is not a psychological phenomenon but a neurological one. Again through the appropriate use of music, residual function can be stimulated.

We often think of memory as being related to history or facts – names, places, dates, etc. Skills are also memories. Memories of how to do things – riding a bike, dancing, eating, walking. Many of these actions are rhythmic in nature and as such can be stimulated or reinforced through rhythmic signals, i.e. rhythmic cueing. One patient, who had a weakness on one side due to a stroke would drag his left leg when walking with a cane. However, when he walked to music he lifted his left leg and stepped exactly in time with the music – not dragging at all. When asked about this he said that when he walked to music he thought of dancing and so his steps were different. In fact, although he was still "walking" his movement was now initiated and influenced by the music rather than his self-initiation of walking which had been impaired.

In many of our patients with neurological diseases initiation is a key problem. They will tell you how they feel like when they want to move but they cannot do it on their own yet you may observe that this movement is possible spontaneously or in another context. For example, in rehabilitation programs, patients are instructed to perform sequential tasks – place pegs in color coordinated holes, manipulate objects, dress, etc. All these tasks have a specific order.

Many times the patient must "think" about "how" to do the specific task. The thinking about "how" or what is referred to as "executive function" is often damaged in those with traumatic brain injuries. However, the patient may be coaxed into function through spontaneous activity with the right stimulus and many times this stimulus is music.

Rhythm can be used to entrain movement when independent movement, initiation or balance is a problem. The rhythm permits a time ordered pattern to which the person entrains their movement. By attending to the auditory cue rather than thinking about how to move, such individuals find that initiation, balance and coordination are enhanced. To get an understanding how it feels when an ability is inhibited, imagine being asked to walk along a 3-inch line on floor, one foot in front of the other. Not a difficult task. Now imagine that the 3-inch line is on a 2 by 4 plank of wood which is elevated several feet above the ground. Fear, lack of experience and other factors will inhibit most people from being able to perform this task. For people with neurological problems it is not fear that keeps them from motor initiation or coordination but rather the inhibition of a neural system. They cannot "think" about how to execute that movement or skill. Providing rhythm to supplement a sense of movement through the modulation of tempi enables the person to follow rather than to initiate. The slight change in orientation, i.e., following rather than initiating, enables for the function to be attained.

For those who have impaired fine and=or gross motor skills, digital music instruments can be used to reinforce a range of motor function. Electronic keyboards can be adjusted for touch sensitivity allowing for the slightest touch to make a tone. Other devices can be on=off triggers for MIDI based instruments. On such device is the Soundbeam, an infrared beam that is projected into a space. When the beam is broken it acts as an On=Off switch to trigger the musical events that were programmed in the Soundbeam controller device. Those events can be chord changes, single tones, or a continuum of sound. As the person moves in space with their arms and hands, they hear an auditory signal that reinforces the target movement. This auditory feedback becomes a very strong and powerful therapeutic tool for enabling the reintegration of the perception of and the actual physical range of movement.

Music therapy has shown to have therapeutic benefit in speech and language problems. Studies in the field of music, speech and language show that there are shared properties, such as syntax and contour. There are elements of singing in speech and speech in singing so that if one is impaired there may be a way to access through the complementary preserved skill.

Individuals who have had a stroke in Broca's area or in an area in the left language region of the brain have difficultly retrieving words and or in expressing themselves in words; however, they are able to comprehend what is being said to them. This is termed non-fluent aphasia. However, many people with non-fluent aphasia can sing words to songs with little difficulty. In the past this phenomenon was viewed as a split brain ability – singing is processed in the right temporal lobe so it is not affected by a left temporal lesion. However, if a person with non- fluent aphasia is encouraged to sing songs many times their ability to speak single words improves and in some cases speech is partially restored.

Song lyrics are often remembered because words within the lyrics are predictable – that is, we can often guess what the next would be. Likewise when we hear songs that we have learned many years ago we are still able to recall the lyrics with little difficulty. In the same way we can encourage people to find words of songs, of lyrics that they once knew and to encourage improved word retrieval. As they become more fluent in singing we can take some of those words away and help them to trigger the recovery of those words in the context of song. The melodic contour can be enhanced musically as well allowing for the internalization of how the spoken phrase should be sounded. Singing may serve as a priming element for speech in such patients stimulating either peripheral language areas or compensatory areas in the right temporal lobe. More research in this area is needed.

We have been studying this phenomenon through video analysis of music therapy sessions with persons with non-fluent aphasia. In the following clinical example you can observe how closely the patient is watching the facial expressions of the therapist many times mirroring the expression and mouth movements. Children learn language through mirroring the facial expressions, tones, and inflections of speech before they are able to use words. It was obvious to us as we analyzed these videos that people with language deficits also rely on other cues to process speech. In the music therapy sessions various protocols are used in addition to facial cues to enhance speech production. These include the use of familiar lyrics, speech phrases enhanced by strong melodic contour, novel phrases put to familiar melodies and, speech phrases enhanced by rhythmic cueing.

The musical cues are eventually removed as independent word retrieval and the use of phrases improves.

Another type of speech impairment is dysarthria, a motor speech problem that occurs in people with stroke, multiple sclerosis, and many other neurological impairment. People with dysarthria have problems in coordinating breath support and articulation. As a result their speech is intelligible. The use of rhythmic cueing to reinforce the words in a phrase as well as singing can be a strong therapeutic tool for improvement in intelligibility in such patients.

In a combined music therapy=speech therapy study with fifteen individuals who had dysarthria, we tested the efficacy of using singing as well as rhythmic self-cueing to enhance speech intelligibility. At baseline the average number of intelligible syllables per person was only three. After three months of working with this group twice a week for 45 minutes the average number of intelligible syllables increased to 19. One of the participants who had cerebral palsy had improved her speech so much that her teachers at another center wanted to know if she was receiving a new prescription but rather she told them that she was singing.

In the following clinical example you can observe the way the music and singing is used to reinforce the phrase 'Where is my pillow'. The song is sung to the melody of the song "Amen". Initially, the original song is learned with each participant cueing themselves by tapping their finger to each syllable while singing. Once this skill is mastered the lyrics are replaced by the target phrase. In the context of singing the patients were relearning the basic speech skills of articulation and breath support.

In addition to the therapeutic benefits of music therapy already presented the use of music therapy to enhance self-expression is also very important for people with neurological impairments. If you can imagine an individual who has lost the ability to move, who has lost the ability to speak, they have in reality become cut off from other individuals. There is no way for them to relate interpersonally with somebody anymore. And yet we know that meaning can be conveyed in musical expression. We can facilitate music-making through digital technologies or active musical improvisations on traditional instruments. In the context of making music together they have means of conveying ideas and relate together as a community – even if words cannot be spoken. For some of our patients who cannot recover lost function we have a way to allow for expression and meaning. That is incredible therapeutic and life affirming.

The following clinical examples could not be incorporated into the powerpoint presentation and so I would like to show these as further examples of how music can be used therapeutically to enhance movement and speech function. The first is of a woman with Parkinson's disease. You see that she has a slowness of movement or Bradykinesia. She slowly reaches out to her aid as the music therapist starts the music. Once the music starts the woman's gait increases and becomes synchronized to the music. Eventually she is able to coordinate both her stride and her arm swing with the music.

Then the second example is another type of speech cueing. In this example the client has a difficult time saying the requested words. However, when the speech therapist cues the words and the music therapists provide both a rhythmic and a melodic structure the client is able to speak the target word and phrase.

The following outline summarizes the diagnosis that can benefit from music therapy treatment.

Based on individual assessment, treatment planning and ongoing program evaluation Music therapy programs benefit residents who suffer from

- Memory deficits
- Depression
- Balance=Gait problems
- Fine motor problems
- Agitation=aggressive behaviors
- Acute or chronic pain
- Poor attention
- Decreased vocal projection=expression
- Non-fluent aphasia
- Poor motivation=increased stress
- Psycho-social withdrawal

The following are the examples of goals for music therapy:

Related to communication skills:
- To improve expressive language (communication of thoughts and feelings)
- To improve receptive language (ability to understand)
- To improve speech and verbal communication
- To promote effective use of non-verbal communication
- To provide opportunities for exceptional moments of human interaction
- To create a new language base and context for patterned communication and response for those who may never speak again

Related to motor skills:
- To utilize a connection to music to stimulate physical movement
- To maintain and improve fine motor functioning
- To maintain and improve gross motor functioning
- To improve hand-eye coordination
- To improve visual and auditory perception
- To maintain and improve range of motion
- To improve reach-grasp-release skills

Related to cognitive skills:
- To improve attention and focus
- To improve sequential tasks and temporal planning
- To improve on task performance
- To improve short- and long-term memory
- To improve complex task performance

So as you see there are many elements of music that can be used therapeutically. As we learn through sharing this information with neuroscientists and others we can begin to understand the underline mechanisms of how music therapy works and convey the importance of its therapeutic potential in the field of neurorehabilitation.

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Chapter 16

Human biochronology: on the source and functions of 'musicality'

"*The doctrine which I am maintaining is that the whole concept of materialism only applies to very abstract entities, the products of logical discernment. The concrete enduring entities are* organisms, *so that the plan of the whole influences the very characters of the various subordinate organisms which enter into it. In the case of an animal, the mental states enter into the plan of the total organism and thus modify the plans of successive subordinate organisms until the ultimate smallest organism, such as electrons, are reached.*

There are thus two sides to the machinery involved in the development of nature. On the one side there is a given environment with organisms adapting themselves to it … The other side of the evolutionary machinery, the neglected side, is expressed by the word creativeness. *The organisms can create their own environment. For this purpose the single organism is almost helpless. The adequate forces require* societies of cooperating organisms. *But with such cooperation and in proportion to the effort put forward, the environment has a plasticity which alters the whole ethical aspect of evolution.*"

(A. N. Whitehead, Science and the Modern World, 1926 Emphasis added)

There appear to be two ways to understand or explain our minds scientifically, an introspective=analytical task not normally demanded of us in the activities of daily life. Theorising, estimating or 'talking about' the process of our experience leads to the two ways psychologists distinguish what is 'real' and what we 'imagine' to be so – how what happens in our heads when we perceive is connected to the actual objects we choose to know, and, especially, to what we are *doing* with them.

Alfred North Whitehead, the philosopher of "Process and Reality" (1929) and co-author, with Bertrand Russell, of "Principia Mathematica" (Whitehead and Russell 1925) called the abstractions of materialistic theories 'products of logical discernment', which he claimed lack a proper account of 'creativity' (Whitehead 1926). The distinction seems to be connected to how we, as different persons, prefer to engage with the world. We approach life either more *practically and realistically*, or more *socially with enthusiasm*. We differently balance the experience of our own effective action, in our one head, with 'things' out there in the world, against the inner promptings of imagination and feelings, in sympathy for what other 'persons' know and feel.

The first materialistic 'theory of human minds' assumes that the basic process is a *sensory input processing* of 'information', called 'cognition', which is rational, constructive, experi- mental, practical, and to a large extent hierarchical and prescriptive. It is *expressive* in the information transferring sense and has been called *propositional* (Bogen 1969a), and its memory is *declarative or semantic* (Tulving 1972). Of course it is very much tied up with language, and with thinking in the kind of language that states what facts are so.

The second theory gives precedence to *motives and feelings* – internally generated as intuitive, aesthetic, creative, poetic and phenomenological or produced by impulses of action and the 'narrative' of experience drawn from the chosen context of our mental life. It is *receptive* and called *appositional* (Bogen 1969b), with an *episodic* memory (Tulving 2002). Its functions or processes and qualities escape unique verbal definition, and require metaphorical allusion.

Corresponding antitheses affecting both theory and method seem to apply in all the sciences, which may be classified as *exact* (or restricted) or *inexact* (or unrestricted) (Pantin 1968). According to the account Albert Einstein gave to the mathematician=psychologist Hadamard (1945), mathematics itself, the symbolic technique for making precise representa- tions of thinking, depends for its invention on 'sensations of bodily movement' which create the solutions before the exacting symbolic summary can be made.

The antithesis certainly does apply in contemporary psychology, which is concerned to be 'exact' and 'reliable' before its 'validity' has been ascertained. The training students of psychology, and the professional literature, heavily favour the interpretations of propositional consciousness and seek evidence from experiments that control for 'random' behaviours deemed 'out of stimulus control'. Scientific psychology has tried to avoid or deny the spontaneous, intuitive components of embodied mental life, and currently explains these as secondary *products* of cognitive processing. However, developments in the explanation of how the brain works, based on both clinical neuropsychology and functional brain imaging, are pushing towards a more synthetic understanding (Damasio 1999, Jeannerod 2006, Gallese 2003, Gallese and Lakoff 2005). Comparative psychobiology and ethology, of course, favour a balanced account that acknowledges the clever subcortical motivations of language-free animals that do not perform elaborate operations of logic (MacLean 1990, Panksepp 1998a, Merker 2006).

The choice, between the 'rational discernment' of experiential material, coolly estimated in single heads, and the creative activity that *makes* experience with socially communicated emotional colour, has profound consequences for how we try to build and apply a psychology of music. Even the rhythm of music, its essential vitality or 'flow' and 'style', which is so socially infectious, has been translated as 'meter' and explained as an abstract information processing cognitive system, or as a set of cultural conventions. This theory leaves in the dark any inner, creative source of the pulse, phrasing and melody of the musical behaviour of an individual or of a group of musicians, as well as the interpersonal appreciation of the music by a listener or audience.

However, there is accumulating scientific evidence that both types of explanation may have natural foundations that the brain has inherent anatomical systems that indicate the two kinds of consciousness are complementary regulators of our intelligence. They have been identified, from research with commissurotomy patients who have the cerebral cortices surgically separated, with different cognitive functions of the left and right hemispheres of the human brain: the left being more able at focussed identification and deduction from collected identifications, and with more responsibility for linguistic semantics; the right being more regulatory for the whole body of the self, more alert to the context of discriminations, and more sensitive to the interpersonal emotions that regulate sympathy of action and experience and the persuasive dynamics of expressive linguistic syntax (Sperry 1982, Trevarthen 1984). However, it appears that the cerebral asymmetry of function elaborated in the cortex, and assessed by various forms of neuropsychological intelligence test, is itself generated and maintained by a deeper causal asymmetry of adaptive motives and emotions arising far down in ancient components of the central nervous circuitry, in the brain stem and limbic structures of the hemispheres (MacLean 1990, Panksepp 1998a), an asymmetry that is evident from the beginnings of human cerebral ontogeny, before the intellectual apparatus of the cerebral cortex begins to form (Trevarthen 1996).

Indeed, these two ways, that animal action is related to perception of stimuli from the world, and their synthesis in the motivation of the whole individual actor, have an ancient evolutionary history, being essential regulations of the movements and perceptions of even in simple life forms. Comparative neurology has firmly established the principle that the central nervous systems of animals have evolved to generate rhythmic patterns of behaviour and to regulate them by selective awareness of the layout and resources of the environment in relation to the form of the body, which determines the spatial 'behaviour field', and by the timing of movement, which drives forward the process of experience in relation to *intentions and expectations of a Self,* even in an earthworm (Merker 2005). It is important that, in both tadpoles and human embryos, spontaneous rhythms of motor activity occur in development *before* sensory guidance is established (Lecanuet 1996, Sillar, Reith and McDearmid 1998). Moving with an adaptive purpose comes first, before sensing and perceiving, which are its servants, and both moving and perceiving are evaluated by emotions generated at their source.

A scientist may, accordingly, approach the phenomena of music in these two different ways. One, old, highly respected and most active in contemporary psychology and musicology, is *psychophysical.* It sees music as *things* (tones, pitches, timbres, harmonies, rhythms, melodies, compositions, etc.) that can be defined 'out there' in the physical world of sound (Helmholz 1863). These elements can be encoded in the conventional notation of musical scores, a technology that stores the sound of music as text stores language. Music becomes an artefact that the human brain as the organ of the mind can pick up, perceive, learn and manufacture for the purposes of communicating *information* of song or instrumental performance to other human minds and brains (Roederer 1995). Music is *sound things* that, through sensory transduction and perceptual and cognitive processing, can stimulate us into moving, can change our feelings, or can activate memories of hearing. Its sounds *cause* movements and *excite* emotions, and these help the formation of musical memories. Musical actions and experiences are *products*, after sensory input perceived. The sound is in some sense active, but its making is not, except as a form of imitation or an acquired skill.

Having studied the spontaneous rhythmic movements of infants from birth, and the innate 'musicality' of their vocal and gestural communication with parents in extended engagements, I take the complementary position, and I propose a different theory of music, a *psychobiologi- cal* one. This sees music, with all other kinds of humanly perceived phenomena, as first an aspect of rhythmic motor activity or what we do – a sound-creating life process that we do in our own time, by moving our human bodies (Trevarthen 1999). Music, and its emotions, as some philosopher students of musical cognition and neuroscientists have proposed, are products of, or 'caused by', the motives of the body moving, and they communicate by some process that transfers the intrinsically generated pulse and quality of movements between persons, their minds and their brains – from body moving to body moving, or to a body feeling *as if* it is moving (Damasio 1999). Musical experience, of individuals or in communities, is, therefore, according to a psychobiological definition, the sound, real or imagined, of a human body moving in sociable, ‘story telling’ (dramatic and ritualised) ways. Musical actions and imaginings are *causes* of musical perceptions and cognitions – the meanings of music are musical *creations*. A scientific theory for musical life requires information on the nature of spontaneous animal movements, on animal expectant awareness of moving, on how animals sensitively regulate their physiological economy to maintain the flow of energy required to move well and effectively.

The mystery of human music is connected with an older mystery of animal vitality in movement – the *animus*. All animals move, and all animal movements are rhythmic or pulsing. Movement is measured in units of a *time for life* that is generated in the nervous system. The active 'central' nervous system integrates, coordinates and regulates moving, setting up integrated patterns and processes of cell activity that seek perceptual information from the 'periphery' of the body in animate time. Centre and periphery 'correspond' or synchronise, and their complementary patterns of activity 'mutually assimilate' to guide effective actions of benefit to the whole organism as a conscious and intentional subject. Every animal organism has regulating' processes *within and between bodies* of foetus and mother, and its main 'frontier' is at the placenta. It is named *amphotero- nomic*, meaning regulation of an intensely shared state of vitality together 'in containment'.

The second requires exchange of information from experience-seeking postural, facial, vocal and gestural movements that engage in the infant-parent dyad and that carry evidence of psychological states and their changes *within and between minds*. Mind states are transmitted 'face to face' over an emotionally regulated 'intersubjective frontier' by means of the forms and dynamic modulations of expressive movements and their 'mirroring'. We name this *synrhythmic*, meaning a joint dynamic control of the rhythm of moving through mind time, generated impulsively like in a flowing river (Trevarthen et al. 2006).

Both these dynamic regulatory processes feed the actions and experiences of music. Both are involved when music is deliberately used to create drama in artistry, to assist education of particular skills, or therapeutically, to benefit processes of healing or the alleviation of stress and discomfort.

Depending on the correspondence set up between internally generated motor images or action plans and environmental 'objects' or 'identities', the active animal is capable of modifying expectations and evaluations of what it experiences – it *learns* to seek certain experiences and to avoid others. It builds a 'personal narrative history' of what is good and what is bad. Evolution has progressively modified this testing of the world and learning how to use it so that separate individuals can share what they intend and how they experience the consequences of what they do. Animals in relationships and communities set up 'social correspondence' that links their actions in cooperative ways. This depends on a set of brain functions in one individual that 'sympathise' with the intentions and emotions associated with actions in other individuals, joining the dance of life expressed in various 'ritual' ways. There are special modifications or 'ritualisations' of innate self-regulatory motor systems and intention movements to reinforce this sympathising (MacLean 1990, Porges 1997, Wallin 1991, Trevarthen 2001).

A theory of Chronobiology, or, as I prefer, Biochronology, must explain how biologically created 'time in the mind' manages both *ergotrophic* action of the body in the world and the *trophotropic* 'housekeeping' of energy within it (Hess 1954, Wallin 1991). These essential functions of animal life, we shall see, operate in different organically generated bands of time, or with the regulation of different 'biological clocks'. The rhythms set up by these time-makers for moving and experiencing in human bodies and minds become the currency of social collaboration, and of all the temporal arts, including music by which deeply sympathetic states are propagated.

Musical moving and *musical narrative time and tonality* may be uniquely human. We humans are powerful mobile animals with immensely complex polyrhythmically active bodies that balance and move about on two feet. We have elaborate activities for sharing the times of both elaborately planned somatic engagements with objects of the world, using especially our hands and mouth, and we display gestures for engaging with one another's intentions and conscious control, which we perceive by touch, by looking and by listening. We are also capable, as are other social animals, of participating in one another's vitally important autonomic changes and the sensations of inner emotional states – of exuberance, power, fatigue, mutually supportive attachment needs, fear of injury or of cold, fight for freedom or food, and so on (Panksepp 1998b). We detect subtle dynamic 'tones' of movement, especially those movements that modulate our vocal productions. Humans have rich *polyrhythmic vitality*, and *dynamic qualities of emotion* ('vitality affects'; Stern 1999) that enable both self-regulation and sharing of the efforts and rewards of living – as these arise in the urgent present (Stern 2004), and as they are motivated and re-experienced or 're-presented' through imagined and remembered times.

These facts of the fundamental processes of life in a moving human body, and how they build up and are shared in relationships and communities, establish the foundation for a natural science of the personal and interpersonal experience of music. The sounds of music can express all tempos and qualities of essential human motivation, transmitting both rhythm, and immediate sympathy between persons in social groups. Music can create rewarding projects that become lasting memories that bring people together (Malloch and Trevarthen 2009).

As the quotation above from Whitehead has explained, successful mastery of environ- ments by life forms requires 'societies of cooperating organisms' that act together. Life of larger organisms depends on confederations of cells that *make time,* and share it, commu- nicating changes in the energy of their separate vitalities, coupling them in synchrony. The integrated activity of large organisms, with many different time-making assemblies, can transform slowly as in the growth of a tree, or quickly as in the flying of a humming bird or a mosquito. Hearts pulse, lungs breathe, guts rumble – eyes flicker, muscles, push, pull, snatch, glide or tremble, and limbs creep, walk, run and jump. All such movements are made possible by obeying the regulations of flexible 'time assemblies'. All animals move purposefully, with estimation of the energy needed over periods of single acts, to complete longer projects, or to pursue projects of a day or a lifetime. To do this they have to control the urgency or relaxation of the prospects of moving by changing the way their time-making systems are coupled. They assess the future of their times of action, the benefits or risks, with emotions of pleasure and pain, satisfaction and anxiety, curiosity and fear that are expressed in the rhythm of action, or as moods and desires that change much more slowly. They seek exercise and check or accelerate their movements to oppose or avoid the destructive effects of stress.

Organic time makers, called 'biological clocks', are not, as mechanical clocks or metro- nomes are, closed within themselves. They have to be open and adaptable, prepared to 'negotiate' with circumstances, which are always subject to change. All organic time makers, in tissues, organs, visceral activities, forms of growth or the coordinating brains of mobile individuals, are designed to be 'reset' – excited to quicken, or sedated to a lower rate. Within the body they are open to one another, and the collective one is responsive to the world outside each organism's adaptive form. Trees respond in synchrony to the cycles and vagaries of the seasons, with opening of flowers and leaves, and the ripening of fruit. Animals react to the rhythm of the immediate experiences their movements stir up, and to the intentions of one another.

Each time-making unit is *creative*, guided, but not fully 'determined', by inner 'genetic' constraints of process and form. An organism is not just a 'dynamic system' that is free to proliferate 'emergent structures' by chaotic encounters between the elements.

Time makers of life have evolved into meticulously regulated physiological states, hormonal systems, and the motives, emotions and moods of brains, all of which estimate and control the energy resources of the organism. They balance inner metabolic need and outwardly directed motor use. Cognitive engagement, with the environment, perception and remembering of information about its resources and changes, *serves* these motive processes; it does not create them.

The great 18th Century philosopher of the Scottish Enlightenment Adam Smith in his "Theory of Moral Sentiments" (1759) took 'sympathy' to designate any kind of 'moving and feeling with', whether motivated positively or negatively, and including posturing and acting in the same expressive way as another's body. He said:

"*How selfish soever man may be supposed, there are evidently some principles in his nature, which interest him in the fortune of others, and render their happiness necessary to him, though he derives nothing from it except the pleasure of seeing it.*"

"*Sympathy … may … , without much impropriety, be made use of to denote our*

fellow-feeling with any passion whatever." Part I – Of the Propriety of Action; Section I – Of the Sense of Propriety Chapter I – Of Sympathy.

By recording spontaneous generation of rhythmic waves of impulses in the nervous system of pieces of cut up earthworms, watching the fin and tail movements of idling fish, and simulating bird flight with models, physiologist Erich von Holst totally refuted the idea of coordination by chains of reflexes or input-out links and conceived the model of 'loosely coupled oscillators' (von Holst 1973, von Holst and von Saint Paul 1962). The coordination of the rhythms of trunk, two arms, hands and fingers in the playing of a pianist is such a system, but one exhibiting much more versatile, and reflective, generation of motor sequences which engages a rich store of imagined and remembered actions and experiences, and ritual forms by which they may be communicated to others.

Von Holst, with Horst Mittlestaedt (1950), realised that the neural instructions to muscles generating body movements had to detect their effects, in anticipated 're-afferent' stimulation, and make adjustments to assimilate or avoid them. Roger Sperry, at the same time (Sperry 1950), proposed that a 'feedforward' signal of intention to move, which he named 'corollary discharge from efference', was essential background information for the detection of the difference between actions of the self and those produced by events or agents in the outside (out of body) world, a problem reflected upon by Helmholtz earlier (1856-1867) in his consideration of visual awareness of a stable world in the presence of intended eye movements.

This admission that effective movements of an animal require subjective anticipation of their effects and that this can be the basis for a function that detects other subjects moving is now the central idea of a new theory of how self-other awareness is mediated in the 'social brain', how the intentions of movement in individuals become 'interpersonal' currency (Thompson 2001, Jeannerod 2006). Physiological studies of the activities of neurons in the prefrontal and superior temporal cortex of monkeys, and functional brain imaging of patterns of activity in cerebral tissue, have proved that social mammals have some kind of direct access to the action imaging strategies other movers use to coordinate and regulate their own movements (Gallese 2003, Rizzolatti et al. 2006).

This sharing of impulses to move, and the feelings associated with them, is precisely what Adam Smith meant by 'sympathy' and it is important to point out that the process that links subjective experiences cannot be a simple reflective 'mirroring'. The sympathetic systems engage motor images in reciprocal and *emotionally charged negotiation* of possible cooperative activity – intersubjectively (Thompson 2001, Bråten 2007). They are directed, coordinated and sequenced with the involvement of an extensive subcortical Intrinsic Motive Formation, incorporating the affective regulations and coordinating conscious environmentally directed action with vital functions within the body (Trevarthen and Aitken 1994, Panksepp 1998b, Panksepp and Trevarthen 2009). 'Mirror neurons' deserve another name.

The first comprehensive modern theory of intentional coordination and regulation of movements was articulated in the 1930s, before von Holst and Sperry published their conclusions, by the Russian physiologist and bio-physicist Nicolas Bernstein (1967) on the basis of accurate measures of the displacements of limbs of soldiers, athletes and workers, and from calculation of how they mastered the inertial forces of their component parts and their engagement with environmental objects and media. Bernstein proved the need for a rhythmic 'motor image' that had to plan desired muscular effects and sense the actual forces created in the process (Fig. 3). He concurred with Baldwin's concept of self-imitated 'circular functions' in motor control (Baldwin 1895) and anticipated Piaget's theory of 'object schemata' (Piaget 1953, 1954).

Bernstein's account of changes in locomotion during development from infancy, and of its involution in senescence, helps clarify his general theory of the creative and adaptive interactions between the cerebral centers (neural structures) and the periphery (motor and mechanical structures and sense organs); that is, between what he calls the *central* and *peripheral* 'synapses' or 'cycles of interaction' – complementary locations for integrative adjustments within, on the one side, the motivating 'motor image generating' centres of the CNS, and, on the other, the pick-up of information at the sensory-motor junction of the body with the environment. The theory assists appreciation of what is involved in the perfection of mature coordinated movements.

In the human social sphere we can relate this conception to the 'zone of proximal development' of Vygotsky (1967), the region in which a teacher aids the aspirations of a pupil in 'intent participation learning'

(Rogoff 2003), or where a music therapist 'improvises' new powers of communication with a client (Nordoff and Robbins 2007). In either case one human agent enters into collaboration with the *intentions* of another, assisting the latter to a higher level of skill, motivation or emotional regulation.

"*There is no question in my mind that to experience music only through the ears is like eating your food with no experience of what it tastes like. For me personally, I have to open up every fibre of my being to be a giver or receiver of sound.*" (Evelyn Glennie, in Dorothy Miell, Raymond MacDonald and David J. Hargreaves (eds.) (2005). *Musical Communication*. Oxford: Oxford University Press, page vi.)

Evelyn Glennie is a remarkably talented deaf percussionist who explores the sounds of her performance and the sounds of other musicians in an orchestra with all her senses, giving movement to the sounds her instruments make. She makes music with the impulses of her body monitored by touch and sight so she can 'hear' it, and so it can be synchronised and 'sympathised' with what she sees and feels her companion musicians doing.

Perceptual uptake of the dynamic information caused to excite sentient agents by their movements was made into a coherent psychology by James Gibson (1979), who described the 'invariants' of stimulation that the agents must assimilate by their 'perceptual systems' to direct their actions. Gibson's pupil David Lee has elaborated a comprehensive mathematical model of how brains plan effects in the space and time of actions with rhythm and elegance.
Lee's 'tau' theory adds precision to Bernstein's theory of a motor image to offer a precise account of how great assemblies of neurones are coupled to command effective sequences of muscle action, planning prospective control of purposeful movements of all kinds. He proposes they do so, in all animals and in all modalities of awareness, by closing space=time 'gaps' – between present locations and configurations in space at present moments in time, and desired future positions and states in future time (Lee 2005). The theory of programmed 'gap closure' by centrally generated 'tau guides' also gives a precise formulation of the *quality* of expressions in movements of communication, e.g. in the vocal organs of a singer, or in the hands and fingers of a pianist or drummer (Lee and Schögler 2009).

Now we can better appreciate how intelligently moving bodies exploit their motor potentialities and the masses and consistencies of the media in which they move to get high efficiency at high speed, or to create beautiful effects with maximum command of the flow of energy through their members. Contrasting living, intentional movement with machine motions of robots that only 'simulate' movement, cybernetics expert and philosopher Andy Clark (1999) describes how the blue fin tuna, a powerful aquatic predator, accelerates at what engineers calculated was an impossible rate by stirring a propulsive vortex in the sea and riding it. This may be compared with how an orator of musical artist creates sounds that propel us into imaginary worlds of thought and virtual actions in ways no robot can contemplate. This is the kind of *efficiency of intended action* that Bernstein proved by the measurements he made 80 years ago, and that von Holst (von Holst 1973) demonstrated had to be mastered by a flying bird. It demands a new, more mental, *psychology of agency* in actions, thoughts and communication (Lakoff and Johnson 1999, Thompson 2001, Gallese and Lakoff 2005).

Moving human selves must anticipate effects within their bodies by what they do, they have to accurately anticipate the physical effects on their body movements and perceptions when they encounter or use objects, and they have to negotiate with the intentions of other live and conscious selves. These *three arenas for moving* have different perceptual, cognitive, motor and emotional requirements or rules. Together they make possible the learning of a way of life that is healthy, practically skilled and socially cooperative. I have diagrammed the three aspects of the self as in Fig. 4, which shows how different perceptual systems regulate the various movements.

Sound has a special integrative role in governing all three facets of the moving self. Animals have evolved vocalisation and hearing from the special visceral and proprioceptive mechan- isms associated with feeding, respiration and locomotion. Perception of sounds generated by movements serves many regulatory functions for the well-being of the body and for engagement with the environment, and has evolved as a principal means of social communi- cation in members of all classes of animals. Vocal cries are heard by their maker as well as by social partners, transmitting actions and emotional states far when other senses have no effect.

A listener senses the movement of the body in the maker of sound. A performer hears their sound within them and it guides their expressions in-proprioceptively. They perceive the exchange of sounds in relationship with other performers. Information is carried in the timing of intervals between separate acts, in the intended *rhythm*. Modulation (acceleration and decelleration) within the act expresses *emotional quality*, and over a series of acts gives rise to the story of expression or *narration*. A pitch or intensity plot is one aspect or 'measure' of this modulation. This helps convey the 'feeling' of hearing in the movement. We can appraise the message over different times and these have different meaning for the body, for action in the world and for our communication with other persons. Expressions of visceral and neurohu- moral rhythms reflect metabolic and autonomic changes, and they enable us to synchronise vital states. Screams, shouts, grunts, sighs and soothing hums, coos, laughter and shrieks convey all manner of states of excitement and affection – the harmony and resonance in the moment of a sound and the harmony of rhythms in a phrase, both are expressive of the energy or effort of moving, and of its planned regulation.

There are many reasons to believe that the first human music evolved to make representa- tions of purposes and concerns in singing, to broadcast and enrich the impulses that could be shared in visual contact by the mimesis of theatre, or more intimately by dance. Instrumental music must have come after dance and song, requiring special technical inventions, making learned skilful use sound-making, which is a major proprioceptive sense for all the manip- ulations of primates, as well as for the movements of eating with the mouth.

The special advantages of sound for coordinating states between distant individuals, as well as for establishing relationships in close encounters are evident in many species. The songs of whales and birds regulate the cohesion of the group and the acts of mating. They can transmit the excitements of present events and seasonal changes of motivation (Merker and Cox 1999, Payne 2000, Wallin et al. 2000). Invertebrates, fish and reptiles also make socially important sounds. Vocalisations of dogs, cats and many other mammals, with ritualised postures and actions that make audible and visible signals, set up hierarchies on which collaborative activities in social groups depend by modulating the tone of voice in intimate encounters. Vervet monkeys signal specific information about predators with different calls for different threats (Cheney and Seyfarth 1990). The delicately modulated grunts of female baboons in the strict hierarchy of a cooperative band, all individuals with their own voice identity, show how human conversational noises began (Smuts 2001, Cheney and Seyfarth 2007).

One can see in this social sound making the source of, and need for, song and music, but even the elaborate and changing song routines of whales can be telling little that resembles the narrative of the simplest song or instrumental melody. The difference must be related to how rituals of a human relationship, group or culture represent the inventive imagination and the memory of many shared meanings, how parables of human understanding are made and built upon by the work of different individuals.

Animal individuals manifestly cooperate. They engage their times together socially to assist mutually supportive activities of reproduction and care of offspring, and they link their intelligences in seeking for and consuming resources for life. As Whitehead said, these social collaborations change the 'ethics' of evolution. Human time is enriched by the infinite resources of moral agency, imagination and knowledge that are encoded in language, and represented in the fabrications of other more material technologies. The historical time of culture permits the accumulation of a far more foresightful power of live and cooperative action over nature, new to animal nature – and many new arts – 'story-making' forms of recreation or play. Mark Turner (1996) calls them 'literary parables'. Merlin Donald (1991) identifies their origin in the evolution of an imaginative pretence that is communicated by 'mimesis'.

Music, with all the other playful rituals of the arts, appears to express the culmination of the evolution of coordinated lifetimes, from pulsing of small groups of cells to the ambitious actions of communities sustained by the *habitus* or 'tastes' of culture (Bourdieu 1990). A dramatic performance, song or a dance has all the poly-rhythms of a human body in action, modified by the narrative imagination and memory of the community, creating, telling and retelling rituals of hope, expectation and performance, making them into lessons of emotion by which they acquire value and moral regulation. Musical experiences link past and future, the unconscious with the conscious, making preferences and habits. These temporal and 'imitative' arts are closer to the human need for inventive play, but everything that is 'made special' (Dissanayake 1988) in the human way carries the enriched meaning of Art.

Musical art is not just a recreational resource for the practical intellect, and it is also a communication of physiological or visceral well-being in the body, drawing us into attach- ments, helping us share the emotions of our privately generated experience, as well as the energy of moving. The sounds of music can calm a frantic heart, change the stress reactions of the skin and the circulation of stress hormones, modify the EEG, excite cerebral activities that are limbic and cognitive, perceptual and intentional, engage with the semantic and syntactic functions of language, and link persons in a fellowship of drama and movement that may be peaceful or hysterical, gentle or violent. Musicality is cultivated from the primary energy of human meaning-seeking action, on the syntactic time base of which also rest the logical processes of reasoning and the mercurial references of language.

Music is the manifestation of rhythmic projection of movement and the formulation of 'flow', the expression of inner well-being in dynamic balance between boredom and anxiety (Csikszentmihalyi and Csikszentmihalyi 1988). It articulates fundamental animal emotions of SEEKING with JOY, and can express SOCIAL AFFECTION or RAGE and FEAR (Panksepp 1998b). Working in our memory it enables us to test our appreciation of ritual forms for their aesthetic and moral significance, prompting us to like or dislike different styles and fashions and leading to the formation of groups and identities of performers and the genre of performances (MacDonald et al. 2002).

"*Because music is an outward sign of human communication, and communication can be achieved with or without audible or visible signals, the inner meaning of a piece of music can sometimes be grasped intuitively. In this case, its structure need not be understood nor need its style be familiar to the listener. But if we are to understand fully its outward form as well as its inner meaning, and particularly the relationship between the two, we cannot study independently any of these things, because all three are interrelated. The function of music is to enhance in some way the quality of individual experience and human relationships; its structures are reflections of patterns of human relations, and the value of a piece of music is inseparable from its value as an expression of human experience.*

The common factor is therefore the experience of the individual in society. If the functions, structure, and value of music can all be related to patterns of individual and social experience, we have the groundwork for a theory of music making that can be applied universally". (Blacking 1969=1995, p. 31)

Language and music are activities of human beings and their minds. Neither is a 'thing'. Both are communicative and both regulate social engagement with the world by building tradition of imaginary and remembered occasions, times when actions went well or not so well. Both *tell affecting stories or parables* (Turner 1996, Imberty 2005).

But language *refers* to definite, real things outside the persons who use it. It is *objective* or entangled with reality. Music is about itself, of the person being alive, seeking company. It is essentially *subjective* and *intersubjective*. The stories it tells are *metaphors*, carriers for human will and feelings in action. Musical narrations are made of flowing tensions of human will, with 'floating intentionality' (Cross 2005). Musicality is thus an essential part of the foundation for human communal belonging, and its time-in-action is at one with that of the syntactic serial ordering or sequencing in the information-rich narrative spaces of speech, language spoken, and text, language read (Brandt 2009). That is why the processes of language and music are found to be so intertwined together in the cerebral circuitry of actions, emotions and the perceptions of human-made sounds and gestures, why they cannot be located in processing centers (Turner and Ioannides 2009).

Music, whether in the form of song or of performance on an instrument that imitates the pulse and melody in the breath of song, is not satisfying, either as spontaneous expressions of the human spirit or as products of highly contrived art, if it is not *improvised in the action*, or imagined to be so improvised, as it is between a happy mother and her infant (Gratier and Apter-Danon 2009). Hearing and knowing how to discriminate and name 'pitches', 'intervals' or 'harmonies', to recognising and synchronising with rhythms, these are not what music is about, they are just facts about essential musical substances.

I will present information from acoustic analyses of the generative dimensions of *pulse*, *quality* and *narrative* in the natural Communicative Musicality of parent-infant play (Malloch 1999), which shows that music is not just a feature of human perceptual or cognitive intelligence, one that can be explained by comparing it to the operations of a physical measuring instrument (like a pitch meter), or to a computer (one that calculates associative probabilities). It is the function of a brain that *generates mind information* in the form of *prospective time for somatic acts*, and that *regulates the energy of embodied life* and its emotional expectations in emotional narratives to which all human minds are attracted. Music is something humans are born to do and hear that way. With experience, it incorporates treasured imaginings and memories of the companionship of life, and it can excite joyful celebrations, bring restful peace, or give comfort and healing to a battered spirit (Malloch and Trevarthen 2009).

The minimal unit of music, what distinguishes it from other sounds and noises and makes us attend to its message, is a *phrase tending to narrative*, a melodious or lyrical fragment that 'tells' something, a wordless utterance that invites synrhythmic participation, and even a newborn infant recognises or 'feels' this. Its message blends with the regulatory rhythms of attachment (Feldman 2007, Dissanayake 2000, Gratier and Trevarthen 2008). Linking phrases permit playful negotiation of predictability and creativity, of order and variation transmitting the information by which we distinguish between pattern or structure and variation or process (Gratier 2008, Imberty 2005).

William James (1890=1992), a prophet of what is now the psychology of embodied consciousness (Varela et al. 1991), described consciousness as a dynamic 'stream', and considered it serves the will; and he found an explanation of emotions in sensations of visceral events (James 1884=1922). The regulation of purposes and awareness in relation to the body and to its affective concerns is a preoccupation of psychologists in the last decade (Panksepp 1998a, b, Damasio 1999, Freeman 2000).

Acting with intention and being 'prospectively aware' of the consequences by way of many senses depends upon 'time in the mind' (Merleau-Ponty 1962, Pöppel and Wittmann 1999). Integrated rhythms of brain function guide the progress of body movements and pace the assimilations of perception. This intrinsic timing of animal vitality can be divided into three zones or bands, each with its own functions in the regulation of a moving consciousness, and each with its 'vitality affects' (Stern 1999) or emotional evaluations of the on-going risks and benefits, to the body, of action (Tables 1-3; Trevarthen 1999).

These times determine the physiological regulations of parasympathetic cardiac cycles below 0.03 Hz and

vasomotor thermoregulatory waves below 0.1 Hz, both concerned with breathing=respiration and circulation of the blood (Delamont et al. 1999), and also mental episodes of memory and 'suspended' imagination below 0.01 Hz; that is, occupying the mind for tens of seconds or more in a multi-modal 'working memory system' (Donald 2001).
Mind and body work together in a wide range of periods: maintaining routines of nourishment and rest through the hours, days and seasons; keeping exercise and stress in safe limits; subordinating active and energy consuming 'ergotropic' engagements with the environment to the needs of 'trophotropic' self-regulating vital functions of the organism (Hess 1934).

The hypothalamus of the brain linked through the pituitary with the adrenal and other hormonal mechanisms is a focal point for this coupling of somatic action with autonomic functions of rest and recuperation, but widespread brainstem core and limbic neural systems of emotion are essential to functions that maintain the well-being of the whole behaving organism (MacLean 1990, Panksepp 1998a, b).

The experience of these functions is 'transcendent', beyond conscious present time. They are motivating for bodily action and responsive to energy needs. In communication and in reflective thinking they are 'narrated and interpreted' and they are shared socially by mimetic syntax, by compositions of dynamic gestures and evolved emotional signals, of face, voice and hands.

The physiological regulations are linked between bodies by 'amphoteronomic' engage- ments, as in the intimate ministrations of comfort for sleep, rhythmic touch and body movement and breast feeding of a mother's care for her infant (Trevarthen et al. 2006). The psycho-social regulation of intentions and experience between individuals by 'synrhythmic'
engagement of states of mind constitute dramatic events in memory of imagination, the minimal unit of which is a *narrative episode*, as in a poetic verse or stanza.

It is of great interest to a psychobiologist that the simple form of narrative we have found in natural mother–infant proto-conversations and baby songs has a period of around 20 to 40 s (Trevarthen 1986b, 1993; Malloch 1999). This coincides with the interval found in studies of 'cardiac vagal tone' that record the autonomic cycles of people when they are sleeping – of heart beat linked to breathing – which in turn are coupled to bursts of a activity or 'cyclic micro arousals' in the cerebral cortex, thought to be an integrating mechanism of the central nervous system (Delamont et al. 1999). Clearly the regulated vital states of the body are part of the process of mental integration and they also pace the self-expression that mediates in intersubjective awareness between persons of any age. When baby and mother share the stories of their mutual interest, they are coupling the movements body and soul with this rhythm. They are sharing 'dyadic regulation of psychobiological states' (Tronick 2005).

For mental health a person must keep an 'allostatic balance' that sets the goals for stress management (McEwen and Stellar 1993). Memories and imaginary situations and events activate the mechanisms of activity and estimate the stress or cost to the organism they may entail. Learned anticipations of pleasure or of painful stress are communicated between individuals as they share experiences, purposes and emotions. This enables human beings to find enthusiasm for great and small actions both inventively and cooperatively (Csikszentmihalyi and Csikszentmihalyi 1988), and it also opens the way for trauma and retention of weakness or suffering associated with particular places, events or persons (McEwen 2001). Reforming a person's assessment of risk and rebuilding their self-confi- dence in psychotherapy (Robarts 2009, Osborne 2009a) depends on the proper management of the dynamic balance of slow processes of autonomic and mental change in what we are calling narrative time periods, outside the immediate conscious present. Effective therapy changes the imagination and memory of a 'personal narrative history' (Trevarthen 2006a, Trevarthen et al. 2006).

Behaviours with a period of more than 300 ms – up to around 6 s (0.16-0.3 Hz) – are within the range of fully conscious, felt action of the body, from the fastest controlled movements to coherently organised bouts of action, or expression, or cycles of selective orientation. This time range is identified as the 'psychological present', the dynamics of which are determined by the actions one is performing now, this instant, and in the 'context' known through the seconds of the 'immediate' past and future (James 1890=1992, Husserl 1964, Varela 1999, Krumhansel 2000, Pöppel 2002, Stern 2004). It is the rhythmic time of action in dance and music (Osborne 2009b), in poetry (Turner and Pöppel 1988), indeed in all the 'imitative arts' (Smith 1777=1982).

As with the far-reaching imagined and remembered narrative time, both physiological and psychological regulations are involved. This zone of lived time extends through the few seconds of a relaxed breath cycle, a 'scan path' of oculomotor exploration picking up foci for inspection, and a phrase in speech or music. But these times are further divided in a polyrhythmic hierarchy related to the different ways in which the body segments are moved in controlled ways. Concise, consciously made actions segment the purposeful present – the 'short-term memory' of the experimental psychologist, a bar in music, a 'foot' in poetry, and a slow step are subdivisions, about half of a phrase, or 1 to 1.5 s. Shorter still are single efficient movements; in rhythmic repetition, the beat in music, a stressed syllable in speech – all with a period of less than a second. Detection of incongruous events, challenging prospective awareness, is possible in a time of two or three hundred milliseconds. The foundation of this time range is in the brain control of proprioceptively guided, body-aware, moving (Sperry 1952, Bernstein 1967, Lee 2005). It is ergo-tropic, experienced, and embodied. Its progress is improvised in communication between subjects by a process of sympathetic engagement of both its polyrhythmic 'intrinsic motive pulse' (IMP) and its emotional expression, 'synrhythmically' (Trevarthen 1999, 2005, Trevarthen et al. 2006).

The metronomic scale of music, from a little less than 1 to near 3 per second (around 50 to 150 beats per minute), defines the range of walking; from a very slow *largo*, through a laid back strolling *andante*, or quiet *adagio* or *moderato*, to bright and cheerful stepping out *allegro*, and hurried *presto*. Within this pulse faster movements are articulated with lips and tongue, fingers, and feet (Osborne 2009b). You do not have to be a musician to have these times in you, you use them with varied expression or style, as well as varied intervals in everything you do, and you are born with them.

Only the fastest, automatic movements fall within this range. They are not consciously controlled while enacted, and can only be registered after the event, or possibly employed for control in highly skilled and intensely practiced activities, such as jazz improvisation. Automatic, quick, repetitive movements and articulations, short syllables, fast gestures and glances, *vibrato* and arpeggios have a frequency of 5-6 Hz; a single eye saccade or the tongue in a trill moves at 10-20 Hz; the minimal perceptible event or a fast reflex may have a rate of 25-200 Hz. All of these are constrained by the limitations of brain-generated times adapted to move the body intelligently.

Much faster physical oscillations or vibrations, the periodicities of which are only dis- criminable by physical instruments, are perceived as qualities or tones of the substances or objects that possess them – as colours, pitches and in combinations as tones, harmonies and textures. They enable spaces, media, objects and substances to be identified or 'analysed' as goals for actions with particular properties that may have use for the subject, or pose a danger. They are the 'molecular' categories of semantic reference.

The times summarised in Tables 1 and 3 are disembedded from the consciously com- prehended actions represented in Table 2, and may become dissociated from the *somatic* body. Both are connected to needs and evaluations of the *visceral* body – one (Table 1) to its sustaining processes, the other (Table 3) identifying goal objects.

Infants, like adults and many animals, move with rhythmic gestures that express motive states and changes of emotion and mood. They communicate and play exuberantly. But the communications and play of human infants have a special creativity and message power independent of any practical needs for engagement with the physical environment. Infants are ready at birth to take turns in a 'dialogue' of movements with a loving parent. They are attracted to extended engagement with human gestures, and sympathetic to many emotions – resonating to the impulses and qualities of movement; imitating, seeking an active part in proto-conversations or playful duets of agency (Trevarthen 1999). When the expressive forms are examined in detail, infant and partner are found to be sharing a subtle 'musicality' of communication (Malloch 1999). Very soon the early musical games become the habits or conventions of a mini-culture, improvised creations of meaning for each pair, of the kind that Maya Gratier, after Boudieu (1990), calls a 'proto-habitus' (Gratier 1999, 2003, Gratier and Trevarthen 2008). They become treasured memories of a special relationship.

Human feelings about intentions, and about the contacts and relationships that arise between us, are signaled as changing tensions and contours of muscular energy in vocaliza- tions and gestures, and we regulate these in the rhythms and phrases of performances that may become long and elaborate. The social engagements of some birds and mammals show certain similar features (Tinbergen 1951, MacLean 1990, Papoušek et al. 1992, Wallin et al. 2000, Eckerdal and Merker 2009). But, when the changes of expressions in human engagement are measured precisely, and the rules of their production determined, it becomes evident that human beings have a different, richer and less reality dependent, much more imaginative or 'disembedded' consciousness than other social animals (Donaldson 1992). Human consciousness is ready, even in a newborn infant, to share polyrhythmic mimetic rituals that tell us about elaborations of the flow of consciousness itself, before there is any awareness of the distinctive affordances of objects or events for immediate use, before reality exists outside human moving, and many months before language (Trevarthen 1999, Trevarthen and Reddy 2007).

Acceptance of these abilities of infants for 'intersubjective' communication (Trevarthen 1998) places cognitive processes of all kinds, including those that make sense of music, in a different light. The human infant's mind is not simply processing information related to the stimuli of the environment that may be perceived as goals for the individual's purposes. It is not just acquiring artificial technical skills in the way that the vocabulary of a language is learned, and it is not only perfecting the logic of 'executive strategies', or gaining a 'theory of mind' to 'explain' or 'interpret' what others do or think. The function of infant communica- tion is to enter into dynamic purposeful engagement with projects immanent in the gestures and facial and vocal expressions of other persons – to share, by mimicry, both the sequences of their intentions and the values of their emotions. This is how cultural learning begins (Trevarthen 1994). The information exchanged and combined is *psychological* information generated in the inquisitive and fanciful motive processes of the human mind, processes that put rhythm, order, grace and harmony into the movements of the human body (Lee 2005, Lee and Schögler 2009), and that are communicative about what the movements intend, and how the actor feels about what he or she is doing and experiencing (Schögler and Trevarthen 2007).

The infant's abilities also have importance for current brain science, which is gaining new sophistication in the appreciation of intentional processes and their sympathetic transmission between actors (Gallese and Lakoff 2005, Iacoboni et al. 2005; Rizzolatti et al. 2006). The inborn responsive musicality of infants is a rich manifestation of the representation of purposes and emotions evoked by one individual's brain in the brain of another. It prepares the way for learning a musical culture – for becoming a musician, or for simply enjoying the music and the companionship it brings (Flohr and Trevarthen 2007).

All musical narratives, even the most arcane, appeal somehow to the polyrhythmic human sense of agency with a versatile body, and to the playful engagement of sympathy between different wills. This sympathy can evoke any and all of the emotions, every feeling for the experience of life shared through time and the space of action.

Human minds act, think and communicate by fabricating, in the actions of their bodies, mimetic stories or parables beyond present needs and circumstances (Donaldson 1992, Turner 1996, Donald 2001). Unlike even apes, we occupy our time, not only with food, sleep and sex, but also with exploration of resources in the natural world and juggling places in a social hierarchy. We dream impossible tasks in impossible places, and try to make them come about, seeking help from one another's knowledge and skill to find rewards in an endlessly complicated cultural life, which takes great pains to record what it has done in symbols of many kinds. The processes begin early. Toddlers are more eager to create fantasy play with amusing self-referring absurdity of actions and meaning than to carry out practical tasks. Their communication is full of teasing and tricky make-believe (Reddy 2003, 2005). Research on the motives and interests of young children proves that these aspirations towards fantasy and the desire to share it are born in us (Leslie 1987, Bjørkvold 1992, Flohr and Trevarthen 2007).

All of what human history has achieved appears to depend upon a special elaboration of the rhythmic sense of time that is at the source of moving, and from a compulsion to share the time of moving. Personal life stories are records of dynamic intentional events, the pulse and emotional qualities of which come from inside minds and inside bodies, and from the shared experience of being active and cooperative in human company (Trevarthen 2004, 2006a).

Narratives or stories, whatever else they are about, have dimensions of *intention* and *emotion*: they express the way the purposes of their agents or protagonists move through time, and they convey evidence of the feelings or concerns that change within the hearts of these persons, and especially *between* them. They are rich in the intersubjective, the 'I-Thou' responsibilities that Martin Buber (1958) identifies as the origin of all in life that is both good and beautiful, the space 'between ourselves' that the philosopher Evan Thompson and his colleagues brought to our attention (Thompson 2001). To better understand that space we need what Vasudevi Reddy calls a 'second position' psychology (Reddy 2008).

Musical stories need no reference outside these mind-in-body experiences of moving in search of company; for music, unlike language, is about itself, about how it intends to move rhythmically and gracefully, and about the emotions that craft the progress of its tones and gestures, and how these fabrications may influence the behaviours of others (Brandt 2009, Cross and Morley 2009). It is mimetic, imitating thought with intentional forms of gesture to tell us what 'might have been' experienced, or 'could be' (Donaldson 1992, Feldman 2002). It is constituted as meta-communicative, self-conscious, 'playful' ways of moving (Bateson 1956). It is dramatic because it carries evidence of impassioned human enthusiasm, about joy and hope or anger, sadness and fear. As Adam Smith said, the stories of music live in suspense between imagination and memory, escaping the constraints of reality and of any language that attempts to define reality in objective, I – It ways.

Communicating infants and their partners have taught us much about the source of this inner 'proto-narrative' motivation of story-telling in movement, and about how stories are shared by immediate sympathy for intentions – for what Daniel Stern describes as 'attunement', responding to the 'vitality contours' of 'dynamic emotional envelopes' that evolve between human beings (Stern 1992, 1999, 2000). Music, even for an infant, is not just the sound of a human body or human bodies moving, *now* – it is the use of movement with heightened expressive qualities to make polyrhythmic messages that transport listeners into the future or back to memories (Stern 2004). Infants are born with the sense of this *time in movement*, an Intrinsic Motive Pulse (IMP) that enables them to synchronise with the impulses in the action of an affectionate parent's voice and gesture that seeks to improvise a 'synrhythmic' proto-conversation (Trevarthen 1999, Trevarthen et al. 2006). Even in early weeks, infants learn little rituals of musicality, in vocal games, in simple rhyming songs, sharing with skill and affectionate good humour their recursive events and carefully contrived surprises (Trevarthen 2002). Infants respond strongly to the different moods of action games and soothing lullabies, allowing the vital rhythms of their minds and bodies to be excited or slowed into peaceful states (Trehub et al. 1993, Trainor 2002). These musical games encourage a germinating human awareness of other minds, and shared thoughtfulness (Hobson 2002, Reddy 2008).

Infants prove to have discriminating perception of musical features of sound, especially those that identify the vocalisations of parents and their expressions of feeling (Trehub 1990).

Their vocalisations express different emotions and are sensitive to the emotions in others' voices (Papoušek et al. 1992, Trevarthen et al. 2006, Powers and Trevarthen 2009).

Research that uses sensitive acoustic techniques to capture the fleeting events of sponta- neous vocal engagements between infants and their parents, and that relates these to the regulations of other expressive body movements, such as gestures of the hands or stepping of the feet or the internal rhythms of the breath and of the heart, proves that our musicality has an innate foundation in its rhythms and tones that makes persons of all ages potential partners in its narrations, and potential actors in its interpersonal dramas.

The theory of the Communicative Musicality (CM) of vocal interplay between infants and adults, defines the measures of 'pulse', 'quality' and 'narrative' revealed by meticulous acoustic analysis (Malloch et al. 1997, Malloch 1999). We have used this model to chart the development of varieties and conventions of expression in infant games over the first year, and to investigate distortions when normal sympathy of companionship breaks down (Deliège 1999). It helps us observe how the expressive sequences of proto-musical narratives and games carry human meaning, and suggests how through improvisation, shared musicality may lead to mastery of many kinds of language, many arts and many technical skills (Dissanayake 2000, Malloch and Trevarthen 2009).

The following examples summarise Malloch's findings. The developing musical commu- nications are placed in a chart of age-related changes in infant behaviour and consciousness in Fig. 5. Development of human psychological abilities – intentional, cognitive and emotional – appears to reflect a succession of age-related changes in innate motivations for moving a changing body with increasing awareness and memory of the consequences, and for engaging in new ways with the intentions of others and with the quality of awareness that they display (Trevarthen and Aitken 2003, Trevarthen and Reddy 2007)

A premature baby in a hospital on Holland, cradled under the clothes of her father in 'kangarooing' (van Rees and de Lieuw 1993). Analysis of an extract from the uncut video showed that the baby was responding with skill to her father's imitations of her simple calls (Malloch 1999). They emitted alternating sounds, 0.2 to 0.5 s in duration, in an improvised dialogue that demonstrated the precisely controlled rhythm of *syllables*, and these were combined in the equivalent of a linguistic *phrase*, with the pattern of onset–onset times for the sounds, in seconds, shown in Fig. 6A.

After the first alternation there is a pause lasting twice the alternation time, then a 3.6 s phrase of 5 syllables, the last of which is longer (0.85 s), as is usual in a spoken phrase. A few seconds after this exchange, while the father was attending elsewhere, Naseera called him with a chain of 3 calls at precise 4 s intervals before her father responded (Fig. 6B). The first of these calls was weak, the second much louder and then the father responded immediately to the third call. This proves that Naseera could 'imagine' phrase-length intervals with no help from her father, and that she was 'expecting' to elicit a response from him.

Other research on early infant imitation proves that it is 'conversational', adapted to reciprocal exchanges, and that it is accompanied by emotions of *interest* and *pleasure* (Kugiumutzakis et al. 2005, Trevarthen 2005, 2006b). The emotions of energetic excitement or attentive waiting in imitative exchanges can be detected by recording changes in heart beat, which accelerates as the neonate infant moves to make the effort to imitate, and decelerates when the baby makes a repeat of the act to provoke the adult to imitate (Nagy and Molnár 2004).

Recent work in Japan confirms the findings with Naseera (Watanabe et al. 2006). Premature infants (born 32 to 34 weeks of gestation) were videotaped at around 36 to 39 weeks of gestation in 3 NICU and neonatal units. Spectrographic analysis revealed softer and more subtly modulated sounds from the premature infants compared to the full-term infants. The mothers responded at an interval of 0.65 to 0.8 s, creating a harmonious rhythmic interplay like a duet in pianissimo. Pitch plots showed regulation of melodious sounds in the region above Middle C.

Musical sounds, especially those resembling the mother's voice, can calm distress of a newborn, giving rhythm to delicate life (Standley 2002). It has been proved that in the last two months of gestation a foetus inside the mother's body can hear and learn the individual features of the mother's speaking or singing voice, and there is evidence that an emotional state of stress transmitted to the foetus by hormonal changes, movements or sounds of the mother's body can affect the developing brain (Trevarthen et al. 2006).

In early weeks after birth, babies are alert to the pulse and subtle harmonies of a mother's speech, turning to tones of sympathy, or withdrawing from their absence (Robb 1999). From the start, given appropriately sensitive response, the infant is an active performer, listening and moving in time with the whole body, in intimate song and dance, synchronizing with the poetry (Miall and Dissanayake 2003). Newborns express their emotions with calls of varying power, and they make other subtle messages with their eyes and hands in engagements with events in the outside world (Trevarthen 2002, Trevarthen and Reddy 2007). These behaviours seem already to be seeking to communicate more than any kitten, puppy or nursling ape wants to do, and in face-to-face communication they are sustained with an intensity of purpose that fascinates human parents.

A few weeks after birth, a normally developing baby is more alert able to take part in long protoconversations (Bateson 1975), drawing family members onto intimate rhythmic en- gagements, making them feel affectionate and causing them to use a special kind of moving and talking that is both dancing and singing.

We recorded with video and sound a six-week-old infant, Laura, and her mother talking to her in the laboratory of Edinburgh University, and Malloch (1999) applied physical acoustic methods to graph the energy bands in sounds of the mother's voice in a typical extract of 30 s. He used this spectrograph (Fig. 7A) to measure the rhythm of the mother's speech and the infant's responses accurately. Then he looked at the resonance features of the voice sounds to detect their timbre, or texture.

The mother was measuring her utterances very carefully, controlling their steps and the contours of their phrasing in ways that resembled notes and melodious bars of a musical score. She set up a regular spacing in her utterances at between 1.5 and 1.6 s corresponding to a *bar*, and these were paired in *phrases* of about 3 s (Fig. 7D). Her speech had a lively but gentle main *pulse* of about 1.25 Hz or *allegro*. She varied the width or 'fullness', sharpness, and roughness or softness of her tones to match the changed tension or affection in the baby's voice, holding her daughter with harmonious and encouraging sounds, inviting her, sympathising with her doubts and surprises and sharing her pleasure (Fig. 7B).

When the vocal sounds were transformed to represent the heard *pitch* the mother's voice was shown to explore the octave above Middle C or 'doh' (Fig. 7C). Some of her utterances swooped up or down over more than an octave, like those of an opera singer, but delicately, maybe teasing a little but with gentle respect for the baby's attention. The pitch plot shows how mother and baby shared and 'emotional narrative', that swelled to an exciting climax, then gently came back to repose on Middle C. From time to time the baby made little sounds that fitted the story, all clustered around the keynote of C.

Malloch's theory of the three principal dimensions of this musical conversation is summarised by the following definitions:

1. *Pulse* is the regular succession of discrete behavioural steps through time, representing the 'future creating' process by which a subject may anticipate what might happen and when.
2. *Quality* consists of the contours of expressive vocal and body gesture, shaping time with expressive movement.
3. *Narratives* of individual experience and of companionship are built from the sequence of units of pulse and quality found in the jointly created gestures – how they are strung together in chains of expression that generate affect.
   (Trevarthen and Malloch 2002, page 11).

Laura and her mother shared the making of a rhythmic melody, synchronising waves of effort, making a story of adventure that tells of expectation, discovery, triumph in excitement, and an ending in repose. This demonstrates the 'emotional narrative' of 'proto-conversation'. It grows out of the motives persons of any age have for mutual 'attunement' of what is pulsing in their minds, and what moves the body to be expressive of that pulse, and to share it with another person (Stern and Gibbon 1980, Papoušek and Papoušek 1981, Beebe et al. 1985, Jasnow and Felstein 1986, Jusczyk and Krumhansl 1993, Trehub, Trainor and Unyk 1993, Pöppel and Wittmann 1999, Schögler 1999, Stern 1999, Wittmann and Pöppel 1999, Jaffe et al. 2001, Lee and Schögler 2009).

Recordings of earliest conversations with infants in many different languages show the same measured time patterns and melodious features that Laura and her mother demon- strated. Mothers draw on the musical and linguistic habits of their experience when they choose to talk with their infants, and they thereby unconsciously transmit the cultural forms of speaking and singing (Custodero and Johnson-Green 2003, Trevarthen and Gratier 2005). At the same time they express the universal sympathetic forms of human emotion (Panksepp and Trevarthen 2009).

When there is inappropriate, emotionally unsympathetic and mistimed response from the mother, an infant demonstrates sensitivity to this 'disharmony' of relating by withdrawal and expression of distress. Lynne Murray made an experimental study of this sensitivity by requiring the mother to interrupt her responses to the baby and remain for a short time with 'blank face' and immobile (Trevarthen 1977, Murray 1980, Murray and Trevarthen 1985). The same test, called 'still face' was applied by Tronick (Tronick et al. 1978). Murray also designed a Double Television communication set-up that enabled replay of the mother's affectionate and responsive talk with the baby so this behaviour, though the same in expressive qualities, was no longer responsive. When a happy minute of the mother's live communication was replayed to the baby, the baby became distressed and turned away, proving how sensitive she was to her mother live presence (Murray and Trevarthen 1985, Trevarthen 1993). The effects of perturbation in contact of young infants with their mothers have been confirmed by Nadel (Nadel, Carchon et al. 1999).

There is a loss of musical rhythm and sympathy when either the baby or the mother is distressed or emotionally 'out of tune'. An unwell premature baby is very hard to understand because he or she does not attend and respond with purpose (Aitken and Trevarthen 1997). A depressed mother does not give her baby the musical talk that the baby can respond to and 'sing' with (Murray et al. 1993), and this can affect the development of the child's confidence and ability to learn (Murray and Cooper 1997). Comparison of the speech of depressed and happy mothers talking with young infants show changes in rhythm and in pitch range. A happy one talks brightly in the octave above Middle C, but a depressed one drops to the octave below, and her speaking lacks rhythm (Robb 1999). The tuneless, halting and repetitive talk of a mother suffering from the anxiety of emotional illness fails to support her infant's interest, and the baby becomes, in turn, stressed and may develop a chronic state of abnormal communication (Gratier and Apter-Danon

2009).

A mother's spirit and her expressions of feeling to her baby may also suffer when she is far from her home country and the community she has grown up in – in a place where she does not feel she belongs. A feeling of 'belonging' or being 'at home' in a familiar world with its valued meanings and habits is important for a person who is required to be sympathetic and playfully inventive in a musical way with a young child (Gratier 1999, 2003).

A few months after birth, the baby is alive to the world of things to grasp and touch and taste, to watchand listen to. Thisnew feast of interesting objects draws the curiosity of the infant's mind and body away from the mother, if she speaks softly as she did when the baby was very young. Now she must dance and sing in a more lively way to capture the spirit of the IMP. And that is exactly what mothers and fathers do everywhere. They invent or remember rhythmic games and songs, gently teasing the baby's interest with animated voice and playful touch and gesture. They repeat favourite rituals and the infants learn them quickly (Eckerdal and Merker 2009).

Research on the music of baby songs, and on infants' perceptions of the musicality in them, is now an important field of developmental psychology (Trainor 2002). In the simple unforgettable poems and dancing melodies of these songs we can detect the creative process that makes conscious activity, and its cultivated forms, interesting, memorable, and commu- nicable. The *syntax*, or linking of elements in these simple dramas, making human messages besides the words, is the foundation for the grammatical conventions of language (Malloch and Trevarthen 2009).

For the baby, musicality is the message. Indeed, many of the 'words' in popular baby songs are nonsensical patterns of sound, and many songs have a complex text with reference to historical events or adult concerns that mean nothing at all to the baby. Whatever the words mean, the lively poetry in baby songs conveys the pattern of human intentions that invites the infant mind to get in step and share an other's interpretations of the world with feeling. I say 'in step' because the rhythms of baby songs and baby poems, like the source of all songs and poetry, is the rhythm of walking. Like walking, the pulse of a song or the 'feet' of a poem vary with the urgency or emotion of the journey. In a lullaby they are the *largo* of very slow, careful steps in time with swaying hips and torso. In contented companionship they are a comfortable *andante*, just strolling along. In joyful celebration they run to *allegro*, to which feet and hands can dance.

At five months, Leanne loved to attend to her mother as she chanted or sang. The teasing song, "Round and Round the Garden" attracted her full attention, up to the 'tickling' climax (Trevarthen 1993). She and her mother vocalised precisely together on the last rhyming word, Leanne harmonising with her mother's note. Megan, another 5-month-old child, cooperated with her mother in a much-loved clapping song, holding her hands outside her mother's, and keeping exactly in time. Megan also liked "Round and Round the Garden", though not so much her mother's vigorous final 'attack' which is what makes the song so dramatic. She was very interested when her mother invited her to be the leader, saying, "Do it to me!", and they joined in the pleasure of the final phrase, "a tickly under there".

Musicians know that the sounds they make come and express a dance inside them, an impulse to move with rhythmic grace. Microanalysis of the movements of Maria, a totally blind 5-month-old girl listening to her mother sing two songs in Swedish demonstrates vividly the innate sympathy between their bodies, a shared feeling about the moving that is independent of which part of the body is being expressive, vocal tract or hands. The baby's hand serves as dancing partner to the mother's voice (Trevarthen 1999, Schögler and Trevarthen 2007).

This is an extraordinarily important case for the science of psychology, because it shows how the motive pulse, the IMP, in the baby, directing activity in muscles of her arm and hand, 'hears' the mother. It assimilates the message heard in the movements of the mother's musical vocal system and feeds them to the rhythms of the baby's hand waiving in a space of melody imagined around her body. Her hand points up to her head as her mother's voice rises in pitch, and drops at the wrist at the close of a stanza, just like the gestures that would be made by a trained conductor who is leading an orchestra. We have to accept that this is a pure innate intuition for the impulse of music, because the baby has never seen her own hands move, or any one else's. She feels the music in her being and moves to let it out.

Moreover, the infant is, like a conductor, *leading* her mother in time. Each of her imitative movements occurs a third of a second *before* the mother's voice moves correspondingly up or down. They move with an elastic coupling, exactly like two dancers or improvising musicians, and from time to time the baby leads, as if she were *causing* her mother's song. She shows her pleasure in sharing these favourite songs by laughing as soon as she hears the first notes of the second song.

The performance of this blind baby is in complete accord with the neurophysiologists' interpretations of brain systems, now known to be very extensive in cortical and sub-cortical systems, that mediate 'mirroring' of actions by identifying, not the particular form of movement, but the motivation or purpose (Rizzolatti et al. 2006, Turner and Ioannides 2009).

As a baby becomes stronger and more aware of the context of experiences at three or four months, so he or she is increasingly motivated to be a performer, one who *tells the story* to others (Trevarthen 1990). From first participations in imitation of a parent's actions and expressions, the emotions of *interest* and *pleasure* mark true intersubjective cooperation (Kugiumutzakis et al. 2005). The sharing of purposes is rewarding to the self. By six months a baby has sufficient independence to show this pleasure when taking initiative in the performance of a learned game (Trevarthen 2002, 2004). We are impressed with what *pride* a baby accepts the message of a song and shows it with the appropriate gestures when far too young to really sing (Trevarthen 2002).

We filmed this pleasure in 'showing off' a learned performance in the University studio. Emma at 6 months was an eager pupil as her mother taught her how to clap to "Clap-a-Clap a Handies". At home we recorded her big smile of pride as, looking intently at the photographer standing beside her mother, she showed her hands clapping when her mother invited her by saying, "Clap Handies!" But Emma's emotion was very different in front of a friendly stranger who did not appreciate what she was showing him when she offered her clapping. He said, "Aren't you going to say something to me?" She became *ashamed* and unsmiling, made an awkward gesture to her head staring at him, then looked away and gently patted her hands for herself (Trevarthen 2002). It is hard when your proudest sense of knowledge and skill is not appreciated. That is why unfamiliar people are not always harmonious company, why their lack of appreciation seems to sound a wrong note. They just do not know how to behave.

These examples illustrate how the musicality of human relating grows in the early months. How creates a world of shared meaning and helps build confidence in other persons' kindness and willingness to share memories, projects and discoveries in ritual forms. By the end of the first year, when the infant has acquired a firm sense of purpose in the use of objects, and an interest in sharing other persons' intentions, it creates a rich mutual awareness that leads a baby to learn quickly many human creations, and how to use many kinds of tool. In a few months the wonderfully flexible and productive tool of true language will be mastered, opening the door to naming of ideas about things that belong to other places and other times, or even the making up of stories about impossible events and creatures. But first what are shared are actions and stories in the present, using what is available 'metaphorically', to invent, build, and celebrate new realities, to 'pretend', and to recall rituals and tasks practiced before.

We have recorded how just nine-month-old babies want to share familiar tasks and take suggestions of new objects or actions from their companions who, if they are sensitive and respectful for the baby's new cooperativeness, become guides and teachers, changing the way they talk and show (Trevarthen and Hubley 1978, Hubley and Trevarthen 1979, Trevarthen and Marwick 1986, Trevarthen 2004), and we have compared two very different cultures (Trevarthen 1988). Basilie, in Edinburgh, was much interested in books and written messages she could share with her mother, though of course she had no idea at all what the words meant, and probably not much idea of the pictures either. Nevertheless, she behaved with total confidence and authority, even sometimes being bossy, telling her mother what to do in an 'authoritative' manner. Adegbenro in Lagos, Nigeria, loved being a musician with his piano, sharing it with his mother and aunt and 'playing' and 'singing' for his own pleasure, and he also asked for and showed his rattle to everyone.

In Crete, Katia Mazokopaki has filmed the joyful recognition of songs shared with mothers, and how under babies under one year respond to recorded music by *listening*, searching for the sound, *smiling*, then bouncing and waving arms in *rhythmic imitation* and attempting to sing.
They are aware of the new strength in their bodies and enjoy celebrating it by 'dancing' to music. The pleasure of participating is clear, as is the need to bring the dramatic sounds into movement (Mazokopaki and Kugiumutzakis 2009).

As the child takes first steps to walk alone, a seriousness, even anxiousness, appears that might seem to threaten the musical sympathy and inventiveness of earlier play. Now a child wants to study the practical intentions of other persons, to use objects as they do, and to perform acts of communicative display, including first words, in the important conventional manner. Then, as walking becomes easy, there is an exuberance of imitation in inventive fantasy play not seen before. The toddler is a creative musician and dancer, loving theatrical play with peers, like the happy 6-month-old child with mother or father, but much more inventive and confident in sociability (Bjørkvold 1992, Custodero 2009). With same-age children, imitation games are made into a kind of market place for ideas, each new invention being shown to others, with the hope they will do the same (Nadel-Brulfert and Baudonnière 1982, Nadel, Guérini et al. 1999). Toddlers take turns at leadership and the role of dramatist or comedian. 'Acts of meaning' expressed by voice and gesture (Halliday 1975, Leslie 1987, 2005) seize hold of human inventions with a special pride, then wickedly transform them in nonsensical ways, for fun (Reddy 2003). Even an 18-month-old baby who speaks few sentences is already experimenting with many expressive conventions, metaphors and symbols of a culture, enjoying with a familiar companion taking a role in a fantasy game with toy household implements, animals and dolls, or imaginary substitutes (Trevarthen and Marwick 1986). Communicative Musicality flourishes at this age, before language (Bjørkvold 1992, Littleton 2002).

Margaret Donaldson in "Human Minds" (1992) explores how a person's experience of life in times and places – the record of 'loci of concern' in action, perception, thought and emotion – grows in early childhood and through adult life. First, in an infant's early awareness, life is a chain of separate moments in the 'point mode', 'here and now'. This becomes a connected, transforming 'line mode', that can sustain projects and solve problems in memory and thought about 'specific things' at certain times in certain places, 'there and then'. This consciousness is alive in a baby's mind before one year. In the second year the 'core construct mode' where generalities of memory, belief and expectation of events that can occur 'somewhere sometime' transforms experience, assisted by language. Donaldson also posits a fourth phase of human mind work comprising two 'transcendent modes' where thoughts and feelings explore outside space and time, 'nowhere, notime'. These modes of being concern both intellectual and emotional experiences, the latter more concerned with felt values and the former with abstract knowledge of states and events in the world, and how to think about it efficiently and describe it 'mathetically' (Halliday 1975).

We have seen the advances in the early modes of activity and awareness reflected in how infant's 'use' musicality. A six-month-old baby knows a verse and enjoys how the verses cycle through memory, carrying imagination in a 'stream of consciousness' that may lead to sleep or laughter. Each verse has an episode in the whole drama of mood change. Then the particulars of the drama or ritual gain importance and narration is both richer in detail and more intensely personal, avidly taking in meaning of words not just their music. But the memory of the music itself is both the earliest and the strongest one. It is not the logical entailment of word meanings and grammatical functions, or the particular form of actions that may accompany a song that is retained; there is a poetico-musical agency that gives coherence to the effort and emotions of the action represented or generated in the mind in sympathy with all levels of the message.

A one-year-old child can attend to how the steps of a task are ordered or grouped – the executive, constructive organisation of prehensions and the carrying out of manipulations that are led by the investigative linking up of orienting moves. The 'point' of the task or story is constantly being carried by the strategy of what a linguist would call the 'context', but this has to capture the child's anticipations. Many a test of a child's intelligence have been invalidated by the experimenter forgetting that the child has a point of view, and a direction of interest. The 'understanding' is in fact 'over' the live action that created, or will create, the performance.

The processes of narration and recollections of purposes evident in the intelligence of a child on the threshold of language are coloured by new emotions. This more lively and constructive mind explores how a walking, dancing, running, crying laughing, shrieking, singing, humming body is used and discovered. Bjørkvold (1992) gives a vivid account of how the pleasures of moving develop into 'children's musical culture' as dramatic inventions of vocalisation with movement of the body are shared in social games, or created reflectively when a child is playing alone. John Matthews (2004) records how toddlers as artists mix the media of emotional expression while making visible marks with audible song and physical indulgence in dance. The clownish fantasy companion of a happy young child is a multi- talented performer generating narrative rituals with every sense of being and moving.

Our waking and intelligent lives are never free from unconscious currents of emotion, never entirely determined by the objects we use and consume, or the things we manipulate and the tools fabricate out of them. We live in relationships of varied and emotionally regulated intimacy in which perception of the emotions and characters or personality of others link or separate our inner beings, making attachments and antipathies we cannot forget. This is the territory of the unconscious that becomes dominant when our bodies are idle, and when our lives are confused by misfortune or mental illness. The thoughts of a schizophrenic are muddled by anxiety and anger, and depression fills intentions with the weakness of shame, sapping self-confidence.

The communicative musicality discovered by microanalysis of the rhythms and emotional qualities of a mother's communication with her infant has provided a set of measures by which we can understand the processes of therapeutic intervention or those of teaching, and how to make these services more effective (Malloch and Trevarthen 2009). The theory also offers a different way to interpret mental illness and the consequences of developmental disorders that disrupt the growth of cerebral functions of attachment and learning in companionship. CM is a theory of how human vitality acts, regulates itself, forms intimate relationships and grows in friendships, and also how it defends itself when the physical or social environment is threatening and can be underlined by illness.

This is the dramatic story of human life that presents itself as an abstract in infancy, and that develops through toddlerhood to the point where the fixed meanings of words can allow the sense of things to become free of responsibilities in relation to present physical and disembodied reality.

The essential step is that change, how we explain the mind to recognise the primacy of the body moving in the world, projecting the symmetry of its form forwards in a space of behaviours and measuring time as an inner control, the output of an energy plan in prospective control of moving that gives perception its aesthetic and moral feelings, relating the apprehended reality to subjective needs in a community of human minds.

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Chapter 17

Resonance and silence – the significance in medicine

What can music contribute to this? Firstly, we need to distinguish between music as such and music used as a specific tool for a particular purpose. The latter represents a functional approach, which requires the definition of aims, such as alleviating pain through music therapy, reducing medication, reducing the level of suffering, increasing the quality of life, etc. Secondly – and this is the actual subject of my discourse – music as the expression of culture, as a positive alternative to soulless medical procedure.

Our team includes a music therapist, Martina Baumann, who also sees herself as a musician and who visits the clinics where she sings to her accordion. The hospital acts as a place of culture in which people would like to feel that they are in good hands.

In this sense, music and music therapy can also have indirect effect on the lives of ill people – when they feel cared for, when they can gain confidence. Thus, music and music therapy can have a systemic influence on hospitals. And just yesterday I opened a conversation with Mr. Jürgen Majerus that this influence can also be evaluated, in that one can include a hospital's image in the calculation of its cost effectiveness. The costs incurred make economic sense for a hospital when music therapy serves to increase the demand for its services.

I should now like to investigate various meanings attributed in medical circles to the term resonance. In particular, my attention is drawn to the expression 'field of resonance'. In his book 'Symphonie des Lebendigen – Versuch einer allgemeinen Resonanztheorie' ('The Symphony of the Living – Towards the Formulation of a general Theory of Resonance'), the molecular biologist Friedrich Cramer of Göttingen has written that resonance is that which keeps the world together in its inmost being. The essence of this concept, which has its origin both in the world of physics and in music, can be used metaphorically to help us grasp complex relationships within organisms and indeed whole institutions. In the light of the resonance theory, the development of the brain can be seen as a reflection of the world. The phylogenetic process of its evolution has occurred in a constant process of mirroring the world, so that its structure cannot be seen as being separate from the global whole.

This includes, as well, the consciousness of relationships. Joachim Bauer has already had something to say about this in the context of mirror neuron theory. Thus the secret that lies behind a sympathetic charisma can be seen as an effect brought about by mirror neurons. In his book 'Warum ich fühle, was du fühlst' ('Why I feel what you feel') Bauer writes: "To allow the mirroring of other people within oneself, to allow oneself to be moved by their views and feelings, appears to be rewarded by sympathy=empathy (Einfühlung). Studies have shown that we most readily sympathise=empathise with those people who for their part can mirror our feelings in a corresponding way."

Something resonates between people. Perhaps an agreeable atmosphere is engendered. One feels in harmony. The way people in love communicate with each other through their looking at each other and their caresses represents a special form of creating harmony together. The lovers' experience is being seen and fulfilled as something precious, as something like an erotic entity. Even though it has found no place either in medical nor in psychological literature. In the exposition which follows I should like to orient myself on the concept of the human soul and thus chart a course which diverges from the metaphors used in neurobiology.

The philosopher Wilhelm Schmid describes the soul as a nebulous structure, as a space which has infinite potential in two different respects: as an imaginary capacity only to be grasped and dimensioned by interpretation and as the actual extent of an energy form which we think of as a sphere or aura encompassing more than that which is contained within the limits of the physical human body. Of interest here is the idea that the soul is not merely the product of our brain structure, but rather it is the soul which uses the brain; it makes use of the nervous system and manipulates it. Albeit to date no clearly identifiable centre has been discovered within the brain which controls the will. The psychiatrist Christoph Mundt of Heidelberg compares the brain to an orchestra without a conductor. How do musicians behave without a guide? Are they then perhaps even stronger in the absence of a conductor, in a state of balance between listening and being active? That which we refer to as 'free will' is practically irrelevant in such a situation. Instead, consciousness can be grasped as a state of sensitive suspension. This expression was coined by the music therapist Eckart Weymann from Hamburg. From the purely linguistic point of view, resonance means essentially an echo, an answer with an equal voice, riding together upon the same wave of sound.

As well as the harmony, however, there is also discord. Dissonances in dealings between humans often invoke an impulse to 'draw the line' – thus a patient wishes to feel cared for, to be treated with respect, and instead of that he or she experiences the hectic rush, contention, time pressure … From the psychological point of view, a lack of resonance is not necessarily to be equated with deficit, but instead it may also have a value in itself, for instance as the means to achieve autonomy and the ability to deal with conflict situations, i.e. to set up appropriate boundaries.

That is to say, people are not simply at the mercy of the phenomena which we associate with resonance, but they are capable of adapting their preparedness to 'resonate' according to circumstances. Here is an example from my consultative practice: A cancer patient was very concerned about the state of her immune system. She frequently felt stressed in the evening when her husband returned home from work. The husband, an impulsive, energetic man who needed to let off steam, was very loud and he filled the whole house with his agitation. As an example of resonance, his behaviour induced an equivalent feeling in my patient. Involun- tarily, her whole bodily system reverberated in wanted resonance with this source of stress and she was afraid that her immune system might be endangered. In the context of this treatment situation it proved necessary to nominate the husband as a co-therapist, to explain how the pair's behaviour interacted and to show them the importance of boundaries. The interplay which takes place between people causes a transfer of energy which can be beneficial, but may also be harmful. This depends partly on the 'dosage level' in each case and also on the attitudes of those taking part.

In my medical-psychological working group at the University Clinic in Heidelberg, we are cooperating with the Gynaecological Clinic in order, amongst other things, to find ways of promoting ill peoples' ability to see their preparedness for resonance in a more conscious manner. For instance, we encourage breast cancer patients to perform exercises with their partners, insofar as they have one, in which they present each other with music. We have about one hundred musical instruments from all over the world which can be played without one having learned to do so. Thus patients can learn to listen to each other with new, experimental and creative methods and also express themselves in new ways. Another concept which we put into practice in receptive music therapy involves listening to music, at first in a group. Then the patients take the respective discs home. I have also produced my own CDs for this purpose. One can make useful discoveries: When is which type of music beneficial in which contexts? For instance, in the case of chemotherapy, when one is anxious.

The point of the exercise is to make conscious decisions as to what one is prepared to allow into one's own sphere and what not. A special form of self-regulation with respect to resonance preparedness can be the decision in favour of silence. The music therapist Monika Lagler from Vienna has presented what I consider to be a ground-breaking study on silence in music therapy for which she was awarded the Johannes Eschen Prize by the German Music Therapy Association (Deutsche Gesellschaft für Musiktherapie). Monika Lagler holds the view that, despite the bombardment with sensory input contained in today's world, quietness is available and has something to say to us. This notion presents quietness, stillness as a positive entity, not merely the negation of the world of sounds, noise, bustle and clamorous hectic. We can make a conscious effort to allow quietness to emerge and, under certain circumstances, to have a healing effect. In this way it is possible to engender a field of resonance for the deeper dimensions of the art of healing. Yehudi Menuhin puts it this way:
"He who wishes to take in sound in its entire dimension must have experienced stillness – stillness as something substantial, not just as the absence of sound. This true silence is clarity, but never colourlessness; it is rhythm, it is the ground of all thought. All creativity grows out of this."

In his book 'Psychologie des mystischen Bewusstseins' ('The Psychology of the mystical Consciousness', 1976), Karl Albrecht invented the term 'Versunkenheitsbewusstsein', which translates approximately to 'contemplative consciousness'. With this he captures the image of a fully integrated, unified and simple, very clear and 'empty' state of consciousness, a consciousness whose stream of experience is slowed down, whose essence is calm and whose single purpose is introspection. In cloisters, churches – and in hospital chapels and meditation rooms in psychosomatic clinics – places of peace and silence are sometimes indeed dedicated to the encounter with the sacred.

Existential borderline experiences can impart a sense of consecration. It is my personal belief that opportunities of encounter with what we call 'holy' or 'spiritual' are of great significance for the curative process. Those people who are ill have a need to feel supported within the context of a greater whole. Nevertheless, stillness can also engender fear.

At the end of the day it is nothing more or less than a question of consideration, of awareness that in this one costly moment of encounter between therapist and patient both are practising the art of healing together. Aspects of this include the search for meaning, the achievement of awareness, the air, the act of breathing, and mortality. A music therapist with whom I worked in Hamburg during a high-tech project in the Radiological Clinic, Friederike von Hodenberg, used to take her lyre with her to patients' bedside and sing very quietly to them or indeed with them. The simple existence of this quiet encounter, its pianissimo led to remarkable changes in the way we all interacted with each other. When a nurse entered the ward for some reason and noticed the music therapist quietly communicating with a patient through her voice and instrument, then she would naturally allow herself to be caught up in this resonance field and not wish to disturb it.

On a recent visit to Japan I was in a conversation with my colleagues on the subject of stillness. Somebody mentioned a poem by Basho, in which he likens stillness to the music of cicadas. As I find the 100,000 cicadas which often disturb my Mediterranean peace rather annoying, I asked a Japanologist, Professor Schamoni of Heidelberg, to trace this poem for me.

He obtained both a German and an English translation, which I should like to recite to you and then present a musical improvisation as accompaniment.

Tranquillity
Tief bohrt sich in den Fels das Sirren der Zikaden. Stillness sinking deep into the rocks, cries of the cicada.

Another English translation runs as follows:

"In the utter silence of a temple a cicadus voice alone penetrates the rocks." Now I have at last reached the essential part of what I wish to say to you.

To help people undergoing treatment to feel that they are 'in good hands', it is necessary to provide resonance fields which open a space for the whole gamut of human feelings within the institutions of the health service. Only thus can a stable basis for a common experience of 'l'art de vivre' arise. Further, a therapist must know which feelings he himself=she herself is unable to accommodate. Such feelings include fear next door to hope, the deep disappointment accompanying a relapse, utter despair, the fear of death, the jagged knife-edge of pain, the existential torment, need, anxious anticipation, the fear of the final devastation of all hope – but also consolation, caring, being able to shout out loudly, at birth but also because of fear and pain, and not least the joy, the joie de vivre, universal understanding, as proof of the will to live, as the common experience of that which makes living worth while.

Along with this, there is the bustle of the doctors, the sterility of the white coats, the time pressure, the decision making, the hospital bureaucracy, balancing budgets – but also gratitude, which I for one consider to be the most important source of spiritual energy.

Therefore I gladly give my patients something, such as my time, of course, my attention, sometimes even one of my CDs with my music.

A therapist who wishes to help other people to gain access to these deep dimensions of human feeling must first ask whether he himself has found access to his own feelings. To this end music opens up wonderful possibilities. In this way a person can, over and above the skin-deep resonance which can only manage a friendly slap on the back and an: "It'll be all right.", develop a more deep seated resonance. But every therapist must find his own, individual way of doing this. Music has been of great help to me along this path. It has enabled me to keep my own 'sacred space' open wide enough for me to believe that now, as a teacher of tomorrow's medical practitioners, I can present myself as a medium which they can use initially as a means of orientation and from that point find their own way to their own selves.

Now I should like to present a short improvisation on the basis of the poem by Basho. Please regard it not so much as an artistic performance but rather as an opportunity, here in this conference hall, to explore part of your own inner physical and spiritual temple. I shall read it once again:

Stillness sinking deep into the rocks, cries of the cicada.
In German: Stille. Tief bohrt sich in den Fels das Sirren der Zikaden. (performance)
For further information on the author's publications, see: www.rolf-verres.de

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Chapter 18

Emotion modulation by means of music and coping behaviour

A large number of previous studies provide support for the proposition that listening to music not only influences the listener's current subjective emotional state, but is also associated with peripheral physiological changes which are taken to be the indicators of a central emotional stimulus processing mechanism (McFarland and Kennison 1989, Sloboda 1991, Vaitl et al. 1993, Krumhansl 1997, Nyklicek et al. 1997, Schubert 2001, 2004). Whereas it was long held that subjectively experienced emotional states are the result of a cognitive evaluation of existing environmental stimuli (Schachter and Singer 1962, Schachter 1964, Lazarus and Folkman 1984, Lazarus 1991), we now know that a reaction to emotional stimuli can take place even without the primary participation of higher cortical structures (LeDoux 1992, 1994, 2000, Cardinal et al. 2002, Zald 2003). Furthermore, the development of new imaging techniques has enabled us to establish that listening to music not only affects neocortical structures which are responsible for analysis and synthesis (Tramo 2001, Griffiths 2003), but is also connected with the activation of subcortical centres which are closely associated with the processing of positive and negative stimuli (z.B. Blood et al. 1999, Blood and Zatorre 2001, Panksepp and Bernatzky 2002, Brown et al. 2004). This provides good grounds to suppose that music represents an important means of influencing mood and emotions, so that listening to music in daily life is of great significance for many people (Rentfrow and Gosling 2003, Altenmüller and Kopiez 2005). Thus both the qualitative studies performed by DeNora (1999, 2000, 2001) and Hays and Minichiello (2005) and a number of quantitatively orientated studies (North and Heargreaves 1996, Heargreaves and North 1999, Sloboda et al. 2001, Sloboda and O'Neill 2001, Pickles 2003, North et al. 2004, Juslin and Laukka 2004, Vorderer and Schramm 2004, Hays and Minichiello 2005) reveal that music is actively implemented in order (a) to modulate emotions and moods, (b) to promote the ability to concentrate and focus attention and (c) to generate or maintain social relationships. Nevertheless, the studies cited must be subjected to the criticism that the conclusions drawn in respect of the significance of and possible inter-individual differences between people's daily 'usage' of music are based entirely on the interpretation of the data gathered.

Thus the frequency with which a given functionality occurs is taken as a measure of its significance and degree of impact. Also, the various areas of research in which music plays the main role are relatively isolated from each other. Thus the results of the studies on neuro-scientific affect and emotion research which are mentioned above, the sociological-sociophysiological results of research on the significance of music in the context of socialisation (e.g. Mende 1991, Baake 1993, Müller 1999, Dollase 2005) as well as the findings on the possible inter-individual differences which have emerged from personality research (Frunham and Allass 1999, McCown et al. 1997, Rentfrow and Gosling 2003, 2006, Litle and Zuckerman 1986, Arnett 1991, Rawlings et al. 1995, 1998, 2000, Robinson et al. 1996, Nater et al. 2005, von Georgi and Gebhardt 2006, von Georgi 2007a, 2007b, von Georgi et al. 2007) all exist in proximity to each other, but the possible points of contact between them have not yet been explored. To put it briefly, one may argue that no bridge between research on effect and research on func- tionality has been built to date. For this reason the development of empirically grounded theory in respect of the use of music and its significance in various areas of life – in dependency on differential disparities – is still in its infancy.

Previous studies have been concerned with gathering information on the usage of music either indirectly or through experiment, together with the attempt to elaborate its significance on an interpretative level. In 2004 and 2005, Georgi et al. undertook a first step towards rendering the various forms of music usage in daily life accessible to empirical measurement (cf. von Georgi et al. 2006a, 2007a). As this approach is relatively novel, the measurement instrument and the theoretical model will be presented here briefly. On the basis of a number of random samples involving a questionnaire it was possible to identify five basic dimensions of interest. In its third version, the resulting questionnaire (IAAM: Inventory for the measurement of Activation and Arousal Modulation by means of music) is designed to register the following basic dimensions, each consisting of 12 items: (1) physical and mental relaxation through music (RX: relaxation), (2) reflection on social and internally contingent affects and emotions (CP: cognitive problem solving), (3) modulation of a state of negative emotional tension (RA: reduction of negative activation), (4) positive psychological and motoric activation and generation of social relations (FS: fun stimulation) as well as (5) the modulation of the capacity for concentration and heightened performance (AM: arousal modulation). Apart from the fact that these basic dimensions accord with the findings of previous studies (e.g. de Nora 1999), it has proved possible to establish a sufficient degree of reliability and validity for the procedure (cf. von Georgi et al. 2006a, submitted; von Georgi 2007a). In parallel with these test-theoretical investigations the authors developed an integrative theoretical model (AAM model: Activation and Arousal Modulation through Music). This model allows on the one hand for confirmation of the inherent significance of the IAAM scales by investigative means. On the other hand it provides for the integration of the various research paradigms involved. In this respect the model is oriented on the neurophysiological ap- proach adopted by Gray (1970, 1972, 1981) and Gray and McNaughton (2000), Corr (2004), McNaughton and Corr (2004) and von Georgi (2006), who differentiates between three dif- ferent neurophysiological systems (cf. Fig. 1 below).

1. The behavioural activation system (BAS), which is associated with a positive affect, the approach behaviour and a greater degree of receptiveness for reward. Here, the dopami- nergetic systems play a leading role.
2. The fight-flight-freezing system (FFFS) which activates rudimentary behavioural programmes in particular (avoidance behaviour: fight-flight). From the neuroanatomical point of view the interaction between the amygdala, the Raphe nuclei and the periaqueductal grey is of decisive importance in this case.
3. Das behavioural inhibition system (BIS), of which the neuroanatomical correlation is represented by the septo-hippocampal system (SHS). In contrast to the better known limbic system, which simply provides an emotional 'dress' for incoming stimuli, the SHS is to be understood as a system which performs an active comparison of the stimuli present with existing (behavioural) aims, causing emotional and motivational activation.

Although all three systems are in a state of permanent activation, the activity of the FFFS increases especially when unconditioned, conditioned or naturally aversive stimuli are involved. The BAS, on the other hand, is mainly activated in the presence of appetitive stimuli. If a configuration of stimuli arises which arouses both the FFFS and the BAS, this leads to the activation of the BIS, which is coupled with an increase in arousal and alertness. In particular, however, such situations are characterised by behavioural inhibition via the lessening of the effects of the avoidance (FFFS) and approach (BAS) behaviour patterns which is associated with the emotion fear. The aim of this behavioural inhibition, in which serotonergetic and GABAerge neurotransmitter systems play a role, is to scan the respective internal and external situation to obtain new information in order to resolve the conflict

existing between the FFFS and the BAS systems. In the context of personality theory, a biologically high degree of sensitivity in respect of the BIS is covariant with neuroticism and a slight tendency towards introversion, whilst the BAS can be associated with extraversion together with low neuroticism (cf. Gray and McNaughton 2000, McNaughton and Corr 2004, Pickering 2004).

The following passage presents the theoretical placement of the five different IAAM- dimensions into the theory of Gray and McNaughton. Within the model of activation and arousal modulation through music (AAM model) it is supposed that the various modulation strategies as measured by the IAAM results from the existing activity of the three systems (BAS, FFFS, and BIS). Here the IAAM dimensions represent learned strategies in the con- text of socialisation on the basis of the inter-individual biological sensitivity of the three neurophysiological systems (personality). The strategies involve music as a means of mani- pulating the current environmental stimulus configuration, thus exercising an influence on the existing affect, the cognition and the state of arousal. Figure 1 above shows the general AAM model. Here, the congenital sensitivity of the individual systems determines the resulting emotionality (affect, arousal and cognition) depending on the external and=or internal stimulus configuration. The existing emotional-affective perception leads to a more or less conscious course of action which has the aim of causing an alteration in the current state of affairs (at this point the integration of action oriented approaches is possible, e.g. Leontyev 1978, Frese and Sabini 1985, Engström 1999). Based on the results of existing studies, the dimensions relaxation (RX) and cognitive problem solving (CP) are assigned to the BIS, whereby RX is ascribed to an increased motoric arousal, whereas CP is related to cognitive processes such as reflection and recollection which take place on a more conscious level. The reduction of negative activation (RA) is assigned to the FFFS, because it is mainly concerned with influencing the activity of rudimentary behavioural programmes (fight, flight: i.e. "I listen to music when I want to let off steam."). The use of music for the purpose of positive stimulation (FS) comes under the sphere of influence of the BAS, for this dimension is especially associated with positive affectivity, social synchronisation and motor skills (von Georgi et al. 2006a, in press, submitted, von Georgi 2007a). At present the assignment of the dimension arousal modulation (AM) remains unclear. For this reason an alternative approach (von Georgi et al. 2006a) was formulated following Carlsson et al. (1997), Carlsson (2001): Carlsson's work suggests that in schizophrenic conditions there is a deficiency of the descending cortical glutamate system. This leads to an augmentation of the thalamic filter system for ascending stimuli and also causes the destabilisation of subcortical dopaminergetic and serotonergetic systems. By inference, this means that with healthy people who also have a lesser descending glutamate activity, specific and continuous stimuli (such as the well-known pieces of music) could be used to bring about a 'contraction' of the filter system, thus ensuring greater focussing of attention. Bearing in mind the participating neurotransmitter systems it may be assumed from a structural point of view that the AM dimension incorporates a partial aspect of the psychoticismic or the ImpUSS dimension (vgl. Eysenck 1985, 1990, Zuckerman 1991, 1996).

The studies to date show that RX, CP and RA are predominantly associated with a negative affect. However, both from the factor-analytical point of view and regarding its content the RA dimension proves to be a construct which is independent of this, as was postulated theoretically (von Georgi et al. in press). It was possible to demonstrate this very clearly in a recent study concerning metal fans. It transpired that this group of people returned high values in the RA dimension, but at the same time showed a lower BIS sensitivity (von Georgi et al. 2006c, submitted). Further, the modulation strategy by which music is used for positive activation (FS) is combined with a positive affect (von Georgi et al. 2006a, 2006b, von Georgi 2007a). Also, relations in respect of musical preferences were registered. Amongst other results, it could be shown that a preference for hard music correlates with the use of music for reducing negative activation (including samples with students) and a preference for rhythmical and energetic music (techno, soul, funk) is accompanied by the use of music for positive stimulation (FS). Those who listen to popular music (Top40, folk music, country, etc.) are characterised rather by a diminished degree of music usage for the purpose of emotional regulation – at least insofar as no marked emotional lability in the personality concerned is present (von Georgi et al. 2006a, 2006b, von Georgi 2007b).

In addition to the findings which are presented briefly here, which individually display a strong degree of personality dependence, it was possible to show for the first time in two studies that listening to music can be used as a strategy for the purpose of counteracting the personality based negative effects on the health of an emotionally labile personality (von Georgi et al. 2006b, in press, von Georgi 2007a). In view of these findings, the question arises as to the extent to which the use of music can be interpreted as a stress management strategy (coping) as defined by Lazarus (Lazarus and Folkman 1984). Thus as early as 1995, Arnett argued that, where a correlation can be established between risk variables such as depression or drugs misuse and 'hard' music, this correlation actually points to a failed attempt to implement such music as a coping strategy. Laiho (2004), too, regarded the prime use of music in daily life as being for the purpose of dealing with emotional demands. However, the authors of the AAM model reject the use of the term 'coping' for their strategies, because on the one hand it is associated with a cognitive scientific approach and on the other hand it encompasses only the aspect of dealing with stimuli which are interpreted as being negative. Although von Georgi's (2007a) work highlights that coping behaviour may well be integrated into the AAM model as a special case, it must be treated with some care in view of recent research results regarding the sub-cortical processing of emotional stimuli (see above). Nevertheless, a large body of research results demonstrates a connection between illness and health on the one hand and the various kinds of coping behaviour on the other hand, so that the coping concept remains in use, especially in the study of psychosomatic conditions, medical psychology and health psychology as well as in the area of music therapy (e.g. Antonovsky 1979, Schüssler, 1992, Schwenkmetzger and Schmidt 1994, Stroebe and Stroebe 1998, Keil 2004, Renneberg and Hammelstein 2006).

The presentation given here provides a basis for enquiry as to whether the various ways in which music is used in daily life can be understood as being the sub-forms of general stress management strategies. As no previous quantitative, empirical studies exist which demon- strate a relationship between the measurable coping strategies and the use of music, the purpose of this study was to perform an initial empirical test concerning possible correlations. This includes investigation as to which specific relationships between these two different construct areas (coping vs. emotion modulation) are present. In addition to this central enquiry a secondary aim was to shed light on a general point of criticism levelled at previous IAAM studies: As the data pools of these studies have mainly been fed by means of information gathered from generally young test persons from an academic milieu, this study was designed to test whether the five IAAM scales would prove to be reliable and scalable for older people as well.

In the spring of 2006 142 questionnaires were distributed to a group of people who were asked to participate voluntarily in the experiment. In selecting the group members, care was taken to ensure a sufficiently equal gender balance in each subgroup and that all members were at least 30 years old. The participants were recruited from medium sized businesses and insurance companies as well as local clubs and associations from the districts of Lahn-Dill and Gießen in Hesse, Germany. The organisations concerned were selected by random. Of the 142 questionnaires distributed 106 were returned to the experiment management [M.G.], which represents a return quota of 75%. The resulting sample set consisted of 53 female and 53 male participants whose average age was 43 years (SD ¼ 6.11; md ¼ 42; min ¼ 32; max ¼ 60).

18.1.1 Methods

IAAM (Inventory for the measurement of Activation and Arousal Modulation by means of music) (von Georgi et al. 2006a, von Georgi 2007a): For each of the dimensions RX (relaxation), CP (cognitive problem solving), RA (reduction of negative activation), FS (fun stimulation) and AM (arousal modulation) which have already been mentioned, 12 items are used to register a person's daily contact with and the use of music using the following scoring system: 0 ¼ never to 4 ¼ very frequently. Cronbach's alpha coefficients yield a suf- ficient degree of reliability for the IAAM scales (RX ¼ 0.918; CP ¼ 0.911; RA ¼ 0.901; FS ¼ 0.866; AM ¼ 0.862).

SVF-S 44 (Stressverarbeitungsfragebogen, i.e. Coping Strategies Questionnaire) (Janke et al. 1995): With its 11 scales the SVF registers the most important coping strategies which people employ in order to reduce stress and feelings of fear. The SVF-S 44 is a short version of the original questionnaire SVF-120 and includes 4 of the best items of each scale. In view of the small number of items per scale Chronbach's alpha coefficients yielded by this study can be regarded as satisfactory: diversion (0.768), minimisation (0.625), relaxation (0.803), flight (0.797), further mental activity (0.870), positive self-instruction (0.758), reaction control (0.706), resignation (0.752), situation control (0.703), social support (0.808), and avoidance tendency (0.814).

PANAS (positive and negative affect scale (Watson et al. 1988, German version: Krohne et al. 1996)): Based on Watson's theory (2000), the two PANAS scales measure the everyday experience of positive and negative affects. The method encompasses two basic dimensions, namely PA (positive affectivity) and NA (negative affectivity), each containing 10 items. These base affect dimensions are considered by Watson (2000) to be the constructs which display a close relationship with the classical dimensions of extraversion and neuroticism and which may even override these. The reliability estimates for this method are also to be regarded as satisfactory: PA ¼ 0.838 and NA ¼ 0.844.

SKI (self-concept inventory: von Georgi and Beckmann 2004): The SKI is designed to register that part of the personality which results mainly from interpersonal interaction. The 5 scales, each containing 8 bipolar items, cover the dimensions ego-strength vs. insecurity (E-I) (sense of personal and existential security together with the lack of feelings of angst; *a* ¼ 0.738), attractiveness vs. marginality (A-M) (self-assessment of own worth=influence in social groups; *a* ¼ 0.790), confidenceness vs. reserve (C-R) (attachment capacity and intimacy; *a* ¼ 0.737)), orderliness vs. insouciance (O-I) (degree of structuring in personal environment; *a* ¼ 0.741) and enforceness vs. cooperation (E-C) (self-assessment of assertiveness in social groups; *a* ¼ 0.719).

18.1.2 Statistical analyses

The predictions regarding the weighting of the various forms of use to which music is put by the test persons were investigated by means of simple correlation and multiple regression analysis on the basis of the SVF. As well as this, the scalability of the IAAM items was tested using the Rasch model. In contrast to the classical test theory (linear measurement error theory), which postulates *a priori* that there is a relationship between the test values and a latent characteristic or skill (cf. Lord and Novick 1968), the Rasch model presents the latent characteristics or skills parameters as the result of the modelling. In this respect an explicit distinction is made between the observed item parameter and the latent person parameter. In this way, the Rasch model can be used to establish whether the observed, measured parameters do, indeed, provide a concrete measure of the degree of weighting within a latent person parameter (Fischer 1995, Rost 1996, Müller 1999, Bond and Fox 2001). Furthermore, by using the so-called mixed Rasch models it is possible to include additional parameters in the model, so that scalable and non-scalable person groups can be distinguished from each other, for instance (for a discussion of the advantages and disadvantages of the Rasch model cf. Rost 1999). To avoid the problem of unoccupied cells, the Rasch analyses were performed on a reduced set of categories for the IAAM items (the marginal categories were aggregated, yielding a total of three categories). As the sample size is too small in relation to the number of possible response sets, the bootstrap procedure with b ¼ 80 was implemented (cf. Davier 1997).

As an initial step, the SVF scales were summed and then correlated with the summed value of the RX, CP and RA scales (as an indicator for negative emotion modulation) and also with the FS and AM scales in order to establish whether general coping behaviour and the modulation strategies are concomitant. This yielded no significant relationship between the SVF summed value and the aggregated IAAM summed value (r ¼ 0.056; p ¼ 0.594). More- over, no relation could be found either to the modulation strategies (r ¼ 0.024; p ¼ 0.810) or to AM (r ¼ 0.047; p ¼ 0.631). Further, there was no connection between the three discrete scales RX, CP and RA and the calculated general coping behaviour (r_{RX} ¼ 0.031 (p ¼ 0.364); r_{CP} ¼ 0.089 (p ¼ 0.364); r_{RA} ¼ 0.029 (p ¼ 0.768)). Gender specific analysis made no difference in respect of the significance values (r < 0.152; p > 0.278).

The following passage describes the regression analysis used to test the prediction of the weighting in the various modulation strategies involving music according to the eleven SVF scales. Table 2 shows that none of the modulation strategies co-varies with the coping scales. As was to be expected, inspection of the b-coefficients for each model reveals only slight
tendencies. The RX scale shows a negative relationship to the SVF scale 'diversion' (b ¼ -0.209; p ¼ 0.087) and there is also a negative relationship between the CP scale and the SVF strategy 'resignation' (b ¼ -0.314; p ¼ 0.062). For the modulation strategies RA and FS there are no further effects at all. For the AM scale a negative relationship to the flight tendency scale (b ¼ -0.295 was established; p ¼ 0.051) together with a positive one in respect of the existing avoidance tendencies (b ¼ 0.223; p ¼ 0.082).

Analyses	RX		CP		AR		FS		AM	
	r	p	r	p	r	p	r	p	r	p
SVF sum score	0.300	0.599	0.357	0.822	0.207	0.959	0.213	0.951	0.333	0.344
SVF scales: women	0.465	0.441	0.469	0.422	0.441	0.550	0.567	0.093	0.635	0.016
SVF scales: men	0.423	0.628	0.314	0.944	0.215	0.998	0.221	0.997	0.441	0.550
SVF scales: :Smd	0.455	0.406	0.398	0.728	0.410	0.547	0.357	0.753	0.443	0.481
SVF scales: >md	0.320	0.954	0.402	0.716	0.587	0.151	0.471	0.635	0.585	0.089
SVF single items	0.580	0.890	0.662	0.674	0.610	0.752	0.584	0.887	0.607	0.767
Mixed Rasch model: class 1	0.314	0.625	0.301	0.626	0.405	0.553	0.408	0.691	0.415	0.325
Mixed Rasch model: class 2	0.334	0.335	–	–	0.504	0.475	0.430	0.596	0.474	0.863

RX: Relaxation; CP: cognitive problem solving; RA: reduction of negative activation; FS: fun stimulation; AM: arousal modulation; R: multiple regression coefficient; p: significance of R; Md: computing two groups ber scale using the median as cut off point (n ¼ 106).

To exclude the possibility that this paucity of connections between the coping behaviour and the emotion modulation using music may be attributable to overlapping gender based preferences, the analysis was repeated for the male and female subgroups, respectively. Table 2 shows that only in the case of the FS scale a very weak statistical tendency can be found in the female sample set. The AM scale does yield a significant result, but this scale cannot be directly connected with the modulation of emotions. The b-coefficients for the female group yielded the following relationships between the FS scale and these strategies: minimisation (b ¼ 0.427; p ¼ 0.013), further mental activity (b ¼ -0.453; p ¼ 0.031) and resignation (b ¼ 0.775; p ¼ 0.010). For the AM scale and the female group there was a clear relationship with the strategies flight tendency (b ¼ -0.769; p ¼ 0.001), positive self-instruction (b ¼ 0.478; p ¼ 0.040), resignation (b ¼ 0.828; p

¼ 0.003), social support (b ¼ -0.399; p ¼ 0.011) and avoidance tendency (b ¼ 0.520; p ¼ 0.008).

A possible explanation for the lack of a clear association between the coping strategies and the emotion modulation strategies may be seen in the fact that such a relationship only appears valid for those persons who do, indeed, make considerable use of music. Therefore the sample set per IAAM scale was split into two groups by means of median separation on the basis of summed scale values, each of which was then subjected to further scrutiny using regression analysis. Here, too, no clear, statistically conspicuous relationship could be established ($p < 0.05$) (Table 2).

Finally, in order to investigate the roles possibly played by individual items of the SVF, all 44 of them were again subjected to regression analysis. As can be seen from Table 2, these operations also produced no statistically significant results. The b-coefficients of the individid- ual SVF items per scale show, as expected, no individual peculiarities.

Generally, it may be stated at this stage that no clear relationship between the coping strategies of the SVF and the IAAM scales on the usage of music appears to exist. Equally, it would seem advisable to obtain further confirmation of the present findings. Thus it is quite possible that the constructs involved in the use of music no longer appear valid to older people or that only a few of them still actively use music as an instrument for emotion modulation. For this reason, a Rasch analysis was performed (rating scale model) in order to confirm the scalability of the constructs. In a second step, mixed Rasch analyses were implemented in order to separate possibly scalable test persons from non-scalable ones, followed by a new regression analysis test of the predictions of the IAAM scale weightings in the light of the SVF scales.

Table 3 shows the results of the Rasch analyses. It may be seen that Rasch scalability according to the rating scale model with $p > 0.05$ is applicable for the scales RX, RA and FS.

Surprisingly enough, this could not be established for the CP scale. That there are inherent problems associated with the AM scale, as it tends to be a rarely used strategy, is also reflected in the lack of scalability (vgl. von Georgi 2007a). The reliability coefficients of the scalable scales are indeed less than Cronbach's alpha coefficients, but with values >0.70 they can be regarded as adequate. The mixed Rasch analyses for two groups return a comparable result with no improvement in the significance of the CP and AM scales. On the basis of the mean values and the correlations between the scale values and the class membership probability it is possible to deduce which of the two groups are most likely to contain those people who may consider the constructs to be valid for themselves. In order to identify possible age or gender effects from the start, the class probabilities were correlated again with the ages and genders. The result was not significant ($p > 0.123$). The regression analyses performed for each class generated produced, once again, no results of statistical note (cf. Table 2).

In order to exclude the possibility that the lack of a connection may be caused by using the shortened SVF scales, these were correlated together with the IAAM scales with the personality variables (PANAS, SKI). It transpires, however, that despite the lack of connection between coping and emotion modulation the scales of both methods co-vary in a meaningful way with personality (Table 4). In respect of the SVF scales it can be seen very clearly that these are accompanied by a modest positive affect (PA). The correlations also show that the strategies minimisation, relaxation and positive self-instruction tend to be coupled with a small negative affect. The relationships are even clearer in the case of the scale ego-strength vs. Insecurity (E-I), which combines introversion and neuroticism aspects in the negative pole (insecurity) (cf. von Georgi 2006). Highly insecure people avail themselves rather less of the strategies minimisation, positive self-instruction and situation control attempts and place more emphasis on a tendency towards flight, further mental activity, resignation and avoidance behaviour. Furthermore, it can be seen that persons who regard themselves as being unattractive in social interaction situations (marginality) (A-M) display distinct avoidance tendencies. Also, those persons who have a pronounced need for order (O-I) are especially characterised by high scores on the scale of reaction control attempts. Finally, it emerges that those with a low level of assertiveness or a high degree of preparedness for social cooperation (E-C) especially favour flight tendencies and resignation as stress management strategies.

In respect of the scales for emotion modulation by means of music the results are not as statistically significant as is the case for the SVF scales; nevertheless, a number of statistical tendencies are apparent which have already been demonstrated to a greater degree in previous studies. Thus the reduction of negative activation co-varies with the positive affect and the use of music for relaxation purposes with the negative affect. Once again, the relationships in the case of the E-I scale emerge more clearly: Insecure people fall back on the use of music for the modulation of negative affects and physical conditions more readily. Furthermore, it is the case that those with high scores in the area of interpersonal capacity for attachment (C-R) achieve positive activation by means of music. The correlations of the emotion modulation strategies with the scale 'orderliness vs. insouciance' (O-R) are worthy of note: The more the subject attaches importance to a structured environment, the less he or she uses music for the purpose of emotional modulation.

This study indicates that no connection can be found between the coping strategies and the use of music for emotion modulation, even when the hypothesis is tested using a variety of different methods. As an explanation for this result, various methodological points of criticism may be raised. Thus it may be that either the IAAM or the SVF scales only have a limited degree of validity. However, in the case of the SVF scales it was possible to show that, despite the small size of the reliability coefficients, they have statistically relevant and meaningful links to the personality variables. For the IAAM scales the intercorrelations are somewhat limited. In addition to possible content related causes (see below), it may be argued that the IAAM scales are not very reliable for the present sample set. On the other hand, not only did the reliability estimates according to classical test theory (Cronbach's alpha) return good to very good values, but also the scalability according to the Rasch model could be demonstrated (with the exception of the CP and AM scales). The non-scalability of the CP scale is due to the fact that the CP construct contains two different aspects (reflection on social and internal conditions) (von Georgi 2007a).

In the course of retrospective scrutiny of the findings one feature became apparent which is of particular significance for the following interpretation: The scale mean values of the complete scales (cf. Table 3) are considerably and conspicuously lower than those obtained from the previously used sample sets. A *post hoc* analysis comparison with the student sample set from a study conducted by von Georgi et al. (in press) reveals significant mean value divergence with $p < 0.001$ (t-test) (RX ¼ 20.48 (±8.78); CP ¼ 19.93 (±9.14); RA ¼ 19.42 (±9.23); FS ¼ 27.52 (±8.22); cf. Table 3). Only the AM scale shows no statistically relevant mean value deviation between the present sample set and that consisting of students. In contrast to these major differences, no difference in the variances could be established (Levene Test, $p > 0.05$). Finally, in order to exclude possible distortion of the results on account of distribution abnormalities, the scales were examined for normal distribution using the Kolmogoroff-Smirnoff test (cf. Table 3). With the exception of a slight and predictable deviation in the AM scale (cf. von Georgi et al. 2006a, in press), no further deviations from the normal distribution could be detected. Thus it may be assumed that the present (non-) findings do not represent a methodological=experimental artefact, but rather explanations must be sought by means of theoretical deliberation in respect of the subject matter itself.

At first sight it would appear that no relationship exists between coping behaviour and emotion modulation using music. This may, on the one hand, be attributed to the possibility that the constructs each represent independent entities which share no common character- istics. On the other hand, it was possible to demonstrate that a weak tendency towards a relationship between the use of music and the generation of positive stimulation for the female sample subset exists. For this reason it appears imprudent to reject the hypothesis that no relationship exists between coping behaviour and emotion modulation using music out of hand.

On closer inspection of the results another possible interpretation emerges. Thus it may be supposed that for a number of members of the present sample set music as a means to an end is of only modest significance or music is generally of little consequence in daily life. This is not to say, however, that these behavioural strategies have simply disappeared. Instead, their various forms remain as strategies for emotion modulation and their degree of expression is measurable. This would lead to the situation that a relationship with coping behaviour would not be unambiguously demonstrable in the present sample set. A comparable effect was apparent in the study on metal fans (von Georgi et al. submitted), in which the strategy of modulating a negative activation by means of music becomes less with increasing age. Thus the tentative connections established between the IAAM scales and the personality dimen- sions could also be the consequence of a general lessening of the significance of music in the middle phase of life.

If one is prepared at this stage to engage in a more extensive interpretation, it could be supposed that persons in groups within a narrow age range and with comparable educa- tion and a preference for popular music are able to influence their emotions by means of music but simply regard such (uncontrolled) ways of influencing emotions with disapproval. This view may be supported by the fact that for the present sample group listening to popular music (upbeat and conventional) is combined with a high degree of interpersonal reserve (r ¼ -0.332; p ¼ 0.001) as well as with reaction control attempts (r ¼ 0.239; p ¼ 0.014) (within the group with a preference for popular music most test persons reported that they listen to pop music (67%), folk music (19%) and country and western music (8%)). Whether the limited extent to which music is used for emotional modulation in the present sample group is to be attributed to its musical preferences or rather has its cause in the realms of de- velopmental psychology and sociology must remain a matter of conjecture at this point.

In the course of this study a supplementary internal statistical validation of the findings was carried out based on the results of the hypothesis testing in respect of a possible relationship between coping and emotion modulation by means of music. This yielded evidence to suggest that a relationship between the coping strategies and the use of music is determined by socio- psychological co-variables: Person groups with a medium level educational background and of middle age which are characterised by a preference for popular music do have the capacity to engage in emotion modulation by means of music, but appear to regard these rudimentary techniques for influencing emotions with a certain disapproval or they see them as being of little significance. This allows the inference that, in contrast to the present result, a relationship in connection with various forms of stress management should be verifiable for juveniles and young adults in particular.

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Chapter 19

Music as a medicine: incorporating music into standard hospital care

Television programs with emotionally stressful content cause a significant increase in heart rate, blood pressure and the production of stress hormones (Gerra et al. 1996); whereas humorous programs can exercise a positive influence on the body's immunological state (Dillon et al. 1985–1986). For example, suitable videos with animal scenes cause significant reduction in blood pressure just after ten minutes (Wells 2005). Phenomena such as these are the subject of the interdisciplinary research area called psycho-neuro-immunology, which investigates, for instance, how stress can influence immunological factors. Negative changes to such immunological factors cause an increase in infection rates that in turn can promote the occurrence or worsening of pathological conditions. According to the American cardiol- ogist Herbert Benson, Associate Professor of Medicine at the Harvard Medical School, up to 90% of all visits to doctors can be attributed to chronic stress and mental pressure[1].

In hospitals, communication media provide the most important means of maintaining contact with the outside world. A telephone conversation with one's children, with one's partner, etc. is just as important for the patient as for his or her friends and relatives. It often represents an important factor for speeding up recovery to be able to keep up 'rituals' such as watching favorite TV programs. When a patient can immerse himself or herself in a familiar series or some other favorite program, it feels like a small corner of 'home'. Unfortunately, though, what may be important and entertaining for one patient, may be irritating or distressing for the one in the next bed. The roommate perhaps just needs peace and quiet, may be in pain or going through a psychological crisis. In such circumstances, a thriller or a gripping episode of "Who wants to be a Millionaire?" may represent the exact opposite of the relaxation and recuperation that he or she desperately needs. In hospital and generally when one is ill, one's physical and mental sensitivity is greatly increased. This means that even those stimuli that one usually finds stimulating and pleasurable may be far too much with which to cope.

Nowadays, stress is also a common phenomenon for hospital staff. The time pressure and pressure of work, together with the weight of responsibility that they carry for the well-being of the patients, create levels of tension that staff can seldom avoid. Despite the hectic pace, they must remain concentrated and alert. The working situation is pervaded by noise from many different sources – noise that one would like to shut out, but it is part of the job to be listening attentively all the time.

The fact that noise levels in hospitals are usually high has a number of different consequences for both the staff and patients alike. As early as 1994, a study in England (Biley 1994) showed that these high noise levels were associated with increased sensitivity to pain and a slower rate of wound repair. Further, staff complained of headaches and nervousness. A study conducted by Joachim Fischer at the University Children's Hospital in Zurich (Fischer 2002) revealed noise levels over 65 dBA in the intensive care unit. The relevant WHO guidelines set maximum values at 45 dBA during the day and 35 dBA at night.

This noise problem can be ameliorated by the implementation of an acoustic 'antidote' involving specially composed audio programs that 'surround' the typical noises and signals emanating from equipment and operative procedures with gentle harmonies and quiet natural sounds. The technique ingeniously exploits the physical phenomenon of acoustic phases and counter-phases in order to render the disturbing noises practically inaudible. This 'sleight of hand' produces a state of quiet that, in the most literal sense of the word, was previously unheard. The atmosphere in the corridors and working areas immediately becomes more relaxed and pleasant. Patient satisfaction increases and the staff's nervousness decreases. The number of complications arising during invasive diagnostic situations goes down.

The technique represents a significant economic benefit for the hospital management as it has a direct positive effect on staff sickness rates (Nilsson et al. 1998).

It was clear to the care staff at the State Hospital in Salzburg that the noise levels to which freshly operated patients were exposed immediately following their operations were extremely trying. Especially in the area of cardiac surgery, there was a demand for a suitable program of music to support patients in this critical phase. As early as 1997, a study conducted in the USA showed that patients react very positively to music following heart operations (Byer and Smyth 1997).

The 'noise saving' effect of music in hospitals has a very practical benefit and can be achieved with music of all kinds, as long as the frequencies in the music match the technical specifications for this purpose. However, what is ultimately more important is that the music that is employed in hospitals fulfills the specific psychological and physiological needs of the patients and the staff in hospitals. Tensions, strain, stress, anxiety, fears, worries, pain, despair, problems falling asleep, readjusting to a normal circadian rhythm after a long operation – the multitude of aspects that the appropriate choice of specific music can address is boundless. In the majority of cases, it is the ward staff that calls for suitable music programs. In Salzburg, it was especially in the gynecological wards that the potential of a musical 'cure of souls' was recognized.

These possibilities have long been a subject of care research in the US. Marion Good, Professor of Nursing at Case Western Reserve University's Frances Payne Bolton School of Nursing has been testing music with post-operative patients for more than 15 years. "I found that music does reduce pain up to about 31% in my studies in addition to medication.", she reports. The results of a five-year study conducted by the National Institute of Health together with the National Institute of Nursing Research, published in the respected Journal of Advanced Nursing (Good and Siedlecki 2006), confirm the observations made in Salzburg. Listening to music brought about significant improvements in pain and depression scale values in chronic pain patients within a week. The use of music in operating theaters has been studied since 1956 (Gros 1956). In a study published in May 2005, anesthetists at the Yale University School of Medicine showed that intra-operative music decreases patient-controlled IV propofol sedation requirements of patients who undergo urological surgery under spinal anesthesia (Ayoub et al. 2005).

Every new study that corroborates the positive effects of music interventions in hospitals adds urgency to the general question as to how music can be implemented in standard daily clinical practice. The structural changes pending in technical hospital management will bring about many changes. The idea of providing patients with laptops and internet access is gaining currency and in the foreseeable future we may expect this to be as normal as present day patient call systems. Therefore, it is urgently necessary to consider carefully how media can be implemented in the clinical environment in a manner that brings about recuperative effects instead of causing additional stress.

Unlimited and unconsidered exposure to all kinds of media carries with it the danger of stress and detrimental strain. It is essential also to take possible negative effects on the immune system into consideration when planning media implementation in hospitals. From the nursing point of view, there are good reasons to doubt the wisdom of providing patients with the same exposure to media as they are used to in their daily lives. In planning such schemes, it is necessary to bear in mind that the media must fulfill other functions in the hospital context and that patients' capacity for recovery should be given first priority. On no account it is advisable to include any kind of program that may have the effect of slowing down the recovery process. The potential problems arising from current developments surrounding the provision of media access to patients should be made the subject of further medical research. Only when all those involved in such planning are aware of the consequences of uncontrolled media access for patients will it be possible to establish a consensus of opinion and thus implement measures based on a firm foundation of solid evidence.

The program of music that constituted the foundation of our investigation was created by Tom Doch[2], a colleague from earlier days who had happened upon the subject of combining music and healing via a quite different path. Owing to an incorrect diagnosis, a tumor the size of a baby's head was 'overlooked'. When, finally, he was operated on, his life was in the balance: "*The period after the operation was hell. Music was my only source of succor during the times of panic, unease and pain. The music certainly played a decisive role in my survival.*" He had made the surprising discovery that the music that helped him was not what he regarded as his favorite music. In his condition, he would not have been able to cope with it; it was "too demanding". Instead, it was with the help of quite different sounds and musical pieces that he was able to find peace and sleep within minutes of putting the headphones on. Tom Doch's experience was consistent with the observations I had made when I supported my own mother with music in the last phase of her life[3].

Our aim, therefore, was to devise a special radio program for hospitals and at the same time to draft a concept for researching the effects of music on patients from various different points of view. Now, after a ten-year period of research and development, involving several universities and hospitals, as well as a host of care staff, researchers and technicians, the program is available to interested institutions (www.sanoson.at).

The evaluation of the clinical implementation of specially composed music programs for the treatment of patients with clearly delineated diagnoses presents a complex, but certainly feasible task. In addition to the development of methods for providing out-patients with specific receptive music therapies for their diagnoses, our aim was to establish ways of supplying music programs to support the healing process for as many hospitalized patients as possible. In order to design a study capable of adequately dealing with a heterogeneous group of subjects as may be expected within a general hospital or university clinic, considerable care is needed in the selection of methods and the basic study parameters. The classical methods employed in music psychology and music reception research are mostly inapplicable for a study on sick people who are bound to the unfamiliar surroundings of a hospital ward. Studies conducted in in-patient care situations are confined to the limits of comparability and constrained by the limitations inherent in quantitative research techniques.

For many years, a dominating opinion in music psychology was that the emotional reactions caused in listeners to music were predominantly of an individual nature. No model to describe a "constancy in reception relationships" appeared to be available (Gembris 1981, 1996). The individual experience of a given piece of music by a given listener was believed to be determined by his or her socialization, musical education, listening habits and by the situational context. However, this view could not explain how it happens that the descriptions of their experiences in listening to the same piece of music, supplied by two very different people, should correspond very closely.

Certain mental-emotional concepts (such as anger and sadness) and qualities of experience (e.g. tenderness and harshness) can be relatively easily communicated using musical means. More complex messages, however, demand metaphors of a more differentiating nature. How is it that most people can understand such implication even if they have not enjoyed a musical education? How does a listener extract meaning independently of cultural clichés? What are the narratives and stories that music tells and people hear? What films are played in the mind of the listener? What storyboards can music draw? What is it that triggers joy, emotion and compassion in most listeners?

Chill research presents a highly interesting perspective. Grewe et al. found that when a general level of attention and sympathy has been created, the characteristics of events can induce a chill seem to be universal for most listeners (Grewe et al. 2005). Courageous research on very young babies has revealed that we are born extraordinarily well equipped to process music. In an fMRI study on 18 newborns, Maria C. Saccuman showed that the capacity to process musical stimuli and to perceive dissonance, as well as subtle violations of tonal syntax, is congenital (Saccuman et al. 2008). Sandra Trehub has shown that babies recognize differences in tone (Trehub et al. 1985), melody, key and rhythm as well as (and sometimes better than) adults (Trehub 2006). She emphasized that tone sequences used in mother-child communication are neither arbitrary nor random, but deliberate acts of interactive modal regulation. Stephen Malloch and Colwyn Trevarthen's concept of 'communicative musicality' (Malloch and Trevarthen 2008) and the auditory mirror function (Koelsch 2006, Molnar- Szakacs and Overy 2006, Gazzola et al. 2006) may be keys to the question as to why music can play such a great role for emotion regulation in children and adult listeners. Do, in fact, stable factors exist that determine the effects of music? If so, what is the order of priorities that govern them?

These are the essential questions surrounding receptive music therapy and the evaluation of the therapeutic effects of functional music programs that can be implemented in clinical practice without the presence of a music therapist. Today, music is used in intensive care and birthing units, as a component of post-surgical pain therapy, and as a sedative in varied situations. The effects on patients who are exposed to this form of therapy have been recorded as being positive in most cases, as is also confirmed by statements made by the patients themselves.

When we commenced with our investigations, we were able to base our work on the results of many years of successful research into the effects of music. In the United States a considerable number of studies have been carried out on receptive music therapy and on the implementation of functional music in medicine since the end of the nineteen-seventies. Rosalie Rebollo Pratt, one of the pioneers of MusicMedicine research in the USA, provided a comprehensive overview of the situation in the paper that she presented[5] at the congress infusion – New Qualities in Health Care (Salzburg 2004).

The main focus of these studies was the documentation of quantifiable evidence of therapeutic effects. However, the psychological mechanisms behind the observed reactions received no close attention from either the American or the German researchers. "The questions surrounding subjective significance and meaning in musical information processing, of emotional experience, of situational conditions and socio-psychological implications are omitted completely. Perhaps these questions are, in the end, the more important ones." (Gembris 1999).

In her book 'Rezeptive Musiktherapie – Theorie und Praxis' ('Receptive Music Therapy – Theory and Practice'), published in 2004, editor Isabelle Frohne-Hagemann put forward a possible reason why little research has been done in Germany. This observation holds even after the reunification, despite the relatively important role that receptive music therapy had previously played in East Germany. Perhaps, she suggested, there is such a thing as a historically motivated '*German allergy*' in respect of all kinds of prescriptive listening to music that could in any way be considered manipulative.

And with the concluding paragraph in his contribution entitled 'Zu einer Theorie der Wirkungslosigkeit von (Hintergrund-)Musik' ('On a Theory of the Ineffectiveness of (Background) Music'), in the 1999 issue of the 'Jahrbuch Musikpsychologie', Klaus-Ernst Behne gets to the bottom line of the (research) issue:

> If progressive music psychology, in a situational, circumstantial context, were to reach the stage of being able to make assertions as to the (yet to be defined) conditions under which music appears to have an effect on people, then it would become clear at the same time that the respective preconditions (attitude, preparedness, routine music-psycho- logical theories) are mainly to be sought in the listening subject who is undergoing the experience. When we use the everyday expression "the effect that music has on people", thereby implying a certain direction of influence, we effectively put the cart before the horse. In fact, the subject which we are discussing is this: The effect of a person's

> expectations on the way in which he experiences music – in other words, the way in which he is prepared to allow effects to affect him. This perspective is not new, but research programs regularly fail to take it sufficiently into account. It may neatly be expressed by borrowing a phrase from the visual arts, where beauty is recognized as residing not in a work of art itself, but 'in the eye of its beholder'.

Six years on, Eckard Weymann and Martin Deuter were still expressing regret in an interview with Gernot Böhme[6] that "The experience of music still appears to be unable to find its place within the traditional framework of music research as a valid subject in its own right.". Böhme continues: "In practice this vitally significant aspect of music has even increased, whereas the theoretical treatment remains insufficient." (ibidem, 2005).

The investigations carried out by Richard von Georgi provide new perspectives on the issue; they confirm that people employ different strategies in the process of using music to exercise conscious influence on what is currently being experienced and felt. The so-called IAAM (Inventory for the registration of Activation and Arousal Modulation using Music), was developed by von Georgi et al. (cf. pp 319-337 in this volume) and presented to the public in September 2005 during the annual conference of the German Association for Music Psychology at the Music University in Würzburg. IAAM has, for the first time, made it possible to register affect modulation, independently of direct experimental musical exposition, in a standardized and consistent manner. As the basic dimensions can be interpreted on the basis of existing activation and arousal theories, it is possible to integrate the research into current neuropsychological concepts. Finally, IAAM provides a means of investigating the functional transformation of music through varying phases of living and through different sample sets.

Holger Schramm, too, investigated the relationships governing "Mood Management through Music" in his Ph.D. thesis (2005), which was supervised jointly by Klaus-Ernst Behne and Peter Vorderer. For most people, a central motive for the utilization of music is the regulation of their mood, i.e. the primary maintenance and strengthening of positive sentiments as well as the suppression or compensation of negative sentiments. Schramm's approach to the question of usage motivation involved the investigation of which people wish to listen to which music in which prevailing moods and for what purpose.

In his Nature essay on science and music published in July, 2008, John Sloboda reconfirmed that researchers must study music as people actually experience it, if they are to understand how it affects thoughts and feelings (Sloboda 2008). However, most music perception re- search methods are limited in their application regarding the effects of music in the clinical practice – the context in which a hospital patient perceives music represents a special challenge to researchers:

> "Hospitalization can result not only in physical stress from invasive treatments and therapies, but emotional stress as well from unexpected news, unfamiliar environments, inability to conduct normal activities and lack of control. Music interventions in the medical setting provide patients a familiar and positive way to cope with their hospitalization." (Lane 2008)

Following intensive inquiry, we resolved to seek instruments and methods that had already been implemented successfully in other areas of research. The psychological theory of morphology, developed by Wilhelm Salber at the University of Cologne, provides a set of instruments for assessing the effects of media exposure that permit investigation of the deep psychological motivational relationships involved. A number of institutes are presently conducting research using these morphological methods, espe- cially in the field of qualitative media research. Marketing research also avails itself of the morphological approach, partly implementing it on its own and partly in combination with quantitative techniques.

Morphological psychology generally takes into account the situational context as part of the observational framework. It seeks to uncover the test subject's subconscious actions and reactions by regarding him or her as being the mouthpiece of the object under investigation, that which expresses its *modus operandi* through the utterances of the test subject. The morphological concept of the 'impact complex' that functions as a governing principle here can be applied to the phenomenon of musical perception as well.

> "If we wish to regard listening to music as a gestalt in the psychological sense, then what this means is the understanding that our experience and behavior recognize the process as a unity, as a whole, as a 'Something' of itself. This may be differentiated from the approach which begins with the unit 'a piece of music' and then poses the question as to how a person receives this particular item: accepts, registers and interprets. Whereas in the latter case two separate entities (here the music, there the listener) are studied in order to investigate the effect of one on the other, the present task is to establish how the picture changes when we define 'listening to music' as being the single, gestalt-forming entity which enters the stage as an observable fact in its own right, presenting itself for investigation as an effectual psychological phenomenon. "Listening to music" is a subject for enquiry whose very name reveals that it is beyond consideration without the listener himself." (Tüpker 2004, in Frohne-Hagemann (Hrsg.) 2004)

Morphological psychology regards the interplay between man and the elements that determine his daily life as an opus whose multi-faceted and multifarious structure consists in a specific psychologic – one that is often characterized by inconsistency, but that for the person involved represents a sufficient and stable framework. The assumption is that man does not control reality, but that the things with which he becomes involved act upon him; that in this way intentional self-treatment processes are engendered, albeit to some extent on an unconscious level.

In this respect, the morphological approach corresponds with the recent investigations on music reception that have already been mentioned. These, too, work on the assumption that the process of allowing music to exercise an influence upon oneself amounts to one self- treatment, i.e. to a course of 'mood management'. The methods used in morphological effect research prove to represent especially suitable means to investigate the exact way in which this process works and which factors determine its course and result.

Morphological psychology assumes the existence of a mental composition of reality that is oriented on certain gestalt factors and is fashioned within the framework of these factors. It makes use of a hexagrammatical representation of these points of reference that serves to shed light on the respective mental construction of reality that a person uses to comprehend himself and his situation within. It is clear that the effect that music has on a listener depends on both the degree of and the type of preparedness to perceive any possible effects. And equally clearly this preparedness is determined by internal, as well as external, conditions that are of therapeutic significance. The set of research instru- ments used in morphological psychology provides a systematic means of registering and analyzing these factors.

The present study represents the first investigation on the experience of music among in-patients based on deep psychological interviews performed during the subjects' stay in hospital. The study presented by Frieske et al. *Musikwirkung unter klinischen Bedingun-gen–Eine Morphologische Wirkungsanalyse* (Frieske et al. 2005) (*The effects of music under clinical conditions – a morphological effect analysis*) pursued the question as to how an audio program specially conceived for clinical conditions was experienced by its listeners from a psychological point of view. As a prerequisite for understanding how such an audio program for hospitalized patients should be created in order to be therapeutically useful, it appeared advisable to first establish a psychological characterization of adult patients' states of mind during a period in hospital.

This antecedent study can be seen as a kind of 'a state of unrest demanding treatment'. Hospitalization implies that a patient is no longer able to control a state of ill-health, a dramatic situation that is associated with a many-faceted turmoil. Here, patients experience the limitations of their capacity for self-treatment. A change in circumstances sweeps what is 'normal' and 'routine' aside, ushering in the need for professional treatment from third parties.

Thus being in hospital is connected with the obligation to 'put oneself at other people's mercy'. The unfamiliar clinical surroundings impinge on the patient as a psychological reality with its own set of rules and conventions. But in fact, it is precisely this state that, under favorable circumstances, creates the conditions necessary to transform the unrest caused by the illness into a new state of calmness. This presents an opportunity to open new possibilities for development. The chief factor influencing the complex of 'disorder-hospital-treatment' is therefore the total relationship between the poles of quietude and agitation. And this is where a dedicated hospital listening program can contribute towards favorable readjustment of this complex.

It was a central aim of the study to establish and then describe the characteristic psychological effect patterns of the audio program. The program displays valuable effectual qualities in respect to every one of the psychological gestalt factors contained in the morphological hexagram. The program was given the general designation of 'musical treatment support, with both calming as well as vitalizing qualities'. These are the two poles – corresponding to the morphological gestalt factors of 'owning' (appropriation) and 'reorganization' (or metamorphosis) – through which it exercises its own special effect. It provides familiar sound patterns that have calming, steadying and stabilizing effects. They lead the listener into a relaxing state of semi-consciousness or act as pleasant, lullaby-like aids to sleep.

Vitalizing sounds can bring about dramatic changes. They can help patients to find a way out of the immobilization caused by their illness. They have a valuable, energizing effect that stimulates (new) developments. In addition, patients receive an acoustical – musical – means of applying self-medication, an active form of self-treatment that they can use to work on their mood and condition, helping to introduce beneficial transformation. In other words, the program represents an effective way of coming to terms with the sense of being 'put upon', of being under other people's control that comes with illness and hospitalization. But in addition, the program delivers a form of passive treatment that also helps to improve the patient's condition. For being under somebody else's control can also mean 'being in good hands', can mean that somebody else is there who, for the moment, will take responsibility for my well- being, leaving me to let the music wash over me. I can drift off, float along, and allow it to give me an acoustical massage and a meditative backdrop. This confirms that the program is utilizing the morphological gestalt factors of 'impact' and 'arrangement', combining them to create a meaningful form of therapy.

To complete the hexagram, the program also provides valuable acoustic characteristics in respect of the last two poles, 'equipment' and 'extension' (or unfolding). Simple and reduced sounds, especially familiar, pure natural noises, take account of patients' 'limitation of condition' without overexerting them. Rather, they are indulged with simple, healthy, earth-bound sounds. In a different way, the program helps the patient to overcome restriction, to free himself from the bounds of his bed and journey somewhere quite different on a metaphysical, acoustical excursion. So acting as a psychological 'media gestalt', the program displays a comprehensive set of effective qualities from a morphological point of view.

The following figure shows the complete hexagram, displaying the six functional as- pects of the hospital audio program. These aspects were revealed by an analysis based on morphological psychology. The detailed evaluation allowed us to correct some program 'bugs' and less effective aspects of the first version and to modify the program in accordance with the psychological structural patterns which have been established in the present study.

In respect of the program's healing support capacity, the study showed that basic aspects of the psychological and physical stress ensuing from patients' conditions and from the hospital situation could be addressed by their listening to the program content. The listeners received 'acoustic food for the soul' – their unease could be calmed and there were revitalizing components to help them cope with their sense of immobilization.

They could apply self-treatment or let themselves be treated. Their horizons were expanded beyond bed and hospital ward through mental passages of sound that led them out into nature and 'back to the roots'. Restrictions fell away and in their imagination they could travel without limitation. For instance, journey of sound could help them to think beyond the present. The music sowed new seeds of survival on the ravaged field of their harshly disturbed condition. Acoustic therapy for the soul multiplied the effectiveness of physical treatment, ushering in a new day with a more positive orientation.

In the context of providing in-patients with support via acoustic media, music has various effects. Patients reported that they experienced relief – the music diverted their attention from the current situation that they found unpleasant and they felt they were being 'carried away', so to speak. They reached another state of consciousness in which emotional and physical pain was perceived as being less acute. On the other hand, music also has the capacity to allow us to sense our own bodies more keenly, as happens when suitable music brings about changes in the breathing pattern. A number of studies have been conducted with the aim of showing that music can be implemented to allow medication dosages to be reduced. This has proved successful in many cases. For pain patients, this is especially important when the tolerable dosage limit has been reached.

Equally, it may be expected that patients who are given access to suitable music will be able to develop a greater degree of capacity for self-treatment (empowerment) (Siedliecki and Good 2006). This may well be accompanied by a request from the patient to have their pain relief medication increased when it is necessary. This indicates that the patient retracts responsibility for himself. Medical pain management aims to keep the patient as pain free as possible and depends on the cooperation of the patient to achieve this goal. So from a nursing perspective, it is a positive sign for treatment progress when a patient asks for something he needs to feel better.

Targeted use of suitable music intervention for hospital in-patients has many proven advantages:

- Support for self-healing processes
- An increase in care quality
- Lower complication rates
- Alleviation of the burden on staff
- Increased patient satisfaction
- Hospitals with music intervention programs are more attractive for patients
- The use of music saves costs

In view of the many reasons in favor of implementing music as part of in-patient care in hospitals, one may ask why this has not long since become standard practice. Were the results of previous studies not compelling enough? As far as we can judge, the reasons lie rather in the issue of differentiation regarding the music to be used. Hardly any single study conducted so far has addressed the question as to which music is most suitable for which patients with which conditions. The more precisely the music intervention is tuned to the particular situation, the disorder in hand and the symptoms involved, the more effective it can be.

Our study and the audio program that we have developed have set the ball rolling. There are already program variants available for a large section of the population of adult in-patients. However, children's needs differ from those of older people and pre-operative and post- operative music therapy must address quite different issues, i.e. compared with palliative medicine.

Likewise, what is required in an intensive care unit is different from that which stroke patients need during the rehabilitation process, and those suffering from dementia must receive a different therapy, which helps patients with Parkinson's disease.

Now that we have come to recognize just how potent music can be as a source of stimulus, research into the required frequency and type of music-based interventions, as well as into the question of how to implement it in the best way, has become a matter of high priority. In addition to the forms of music therapy already known and in use today, it will, in future, be necessary to develop a wide range of specialist variations within the discipline in order to exploit the therapeutic potential of music fully.

Another aspect concerning the application of suitable music content in the hospital context that has received insufficient attention so far is that of its technical implementation. To date, the situation in this respect remains very disorganized. In order to provide an optimized solution in any given hospital, not only the medical and care staff but also the technical and administrative staff must be prepared to make a contribution and find out about the issues involved. The ideal music concept must take into account the various care levels involved and it must be possible to implement it and integrate it smoothly into the daily clinical routine within the realms of what is feasible.

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